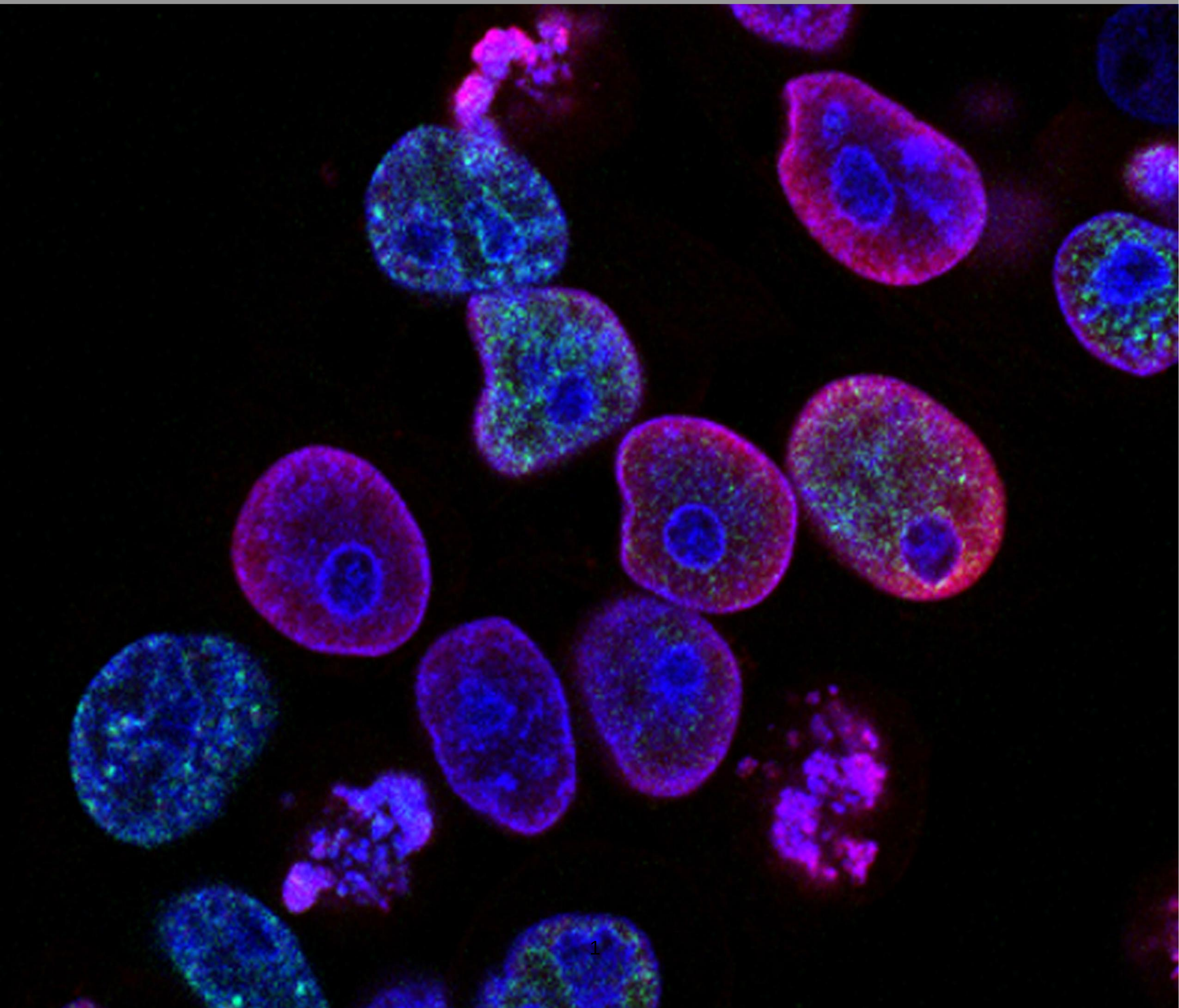
Biology for High School Diploma



Biology for High School Diploma

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MAIN CONTENT

CHAPTER 1

Introduction to Biology

Chapter Outline

1.1 Scientific Method

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Last Modified: Jan 18, 2022

What you will learn

- What is a **scientific investigation**
- Steps of the scientific method

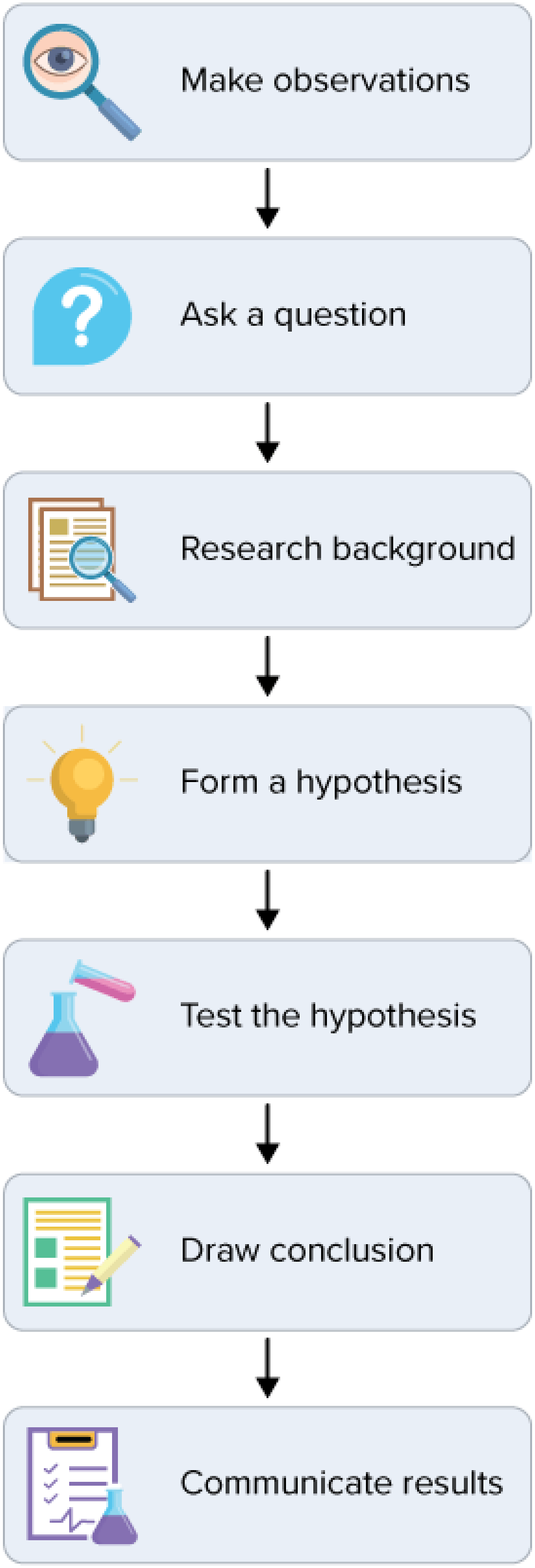
[Figure 1]

Chances are you've heard of the scientific method. What exactly is the scientific method?

Is it a precise and exact way that all science must be done? Or is it a series of steps that most scientists generally follow, but may be modified for the benefit of an individual investigation?

The Scientific Method

There are basic methods of gaining knowledge that are common to all of science. At the heart of science is scientific investigation, which is done by following the **scientific method**. A **scientific investigation** is a plan for asking questions and testing possible answers. It generally follows the steps listed in the **Figure** below. In reality, however, the process doesn't always go in a straight line.



[Figure 2]

Steps of a Scientific Method. A scientific investigation typically has these steps. Scientists often develop their own steps they follow in a scientific investigation.

DID YOU KNOW?

Galileo Galilei is referred to as The Father of Modern Science for his contribution to the systematic development and description of a scientific method.

Making Observations

A scientific investigation typically begins with **observation**. An **observation** is anything detected with the senses, which include sight, hearing, touch, smell, and taste. You make observations all the time. Let's say you take a walk in the woods and observe a moth, like the one in the **Figure** below, resting on a tree trunk. You notice that the moth has spots on its wing that look like eyes. You think the eyespots make the moth look like the face of an owl.

[Figure 3]

Does this moth remind you of an owl?

Asking a Question

Observations often lead to questions. For example, you might ask yourself why the moth has eye spots that make it look like an owl's face. What reason might there be for this observation?

Research Existing Knowledge About the Topic

No matter what you observe, you need to find out what is already known about your questions. For example, is anyone else doing research on eyespots in moths? If yes, what did they find out? Do you think that you should repeat their research to see if it can be duplicated? During your research, you might learn something that convinces you to change or refine your question. From this, you will construct your **hypothesis**.

Forming a Hypothesis

The next step in a scientific investigation is forming a hypothesis. A **hypothesis** is a possible answer to a scientific question, but it isn't just any answer. A hypothesis must be based on scientific knowledge, and it must be logical. A hypothesis also must be **falsifiable**. In other words, it must be possible to make observations that would disprove the hypothesis if it really is false. Assume you know that some bird eat moths and that owls prey on other birds. From this knowledge, you reason that eye spots scare away birds that might eat the moth. This is your hypothesis.

Testing the Hypothesis

To test a hypothesis, you first need to make a **prediction** based on the hypothesis. A **prediction** is a statement that tells what will happen under certain conditions. It can be expressed in the form: If A occurs, then B will happen. Based on your hypothesis, you might make this prediction: If a moth has eyespots on its wings, then birds will avoid eating it.

Next, you must gather **evidence** to test your prediction. **Evidence** is any type of data that may either agree or disagree with a prediction, so it may either support or disprove a hypothesis. Evidence may be gathered by an experiment. Assume that you gather evidence by making more observations of moths with eyespots. Perhaps you observe that birds really do avoid eating moths with eyespots. This evidence agrees with your prediction.

Check your understanding!

PROGRESS 0 / 4

1.

Which of the following statements best describes a prediction?

a The number of deformed frogs in five ponds that are polluted with chemical X is higher than the number of deformed frogs in five ponds without chemical X.

b If the water in a pond has lower levels of pesticide then there will be less deformed frogs.

c The number of deformed frogs is not affected by the presence of chemical X in the pond.

Check It

Hint

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Drawing Conclusions

Evidence that agrees with your prediction supports your hypothesis. Does such evidence prove that your hypothesis is true? No; a hypothesis cannot be proven conclusively to be true. This is because you can never examine all of the possible evidence, and someday evidence might be found that disproves the hypothesis. Nonetheless, the more evidence that supports a hypothesis, the more likely the hypothesis is to be true.

Communicating Results

The last step in a scientific investigation is communicating what you have learned with others. This is a very important step because it allows others to test your hypothesis. If other researchers get the same results as yours, they add support to the hypothesis. However, if they get different results, they may disprove the hypothesis.

When scientists share their results, they should describe their methods and point out any possible problems with the investigation. For example, while you were observing moths, perhaps your presence scared birds away. This introduces an error into your investigation. You got the results you predicted (the birds avoided the moths while you were observing them), but not for the reason you hypothesized. Other researchers might be able to think of ways to avoid this error in future studies.

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KQED: Why I Do Science

Dan Costa, Ph.D. is a professor of biology at the University of California, Santa Cruz, and has been studying marine life for well over 40 years. He is a leader in using satellite tags, time and depth recorders and other sophisticated electronic tags to gather information about the amazing depths to which elephant seals dive, their migration routes and how they use oceanographic features to hunt for prey as far as the international dateline and the Alaskan Aleutian Islands.

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Summary

- At the heart of science is the scientific investigation, which is done by following the scientific method. A scientific investigation is a plan for asking questions and testing possible answers.
- A scientific investigation typically begins with observations. Observations often lead to questions.
- A hypothesis is a possible logical answer to a scientific question, based on scientific knowledge.
- A prediction is a statement that tells what will happen under certain conditions.
- Evidence is any type of data that may either agree or disagree with a prediction, so it may either support or disprove a hypothesis. Conclusions may be formed from evidence.
- The last step in a scientific investigation is the communication of results with others.

Review

1. Outline the steps of a scientific investigation.
2. What is a scientific hypothesis? What characteristics must a hypothesis have to be useful in science?
3. Give an example of a scientific question that could be investigated with an experiment. Then give an example of a question that could not be investigated.
4. Can a hypothesis be proven true? Why or why not?
5. Why do scientists communicate their results?

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1.2 Experiment

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What you will learn

- What is an experiment
- Independent and **dependent variable**
- Importance of **sample size** and repetition

[Figure 1]

So what exactly is an experiment?

At first you may picture a science laboratory with microscopes and chemicals and people in white lab coats. But do all experiments have to be done in a lab? And do all scientists have to wear lab coats?

Experiments

The **Figure** below shows a laboratory experiment involving plants. An **experiment** is a special type of scientific investigation that is performed under controlled conditions, usually in a laboratory.

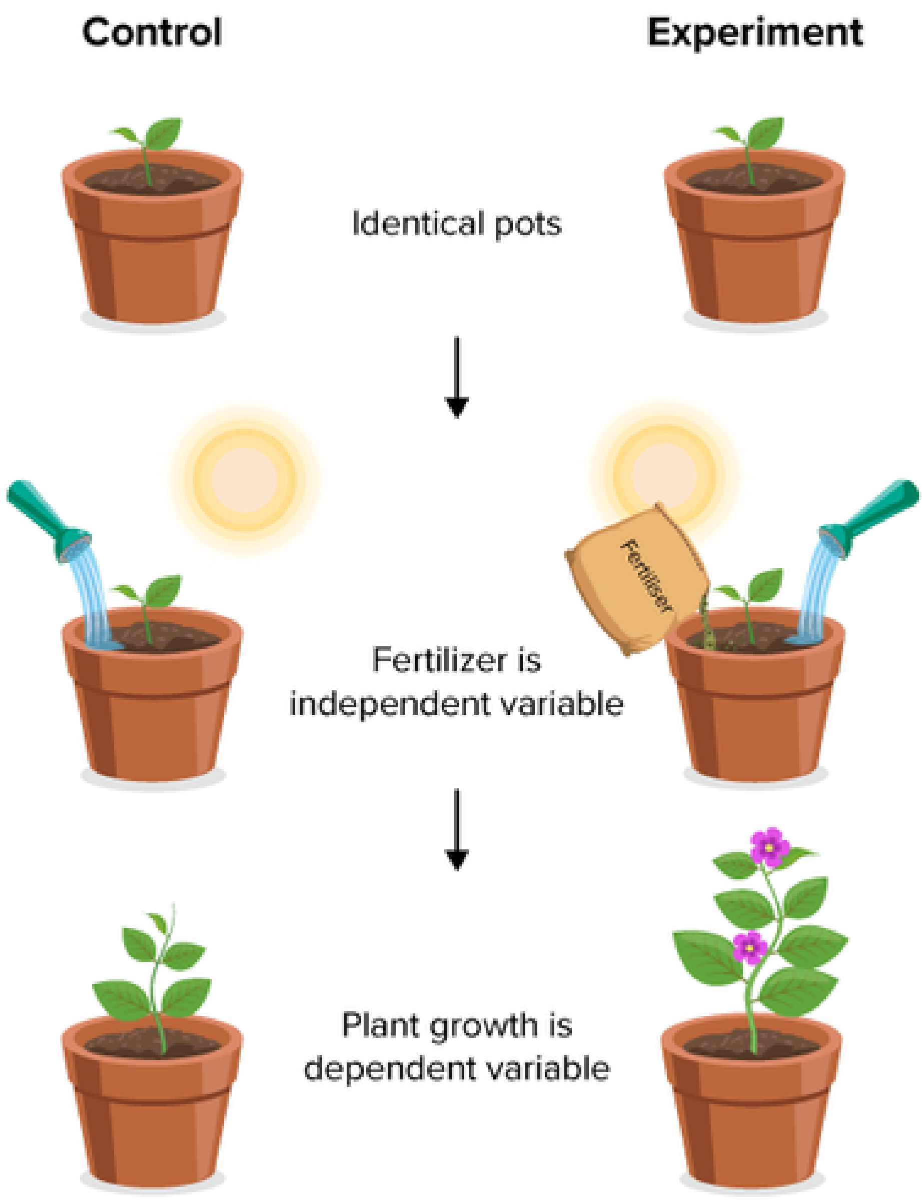
[Figure 2]

A laboratory experiment studying plant growth. What might this experiment involve?

Some experiments can be very simple, but even the simplest can contribute important evidence that helps scientists better understand the natural world. As many different types of experiments are possible, an experiment must be designed to produce data that can help confirm or reject the hypothesis.

Variables

An experiment generally tests how one variable is affected by another. The affected variable is called the **dependent variable**. In the plant experiment shown in the **Figure** below, the dependent variable is plant growth. The variable that affects the dependent variable is called the **independent variable**. In the plant experiment, the independent variable could be fertilizer—some plants will get fertilizer, others will not. The scientists change the amount of the independent variable (the fertilizer) to observe the effects on the dependent variable (plant growth). An experiment needs to be run simultaneously in which no fertilizer is given to the plant. This would be known as a control experiment**.** The plants that do not receive the fertilizer are the control group. An experiment must have a control group. In the control group, nothing is changed. It is not subjected to the independent variable. In any experiment, other factors that might affect the dependent variable must be controlled. In the plant experiment, what factors do you think should be controlled? (*Hint:* What other factors might affect plant growth?)



[Figure 3]

(Left): Control group; (Right): Experimental group

Check your understanding!

PROGRESS 0 / 4

1. The independent variable is the variable under the control of the experimenter.

a TRUE

b FALSE

Check It

Hint

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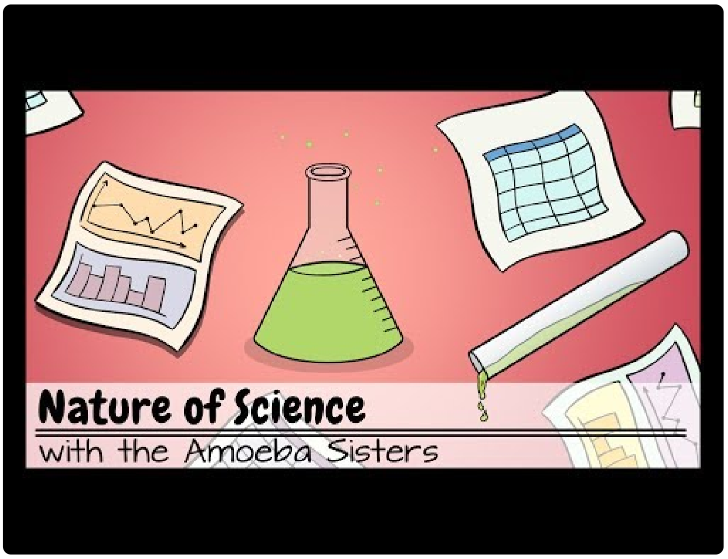
Sample Size and Repetition

The sample in an experiment or other investigation consists of the individuals or events that are studied, and the size of the sample (or sample size) directly affects the interpretation of the results. Typically, the sample is much smaller than all such individuals or events that exist in the world. Whether the results based on the sample are true in general cannot be known for certain. However, the larger the sample is, the more likely it is that the results are generally true.

Similarly, the more times that an experiment is repeated (which is known as repetition) and the same results obtained, the more likely the results are valid. This is why scientific experiments should always be repeated.

Experimental Error

Scientists make many measurements during experiments. Humans and equipment can make mistakes. Errors are often unavoidable. This is called experimental error. Errors may be due to the equipment being used. In this case, the numbers may be always skewed in one direction. For example, a scale may always measure one-half of an ounce high. People can also make errors. A measurement may not be made precisely. For example, a stopwatch may be stopped too soon or too late. But probably not always in the same direction. To correct for this, many measurements are taken. The measurements are then averaged. Experiments always have a margin of error associated with them.



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Super Microscopes

Microscopes are arguably one of the most important tools of the biologist. They allow the visualization of smaller and smaller biological organism and molecules. With greatly magnified powers, these instruments are becoming increasingly important in modern day research.

[Figure 4]

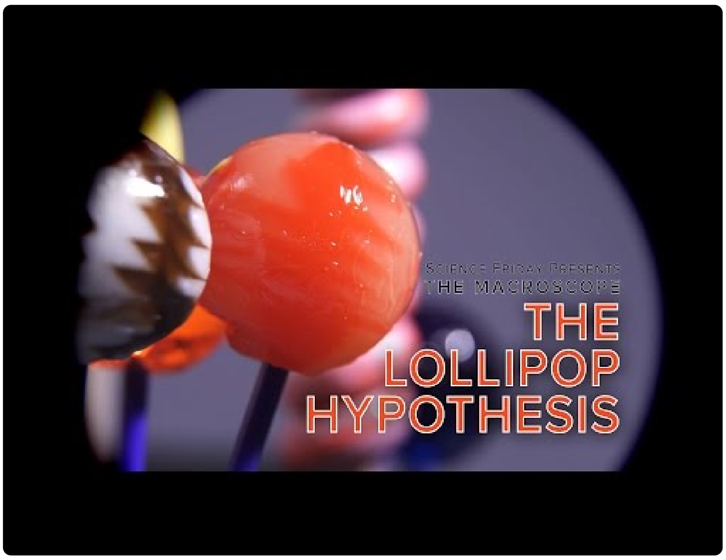
In this experiment, a scientist is conducting research (and taking notes) while looking through a microscope.

DID YOU KNOW?

Zacharias and Han Jansen created the first compound microscope in the 1590s with two lenses. The optical microscopes were developed between the 1590s and 1660s. For over 200 years, there was not much development in microscopes until a German engineer, Carl Zeiss, revolutionized the quality of lenses in the 1850s.

Science Friday: The Lollipop Hypothesis

Ever wondered how many licks it takes to reach the center of a lollipop? Mathematicians at NYU's applied mathematics lab have designed experiments to determine this. Find out in this video by Science Friday.



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Summary

- An experiment is a special type of scientific investigation that is performed under controlled conditions, usually in a laboratory.
- An experiment generally tests how one variable is affected by another.
- The sample size in an experiment directly affects the interpretation of the results.
- Repetition is the repeating of an experiment, validating the results.
- Errors are always possible in human endeavors. Scientists have ways to reduce the effects of errors on their data.

Review

1. What is an experiment?
2. Compare the dependent variable to the independent variable.
3. Identify the independent and dependent variables in the following experiment: A scientist grew bacteria on gel in her lab. She wanted to find out if the bacteria would grow faster on gel A or gel B. She placed a few bacteria on gel A and a few on gel B. After 24 hours, she observed how many bacteria were present on each type of gel.

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1.3 Scientific Theories

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What you will learn

- How hypothesis become scientific theories
- Examples of scientific theories in biology: **theory** of evolution, **cell theory**, and **germ theory**

[Figure 1]

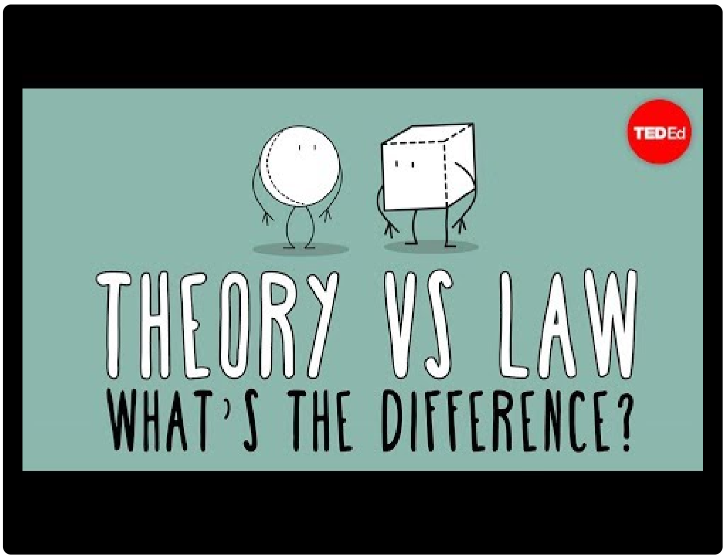
Theory vs. theory. Is a scientific *theory* different from the everyday use of the word *theory?*

A scientific theory is accepted as a scientific *truth*, supported by evidence collected by many scientists. The germ theory of disease is a classic scientific theory in biology.

Scientific Theories

With repeated testing, some hypotheses may eventually become scientific theories. Keep in mind, a hypothesis is a possible answer to a scientific question. A scientific **theory** is a broad explanation for events that is widely accepted as true. To become a theory, a hypothesis must be tested over and over again, and it must be supported by a great deal of evidence.

Many people think that any idea that is completely accepted in science is a **law**, but that is not true. In science, a **law** is something that always applies under the same conditions. A theory is much more complex: it explains why something happens. A law only describes what happens. Additionally, people commonly use the word *theory* to describe a guess about how or why something happens. For example, you might say, “I think a woodchuck dug this hole in the ground, but it’s just a theory.” Using the word *theory* in this way is different from the way it is used in science. A scientific theory is more like a fact than a guess because it is so well-supported. There are several well-known theories in biology, including the theory of evolution, cell theory, and germ theory.



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The Theory of Evolution

The theory of evolution by natural selection is a scientific theory. **Evolution** is a change in the characteristics of living things within a species over time. Evolution occurs by a process called **natural selection**. In natural selection, some living things produce more offspring than others, so they pass more gene to the next generation than others do. Over many generations, this can lead to major changes in the characteristics of living things. The theory of evolution by natural selection explains how living things are changing today and how modern living things have descended from ancient life forms that no longer exist on Earth. No evidence has been identified that proves this theory is incorrect. More on the theory of evolution will be presented in additional concepts.

The Cell Theory

The cell theory is another important scientific theory of biology. According to the **cell theory**, the cell is the smallest unit of structure and function of all living organism, all living organisms are made up of at least one cell, and living cells always come from other living cells. Once again, no evidence has been identified that proves this theory is incorrect. More on the cell theory will be presented in additional concepts.

The Germ Theory

The **germ theory** of disease, also called the pathogenic theory of medicine, is a scientific theory that proposes that microorganisms are the cause of many diseases. Like the other scientific theories, lots of evidence has been identified that supports this theory, and no evidence has been identified that proves the theory is incorrect.

DID YOU KNOW?

The germ theory of disease was confirmed by Robert Koch and Louis Pasteur in the late nineteenth century through a series of experiment. They were able to establish that diseases like anthrax, rabies, plague, cholera, and tuberculosis were caused by microorganisms. Louis Pasteur and Robert Koch are rightly known as ‘Father of microbiology’ and ‘Father of bacteriology’ respectively for their contributions.

Summary

- With repeated testing, some hypotheses may eventually become scientific theories. A scientific theory is a broad explanation for events that is widely accepted as true.
- Evolution is a change in species over time. Evolution occurs by natural selection.

- The cell theory states that all living things are made up of cells, and living cells always come from other living cells.
- The germ theory proposes that microorganisms are the cause of many diseases.

Review

1. Contrast how the term theory is used in science and in everyday language.
2. Explain how a hypothesis could become a theory.
3. Describe the evidence that proves the cell theory is incorrect.

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1.4 Characteristics of Life

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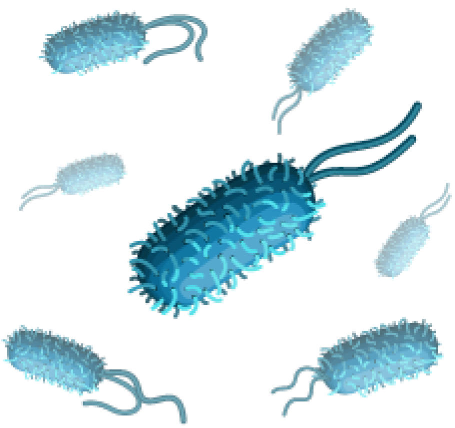
What you will learn

- What are the characteristics of living things



[Figure 1]

[Figure 2]

What do a bacterium and a frog have in common?

Do they share characteristics with us? All living organism, including the smallest bacterium and a frog, share certain characteristics of life. Without these characteristics, there is no *life*.

Characteristics of Life

Look at the duck decoy in the **Figure** below. It looks very similar to a real duck. Of course, real ducks are living things. What about the decoy duck? It looks like a duck, but it is actually made of wood. The decoy duck doesn't have all the characteristics of a living thing. What characteristics set the real ducks apart from the decoy duck? What are the characteristics of living things?

[Figure 3]

This duck decoy looks like it's alive. It even fools real ducks. Why isn't it a living thing?

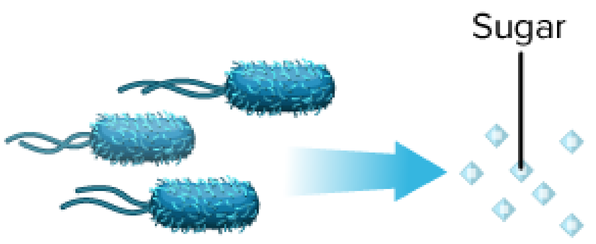
Not all scientists agree exactly about what makes up life. Many characteristics describe most living things. However, with most of the characteristics listed below, we can think of one or more examples that would seem to break the rule, with something non-living being classified as living or something living being classified as non-living. There is not just one distinguishing feature that separates a living thing from a non-living thing. A cat moves but so does a car. A tree grows bigger, but so does a cloud. A **cell** has structure, but so does a crystal. Biologists define life by listing characteristics that living things share. Something that has all of the characteristics of life is considered to be alive.

There are many characteristics that living organisms share. All living organisms:

- Respond to their environment.
- Grow and develop.
- Produce offspring.
- Maintain **homeostasis**.
- Have complex chemistry.
- Consist of cells.

Response to the Environment

All living things detect changes in their environment and respond to them. What happens if you step on a rock? Nothing; the rock doesn't respond because it isn't alive. But what if you think you are stepping on a rock and actually step on a turtle shell? The turtle is likely to respond by moving—it may even snap at you!



[Figure 4]

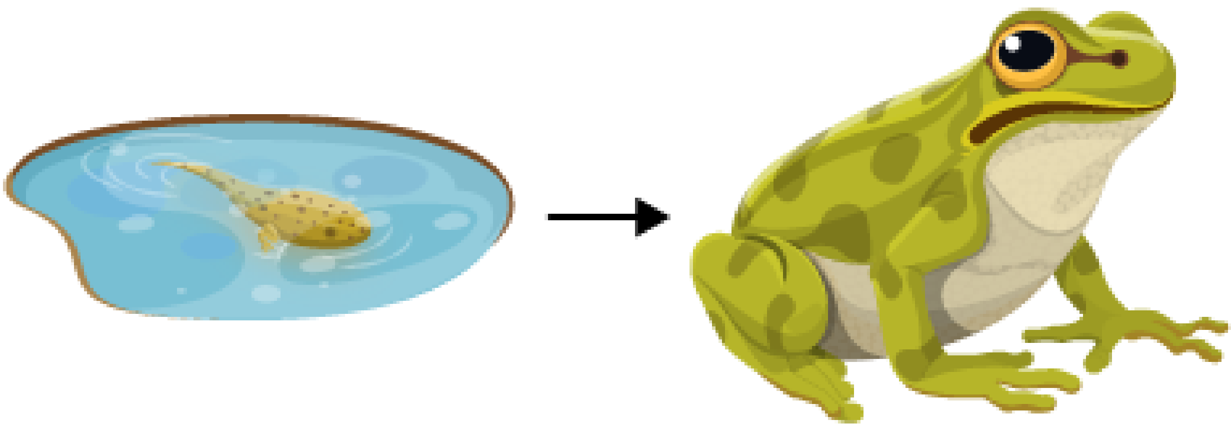
Most bacteria are attracted to sugar crystals.

[Figure 5]

If you step close to a frog it will likely jump away quickly.

Growth and Development

All living things grow and develop. For example, a plant seed may look like a lifeless pebble, but under the right conditions, it will grow and develop into a plant. Bacteria grow by increasing in cell size and volume. animal also grow and develop. How will the tadpole change as they grow and develop into adult frogs?



[Figure 6]

Tadpoles go through many changes to become adult frogs.

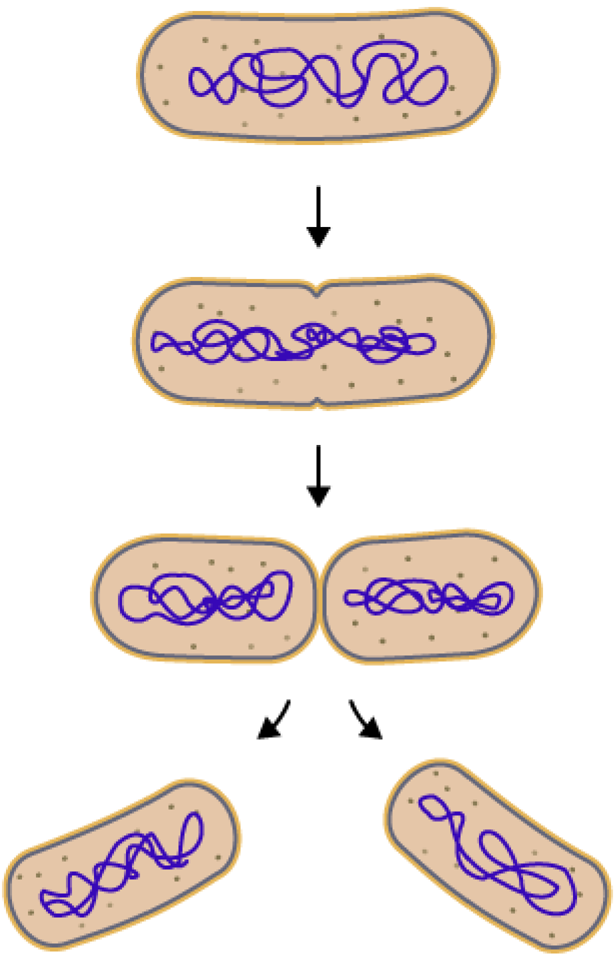
DID YOU KNOW?

If iodine is absent in water, a tadpole cannot grow and develop into a frog.

Reproduction

All living things are capable of **reproduction**. Reproduction is the process by which living things give rise to offspring. Reproducing may be as simple as a single cell dividing to form two daughter cell. Generally, however, it is much more complicated. Nonetheless, whether a living thing is a frog or a microscopic bacterium, it is capable of reproduction.

There are two types of reproduction, asexual and **sexual reproduction**. **Sexual reproduction** is a type of reproduction that involves two parents and produces genetically different offspring. **asexual reproduction** is a type of reproduction that involves a single parent and results in offspring that are all genetically identical to the parent. For example, bacteria reproduce by asexual reproduction creating an exact copy of themselves.

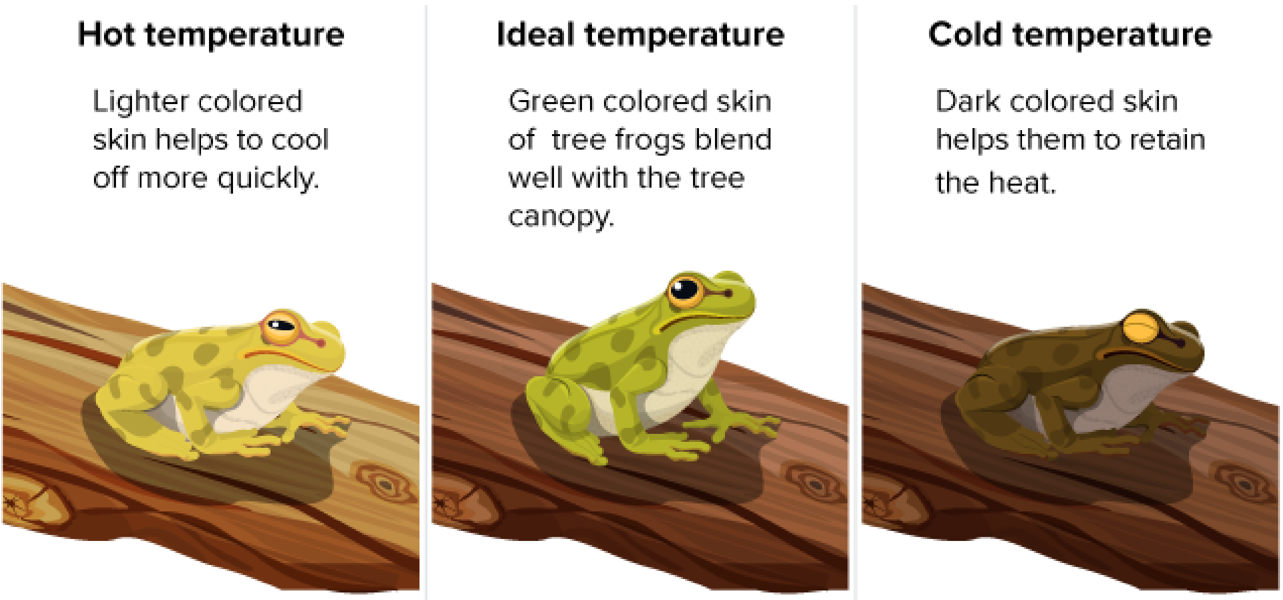


[Figure 7]

Binary fission is a type of asexual reproduction in bacteria.

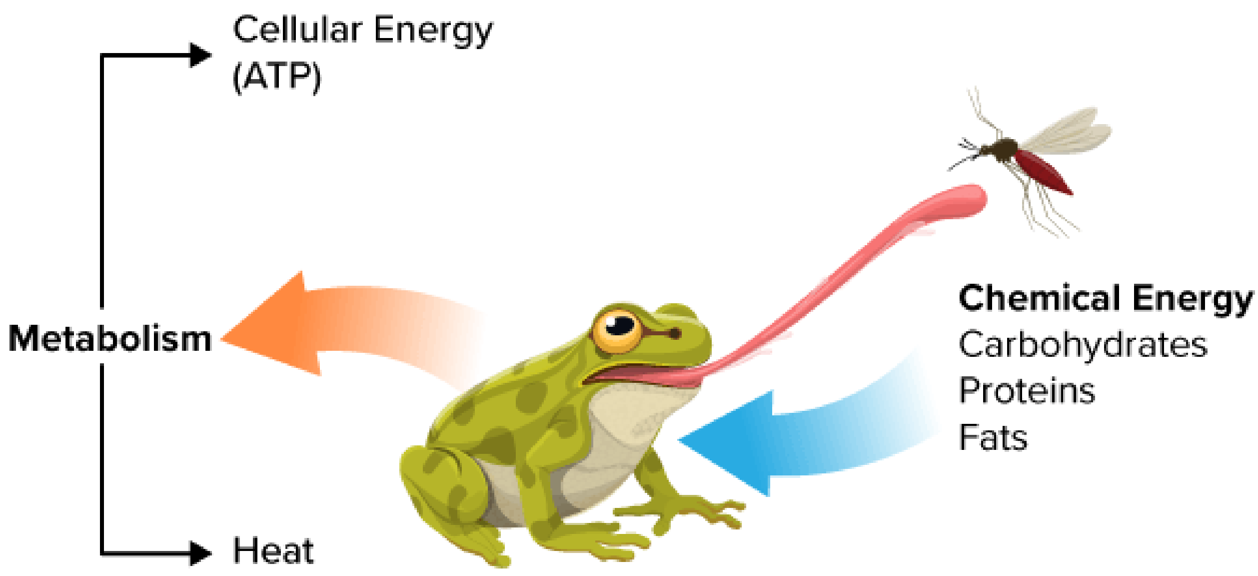
Keeping Things Constant

All living things are able to maintain a more-or-less constant internal environment. They keep things relatively stable on the inside regardless of the conditions around them. The process of maintaining a stable internal environment is called **homeostasis**. Human beings, for example, maintain a stable internal body temperature. If you go outside when the air temperature is below freezing, your body doesn't freeze. Instead, by shivering and other means, it maintains a stable internal temperature. Some species of tree frogs adjust their skin color as temperature changes in their environment.



Complex Chemistry

All living things—even the simplest life forms—have complex chemistry. Living things consist of large, complex molecules, and they also undergo many complicated chemical changes to stay alive. Thousands (or more) of these chemical reaction occur in each cell at any given moment. **metabolism** is the accumulated total of all the biochemical reaction occurring in a cell or organism. All living things need a continuous input source of energy to sustain life processes. Complex chemistry is needed to carry out all the functions of life.



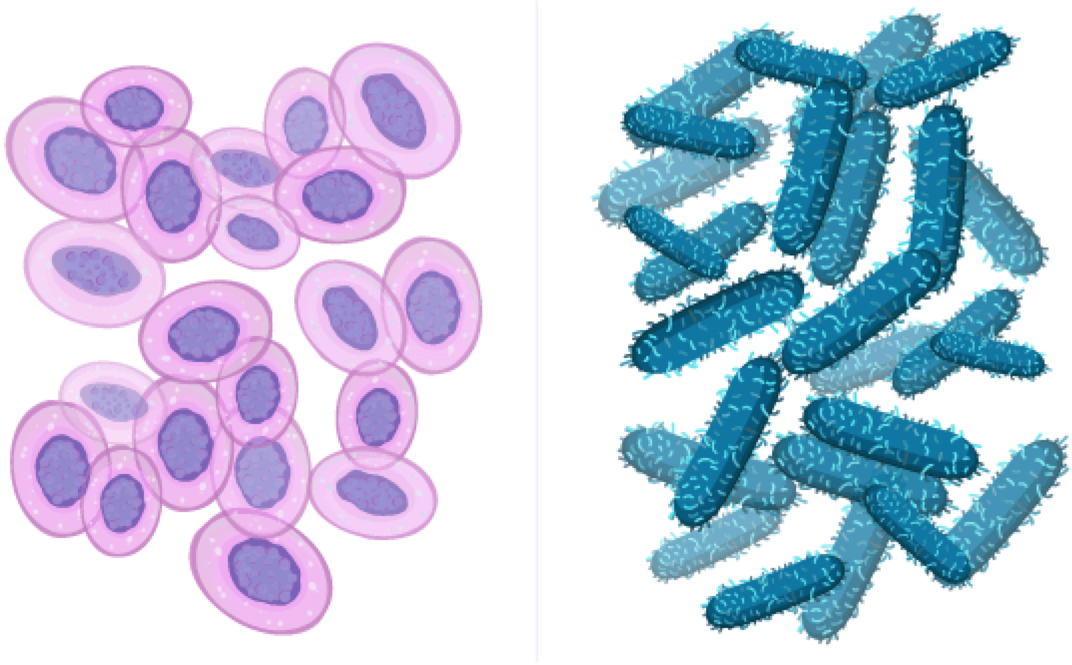
[Figure 8]

Living organisms consume food to transform it into energy to stay alive.

Cells

All forms of life are built of at least one cell. A **cell** is the basic unit of the structure and function of living things. Living things may appear very different from one another on the outside, but their cells are very similar. Compare illustrations of the frog cells on the left and bacteria cells on the right in **Figure** below. How are they similar?

If you zoom in very close on a leaf of a plant, or on the skin on your hand, or a drop of blood, you will find cells. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or paramecium, are unicellular, made of just one cell. Other organisms have millions, billions, or trillions of cells.

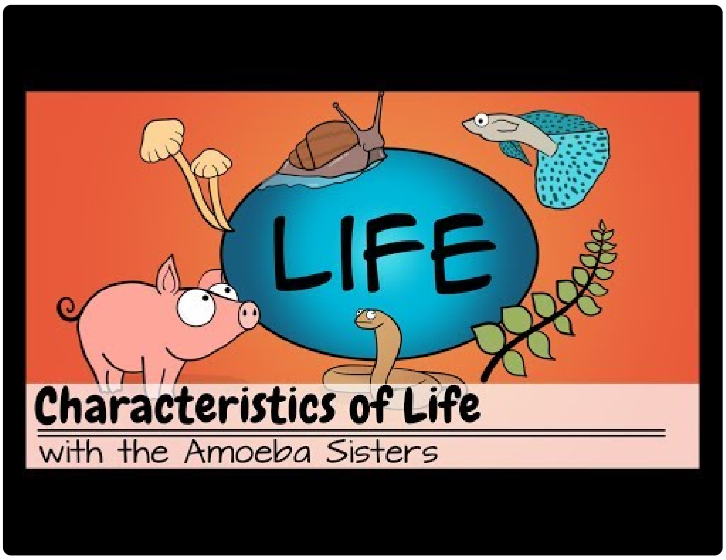


[Figure 9]

Frog Cells (left) and Bacteria Cells (right).

DID YOU KNOW?

A virus is a non-living thing. A virus is essentially DNA or RNA surrounded by a coat of protein. It is not made of cells, cannot reproduce on its own, and cannot maintain a stable internal environment.



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Summary

- All living things detect changes in their environment and respond to them.
- All living things grow and develop.
- All living things are capable of reproduction, the process by which living things give rise to offspring.
- All living things are able to maintain a constant internal environment through homeostasis.
- All living things have complex chemistry.
- All forms of life are built of cells. A cell is the basic unit of the structure and function of living things.

Review

1. List the characteristics of life.
2. Define homeostasis.
3. What is a cell?
4. Making the next generation is known as ______________.

5. Assume that you found an object that looks like a dead twig. You wonder if it might be a stick insect. How could you determine if it is a living thing?

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1.5 Principles of Biology

FlexBooks 2.0 > Biology For High School Diploma > Principles of Biology

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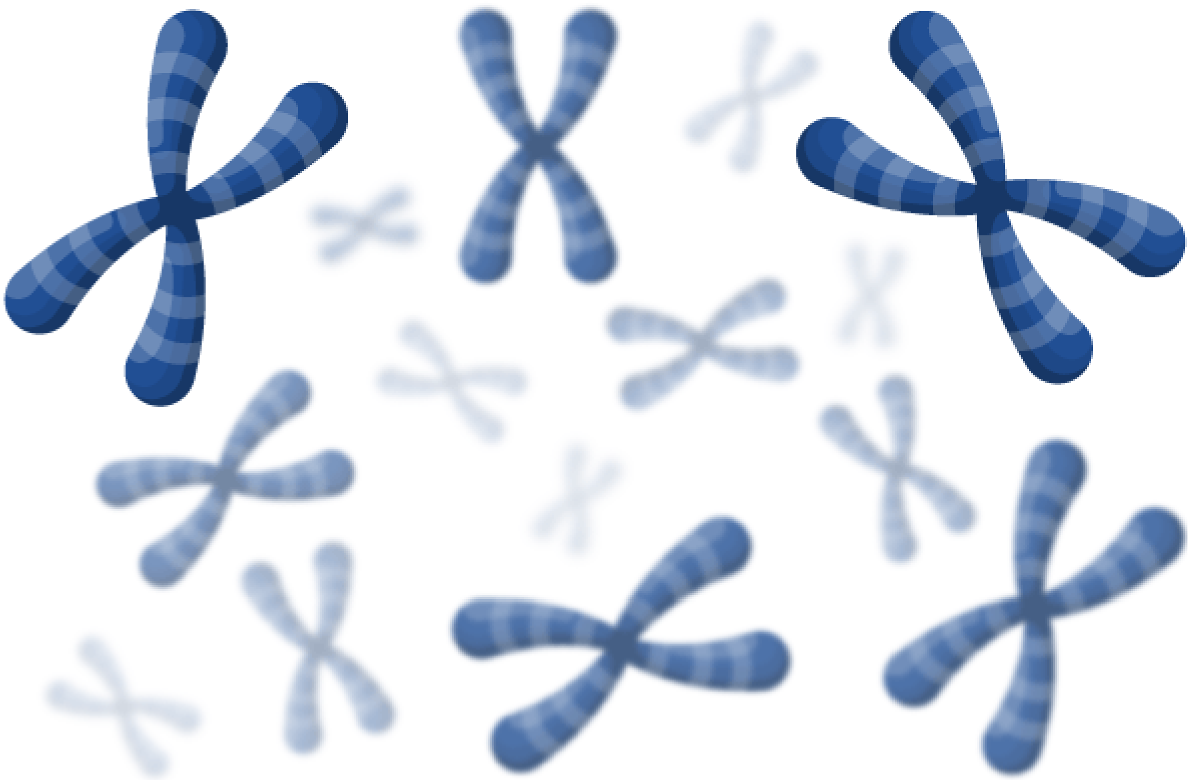
What you will learn

- The unifying principles of biology: **cell theory**, **gene theory**, **homeostasis** and evolution



[Figure 1]

Reproduction, homeostasis, evolution, metabolism, heredity. What controls the characteristics of life?

Characteristics of life are controlled by **gene**, which are passed from parents to offspring, and are located on **chromosome**, like the ones shown here, that are found in every cell. This describes a fundamental idea of gene theory, one of the four unifying principles of biology.

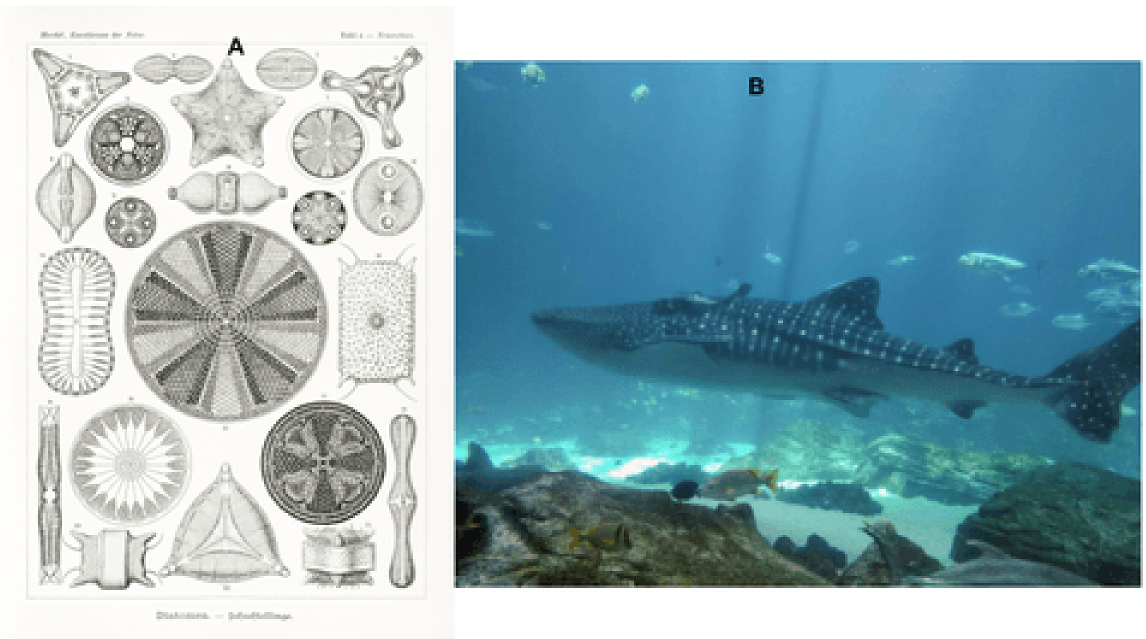
Unifying Principles of Biology

Four unifying principles form the basis of biology. Whether biologists are interested in ancient life, the life of bacterium, or how humans could live on the moon, they base their overall understanding of biology on these four principles:

1. cell theory
2. gene theory
3. homeostasis
4. evolution

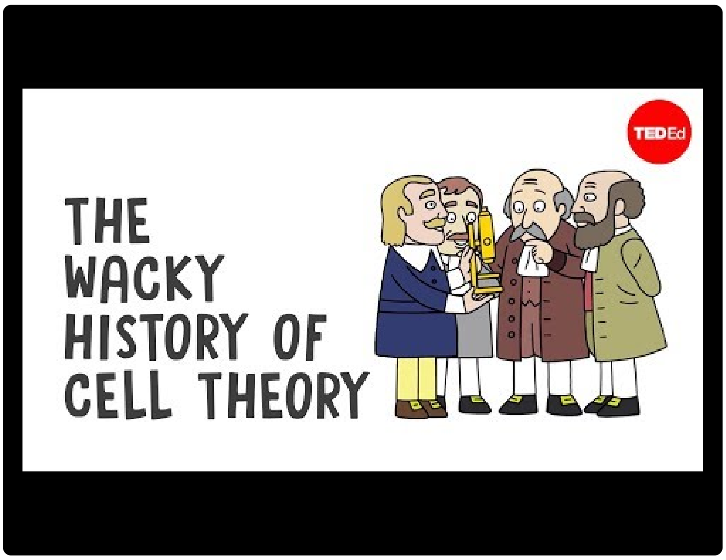
The Cell Theory

According to the **cell theory**, all organism are made up of one or more cells, all the life functions of an organism occur within cells, all cells come from preexisting cells. In fact, each living thing begins life as a single cell. Some living things, such as bacteria, remain single-celled. Other living things, including plants and animal, grow and develop into many cells. Your own body is made up of an amazing 100 trillion cells! But even you—like all other living things—began life as a single cell.



[Figure 2]

(A) Diatoms are about 20 μm in diameter and are made up of one cell, whereas (B) whale sharks can measure up to 12 meters in length and are made up of billions of cells.



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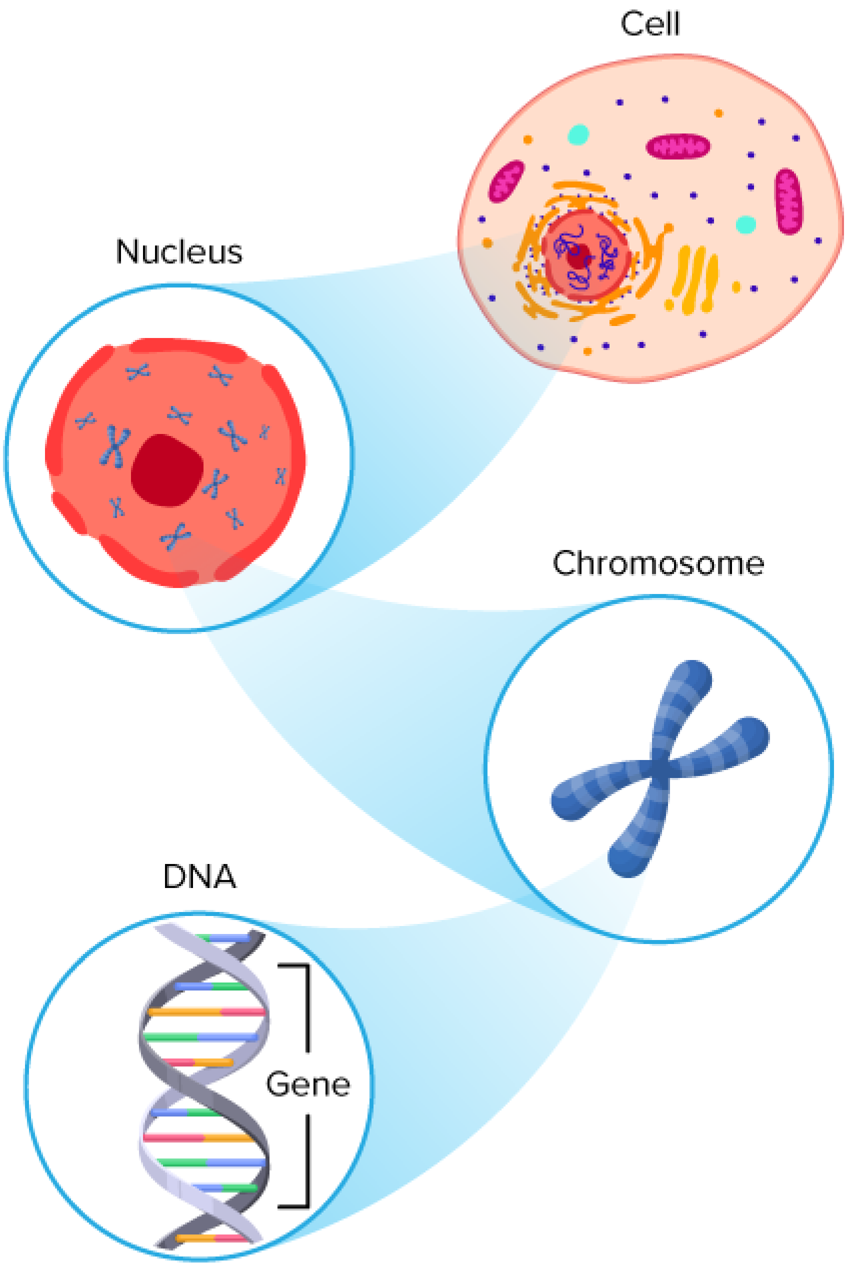
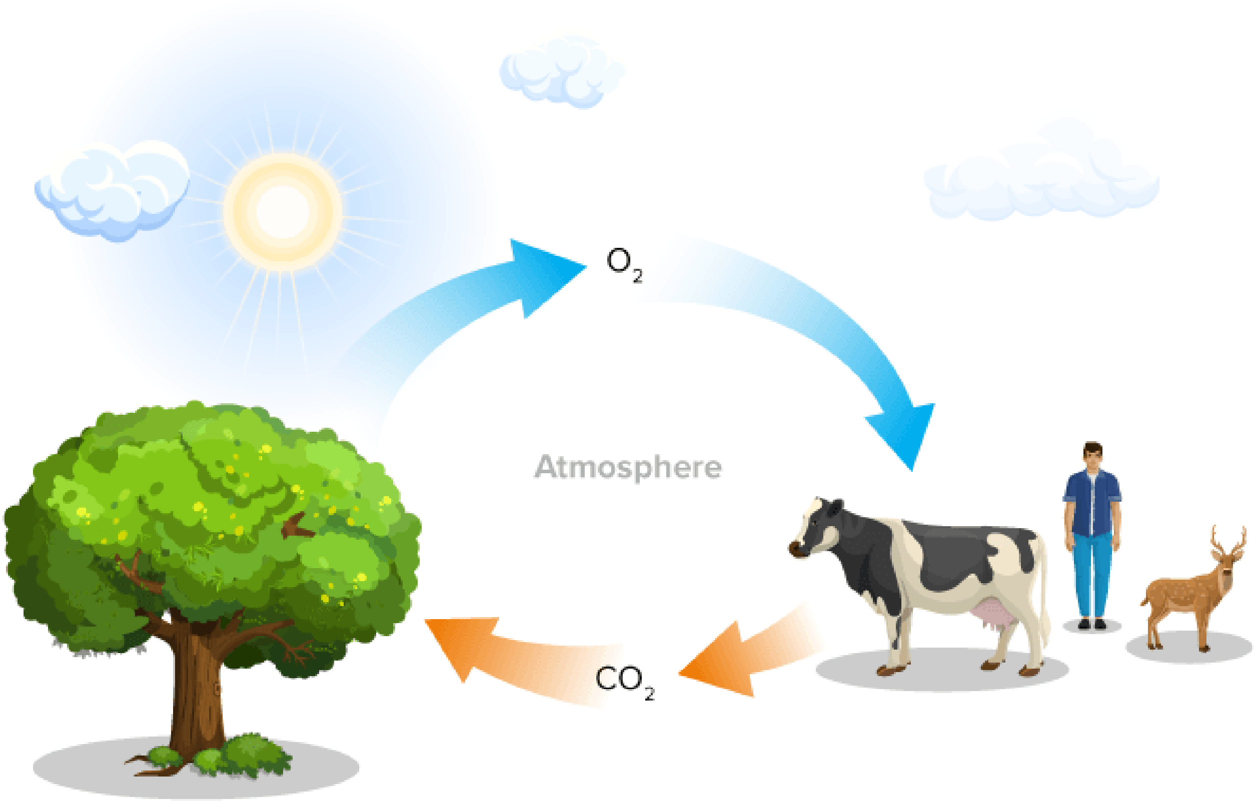
The Gene Theory

The **gene theory** is the idea that the characteristics of living organisms are controlled by genes, which are passed from parents to their offspring. A **gene** is a segment of DNA that has the instructions to encode a protein. Genes are located on larger structures, called **chromosomes**, that are found inside every cell. Chromosomes, in turn, contain large molecules known as DNA (deoxyribonucleic acid). Molecules of DNA are encoded with instructions that tell cells what to do.



Homeostasis

Homeostasis, which is maintaining a stable internal environment or keeping things constant, is not just a characteristic of living things. It also applies to nature as a whole. Consider the concentration of oxygen in Earth's atmosphere. Oxygen makes up 21% of the atmosphere, and this concentration is fairly constant. What keeps the concentration of oxygen constant? The answer is living things. Most living things need oxygen to survive, and when they breathe, they remove oxygen from the atmosphere. On the other hand, many living things, including plants, give off oxygen when they make food, and this adds oxygen to the atmosphere. The concentration of oxygen in the atmosphere is maintained mainly by the balance between these two processes.



[Figure 3]

The oxygen cycle is the biogeochemical cycle that helps in maintaining almost constant levels (21%) of oxygen in the atmosphere.

Evolution

Evolution is a change in the characteristics of living things over time. Evolution occurs by a process called natural selection. In natural selection, some living things produce more offspring than others, so they pass more genes to the next generation than others do. Over many generations, this can lead to major changes in the characteristics of living things. Evolution explains how living things are changing today and how modern living things have descended from ancient life forms that no longer exist on Earth.

As living things evolve, they generally become better suited for their environment. This is because they evolve **adaptation**. An **adaptation** is a characteristic that helps a living thing survive and reproduce in a given environment. Look at the mole in **Figure** below. It has tentacles around its nose that it uses to sense things by touch. The mole lives underground in the soil, where it is always dark. However, by using its touch organ, it can detect even tiny food items in the soil in total darkness. The touch organ is an adaptation because it helps the mole survive in its dark, underground environment.

[Figure 4]

This mole uses its star-shaped nose organ to sense food by touch in the dark. The mole's very large front claws are also an adaptation for its life in the soil. Can you explain why?

https://flexbooks.ck12.org/flx/render/embeddedobject/309624

DID YOU KNOW?

Humans have evolved from chimpanzees is a myth!!! Humans and chimpanzees have in common almost 99% of their DNA but they did not evolve from each other. It is now known that humans, chimpanzees, and gorillas evolved from a common ancestor that existed more than 6 million years ago.

Summary

- The cell theory states that all living things are made up of cells, and living cells always come from other living cells.
- The gene theory states that the characteristics of living things are controlled by genes.
- Homeostasis is maintaining a constant internal environment.
- Evolution is a change in species over time.

Review

1. Identify four unifying principles of modern biology.
2. How are genes related to chromosomes?
3. Define homeostasis.
4. How are adaptations related to evolution?

Report Content Errors

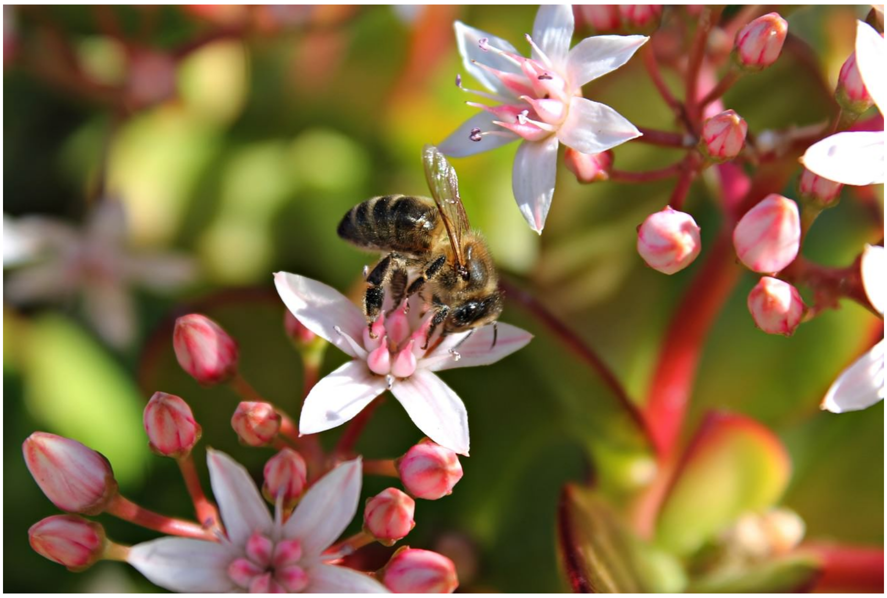
1.6 Interdependence of Living Things

FlexBooks 2.0 > Biology For High School Diploma > Interdependence of Living Things

Last Modified: Sep 09, 2021

What you will learn

- How living things are interdependent on each other
- Important interactions between **organism**: symbiotic relationships and **competition**



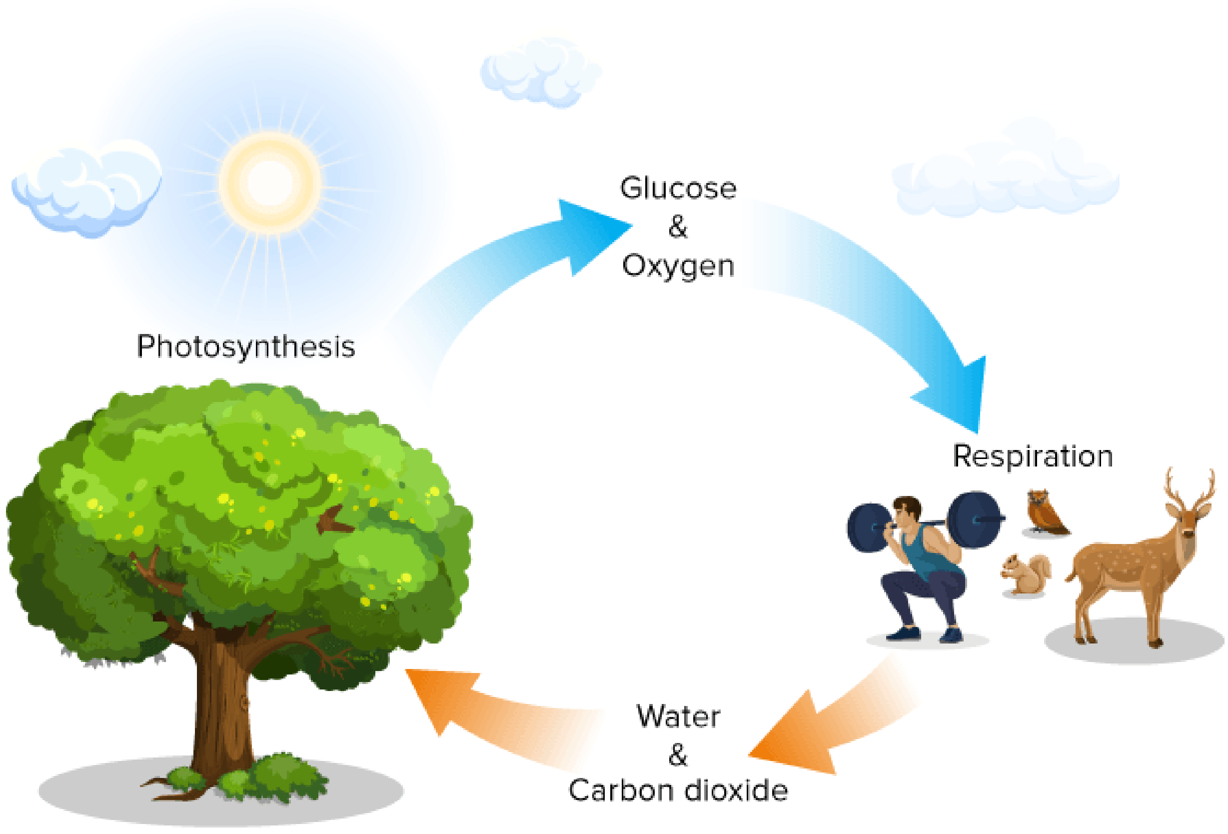
[Figure 1]

What other species do you need to survive?

species cannot live alone. All life needs other life to survive. Plants have evolved flower with traits that promote pollination by particular species. pollinator species, in turn, have evolved traits that help them obtain pollen or nectar from certain species of flowers. The flowering plants and the pollinators, such as a bird or insect, both benefit from the relationship. This is an example of a symbiotic relationship.

Interdependence of Living Things

All living things depend on their environment to supply them with what they need, including food, water, and shelter. Their environment consists of physical factors—such as soil, air, and temperature—and also of other organisms. An **organism** is an individual living thing. Many living things interact with other organisms in their environment. In fact, they may need other organisms in order to survive. This is known as **interdependence,** as depicted in the **Figure** below. For example, living things that cannot make their own food must eat other organisms for food. Other interactions between living things include symbiotic relationships and competition for resources.



[Figure 2]

Symbiosis

symbiosis is a close relationship between organisms of different species in which at least one of the organisms benefits. The other organism may also benefit, it may be unaffected by the relationship, or it may be harmed by the relationship. **Figure** below shows an example of symbiosis. The bird in the picture is able to pick out food from the fur of the antelope. The antelope won't eat the bird. In fact, the antelope knowingly lets the bird rest on it. What, if anything, do you think the antelope gets out of the relationship?

[Figure 3]

An oxpecker looks out, before searching for parasites on an antelope.

Competition

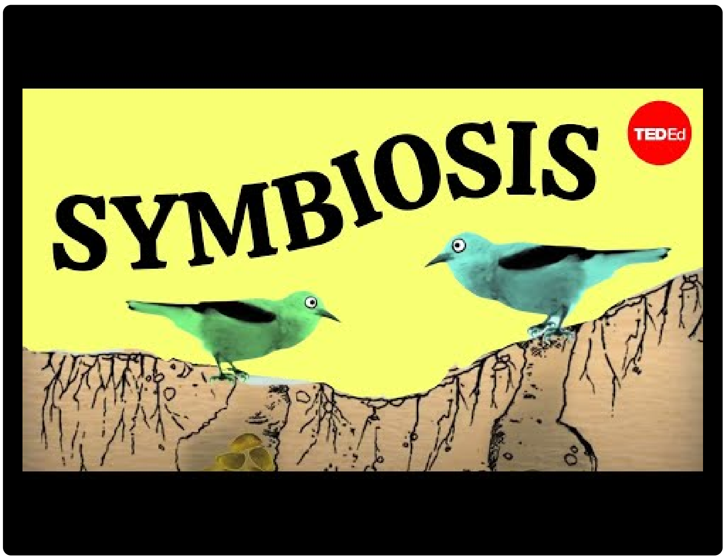
Competition is a relationship between living things that depend on the same resources. The resources may be food, water, or anything else they both need. Competition occurs whenever the two species try to get the same resources in the same place and at the same time. The two organisms are likely to come into conflict, and the organism better able to obtain that resource will "win" out over the other organism. What makes an organism better able to obtain a resource? They may be any of countless reasons, but each is considered an adaptation that makes an organism more fit to live in its environment.

[Figure 4]

Bears fighting in competition for food or a possible mate.

DID YOU KNOW?

The antibiotic that are used to treat many serious bacterial infections are actually chemicals produced by other bacterium or fungus. They produce these chemicals to kill other microbes which "compete" for nutrient in their natural environment.



https://www.youtube.com/embed/2AM3ARs9MMg

Summary

- All living things depend on their environment to supply them with what they need, including food, water, and shelter.
- Symbiosis is a close relationship between organisms of different species in which at least one of the organisms benefits.
- Competition is a relationship between living things that depend on the same resources.

Review

1. What is meant by interdependence?
2. Describe an example of a way that you depend on other living things.
3. Compare and contrast symbiosis and competition.
4. Give three examples of resources organisms may compete for.

Report Content Errors

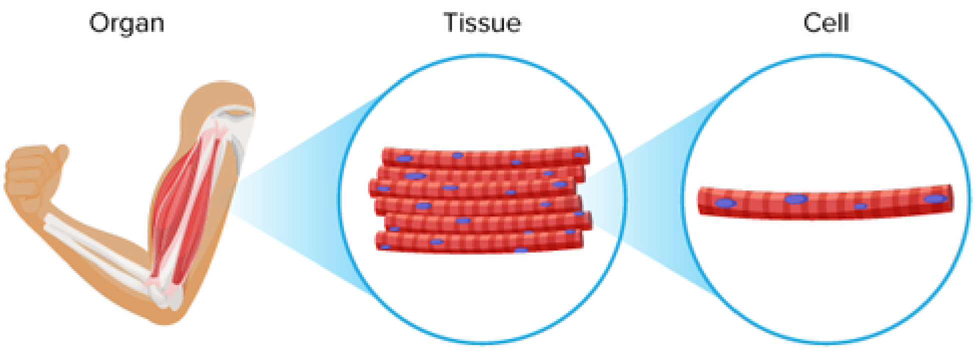
1.7 Organization of Living Things

FlexBooks 2.0 > Biology For High School Diploma > Organization of Living Things

Last Modified: Sep 09, 2021

What you will learn

- Levels of organization of living things within an **organism**
- Levels of organization in the **biosphere** above the individual organism
- Diversity of life on Earth



[Figure 1]

What does *'Organization of Living Things'* mean?

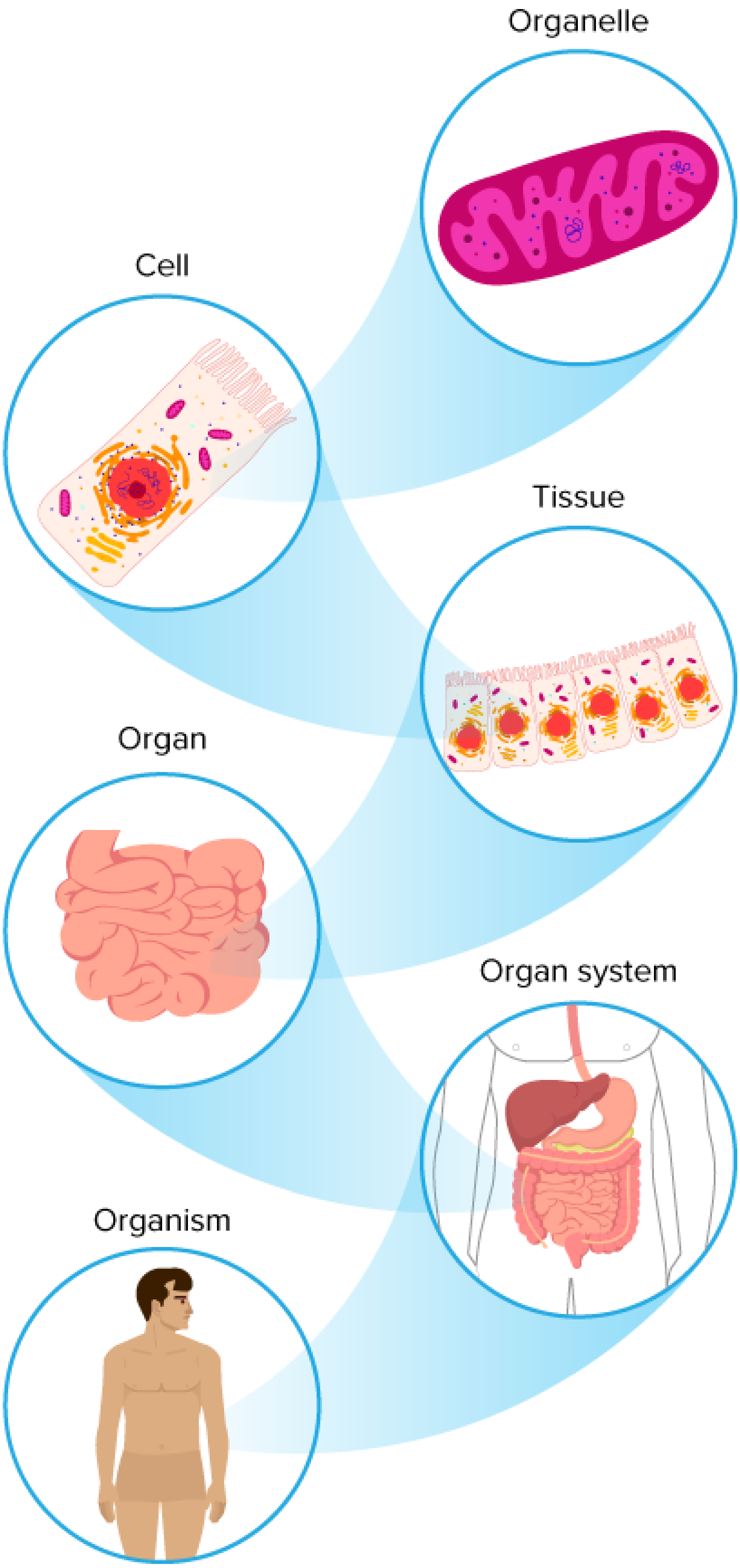
We know it all starts with the **cell**. And for some species, it ends with the cell. But for others, the cells come together to form **tissue**, tissues form **organ**, organs form **organ system**, and organ systems combine to form an organism.

Levels of Organization

The living world can be organized into different levels. For example, many individual organisms can be organized into the following levels:

- **Cell**: Basic unit of structure and function of all living things.
- **Tissue**: Group of cells of the same kind that perform the same function.
- **Organ**: Structure composed of two or more types of tissues. The tissues of an organ work together to perform a specific function. Human organs include the brain, stomach, kidney, and liver. Plant organs include roots, stem, and leaves.

- **Organ system**: Group of organs that work together to perform a certain function. Examples of organ systems in a human include the skeletal, nervous, and reproductive systems.
- **Organism**: Individual living thing that may be made up of one or more organ systems.

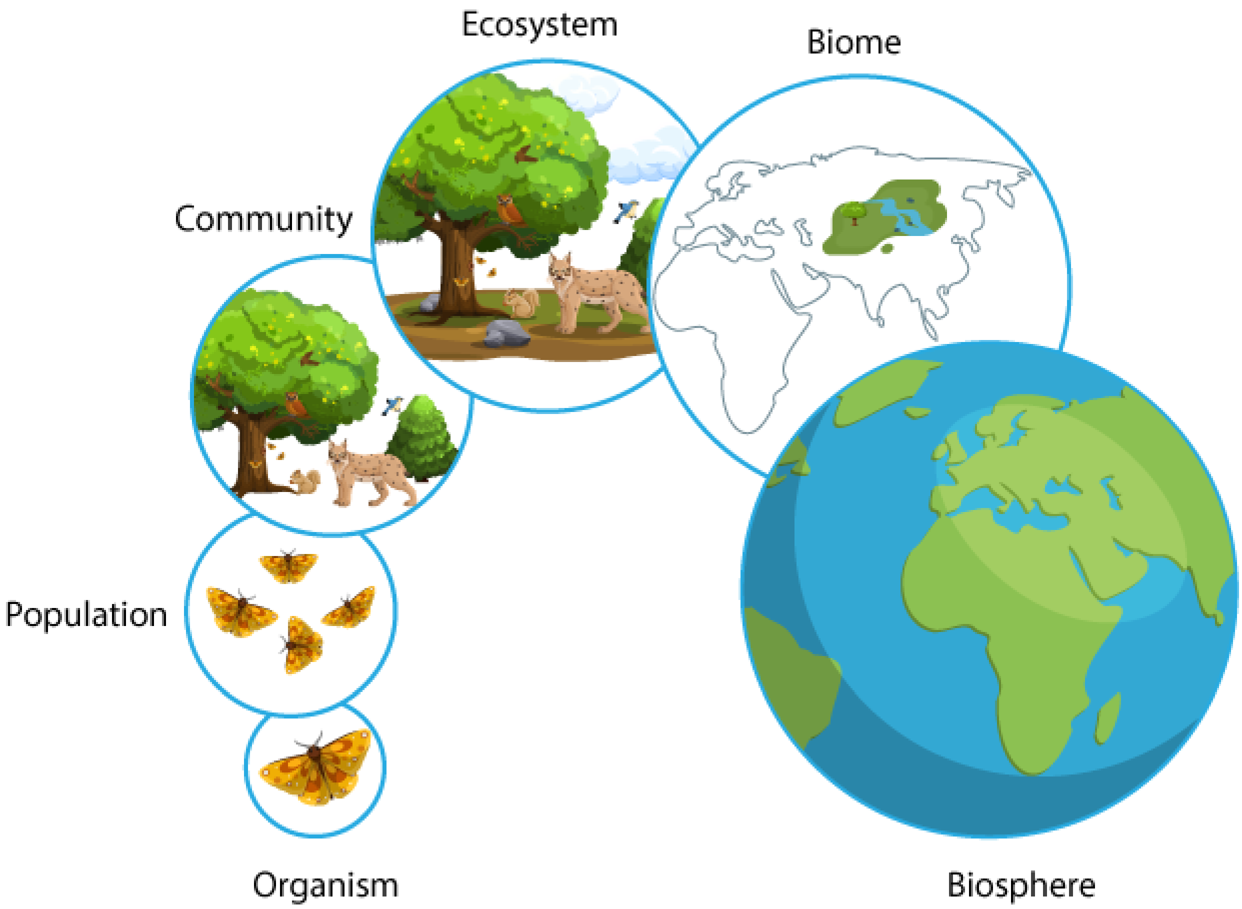

Organelle
Cell
Tissue
Organ
Organ system
Organism

DID YOU KNOW?

An average human body has about 38 trillion cells! However, they can be grouped into just four major tissue types which include epithelial tissue, muscular tissue, connective tissue, and nerve tissue.

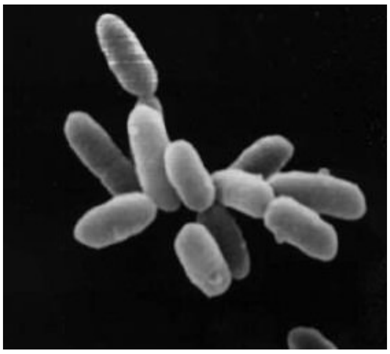
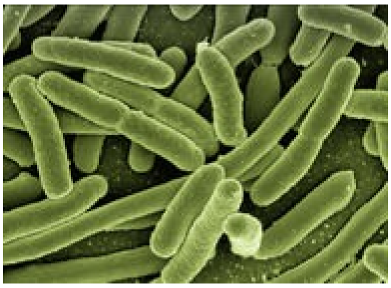
There are also levels of organization above the individual organism.

- Organisms of the same species that live in the same area make up a **population**. For example, all of the goldfish living in the same area make up a goldfish population.
- All of the populations that live in the same area make up a **community**. The community that includes the goldfish population also includes the populations of other fish, coral, and other organisms.
- An **ecosystem** consists of all the living things (**biotic factors**) in a given area, together with the nonliving environment (**abiotic factor**). The nonliving environment includes water, sunlight, and other physical factors.
- A group of similar ecosystems with the same general type of physical environment is called a **biome**.
- The **biosphere** is the part of Earth where all life exists, including all the land, water, and air where living things can be found. The biosphere consists of many different biomes.



Diversity of Life

Life on Earth is very diverse. The diversity of living things is called **biodiversity**. A measure of Earth's biodiversity is the number of different species of organisms that live on Earth. At least 10 million different species live on Earth today. They are commonly grouped into six different kingdoms. Examples of organisms within each kingdom are shown in the **Table** below.

 [Figure 2]	 [Figure 3]	 [Figure 4]
Archaea	bacterium	protist
 [Figure 5]	 [Figure 6]	 [Figure 7]
fungus	Plant	animal

https://flexbooks.ck12.org/flx/render/embeddedobject/309180

Summary

- Many individual organisms can be organized into the following levels: cells, tissues, organs, and organs systems.
- An ecosystem consists of all the populations in a given area, together with the nonliving environment.
- The biosphere is the part of Earth where all life exists.
- The diversity of living things is called biodiversity.

Review

1. Describe the levels of organization of a complex, multicellular organism such as a mouse, starting with the cell.
2. Explain how a population differs from a community.
3. What is an ecosystem?
4. Give three examples of the nonliving environment.
5. What is biodiversity?

Report Content Errors

1.8 Evolution of Life

FlexBooks 2.0 > Biology For High School Diploma > Evolution of Life

Last Modified: Sep 09, 2021

What you will learn

- Timeline of the history of life on Earth
- Darwin's theory of evolution by natural selection
- evidence to support the theory of evolution
- Misconceptions about evolution

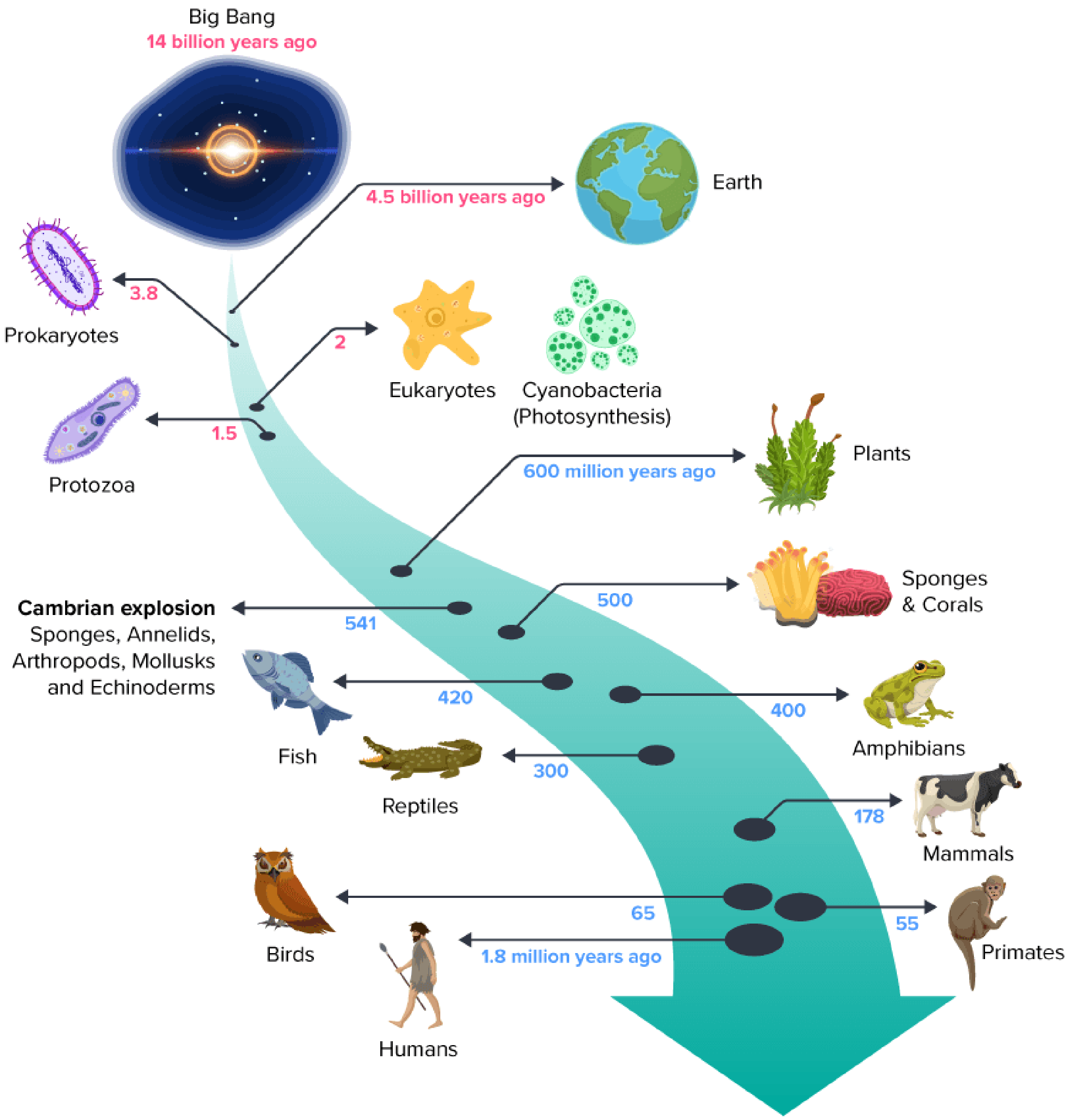
[Figure 1]

Are dinosaurs evidence of past life forms?

Evolution can be described as *a change in species over time*. dinosaur fossil are significant evidence of evolution and of past life on Earth.

Evolution of Life

The diversity of life on Earth today is the result of evolution. Life began on Earth at least 3.5 to 4 billion years ago, and it has been evolving ever since. At first, all living things on Earth were simple, single-celled organism. Much later, the first multicellular organism evolved, and after that, Earth's biodiversity greatly increased. **Figure** below shows a timeline of the history of life on Earth. In the entire span of time, humans are relatively a new addition.



[Figure 2]

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Today, the most accepted theory of life on Earth is evolution, and there is a vast amount of evidence supporting this theory. However, this wasn't always the case.

Darwin and the Theory of Evolution

The idea of evolution has been around for centuries. In fact, it goes all the way back to the ancient Greek philosopher Aristotle. However, evolution is most often associated with Charles Darwin. Darwin published a book on evolution in 1859 titled *On the Origin of Species*. In the book, Darwin stated the theory of evolution by natural selection. He also presented a great deal of evidence that evolution occurs.

Evolution is a change in the characteristics of living things over time. As described by Darwin, evolution occurs by a process called **natural selection**. In natural selection, some members of a species, being better adapted or suited to their environment, produce more offspring than others, so they pass "advantageous traits" to their offspring. Over many generations, this can lead to major changes in the characteristics of the species. Evolution explains how living things are changing today and how modern living things have descended from ancient life forms that no longer exist on Earth. As living things evolve, they generally become better suited for their environment. This is because they evolve **adaptation**. An **adaptation** is a trait that helps an organism survive and reproduce in a given environment.

An example of natural selection is shown in the **Figure** below. In this population of giraffes, long necks as well as short necks exist. The long neck giraffes appear to have an advantage in this environment. Having longer necks enabled these giraffes to feed off the higher branches. Over time, the giraffes with longer necks survived long enough to reproduce and pass on this trait to their offspring.

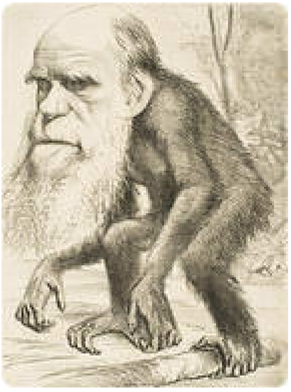
[Figure 3]

[Figure 4]

[Figure 5]

Natural selection of the long-neck trait in giraffes

Despite all the evidence Darwin presented, his theory was not well-received at first. Many people found it hard to accept the idea that humans had evolved from an ape-like ancestor, and they saw evolution as a challenge to their religious beliefs. Look at the cartoon in **Figure** below. Drawn in 1871, it depicts Darwin himself as an ape. The cartoon reflects how many people felt about Darwin and his theory during his own time. Darwin had actually expected this type of reaction to his theory and had waited a long time before publishing his book for this reason. It was only when another scientist, named Alfred Russel **Wallace**, developed essentially the same theory of evolution that Darwin put his book into print.



[Figure 6]

Charles Darwin's name is linked with the theory of evolution. This cartoon from the 1870s makes fun of both Darwin and his theory.

Although Darwin presented a great deal of evidence for evolution in his book, he was unable to explain how evolution occurs. That's because he knew nothing about gene. As a result, he didn't know how characteristics are passed from parents to offspring, let alone how they could change over time.

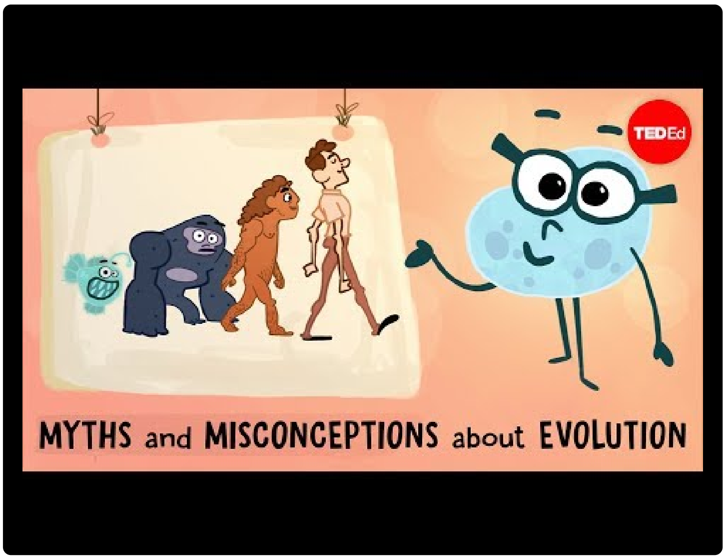
Evolutionary Theory After Darwin

Since Darwin's time, scientists have gathered even more evidence to support the theory of evolution. Some of the evidence comes from fossils, and some comes from studies that show how similar living things are to one another. By the 1930s, scientists had also learned about genes. As a result, they could finally explain how characteristics of organisms could pass from one generation to the next and change over time.

Using modern technology, scientists can now directly compare the genes of living species. The more genes different species share in common, the more closely related the species are presumed to be. Consider humans and chimpanzees. They share about 98% of their genes. This means that they shared a common ancestor in the not-too-distant past. This is just one of many pieces of evidence that show we are part of the evolution of life on Earth.

Misconceptions About Evolution

Today, evolution is still questioned by some people. Often, people who disagree with the theory of evolution do not really understand it. For example, some people think that the theory of evolution explains how life on Earth first began. In fact, the theory explains only how life changed after it first appeared. Some people think the theory of evolution means that humans evolved from modern apes. In fact, the theory suggests humans and modern apes have a common ancestor that lived several million years ago. These and other misconceptions about evolution contribute to the controversy that still surrounds this fundamental principle of biology.



https://www.youtube.com/embed/mZt1Gn0R22Q

Summary

- Life began on Earth at least 3.5 to 4 billion years ago, and it has been evolving ever since.
- Darwin stated the theory of evolution by natural selection, presenting a great deal of evidence to support his theory.
- Evolution is a change in the characteristics of living things over time. Evolution occurs by natural selection.
- Characteristics of organisms are passed from one generation to the next through their genes.

Review

1. What is evolution?
2. What is natural selection?
3. Briefly, explain the theory of evolution.

Report Content Errors

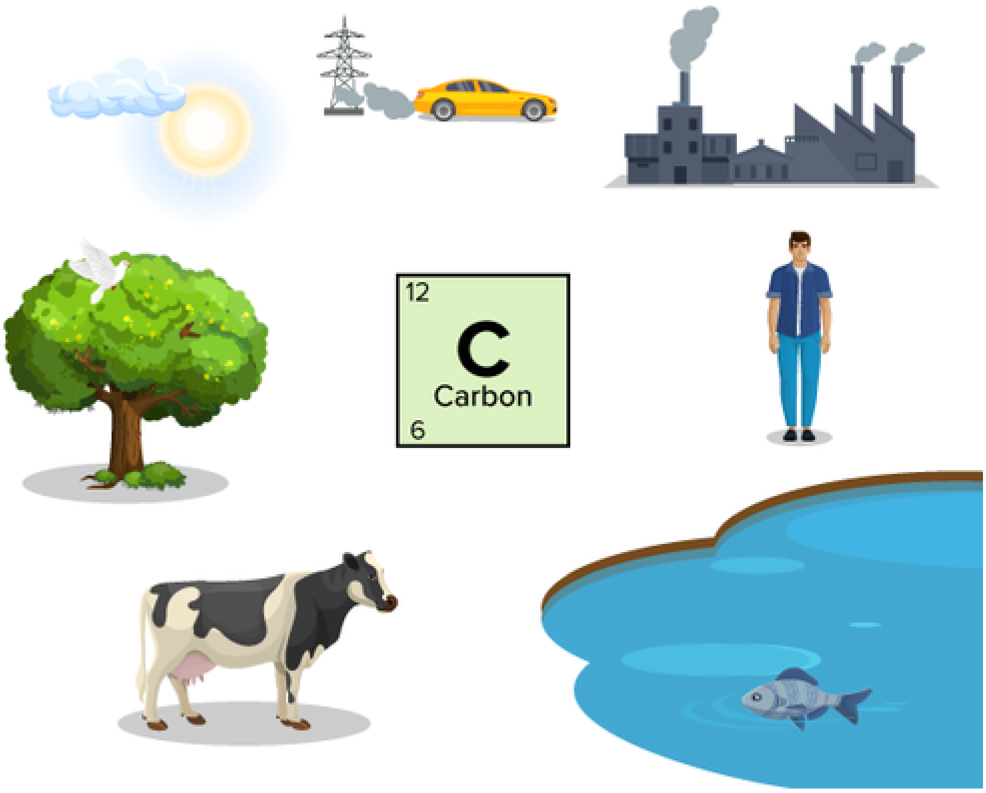
1.9 Significance of Carbon

FlexBooks 2.0 > Biology For High School Diploma > Significance of Carbon

Last Modified: Sep 09, 2021

What you will learn

- The importance of carbon for life on Earth
- The basic structure and function of the four major types of **organic compound**



[Figure 1]

Carbon. Element number six. Right in the middle of the first row of the Periodic Table. ***So what?***

Carbon is the most important element to life. Without this element, life as we know it would not exist. As you will see, carbon is the central element in compounds necessary for life.

The Significance of Carbon

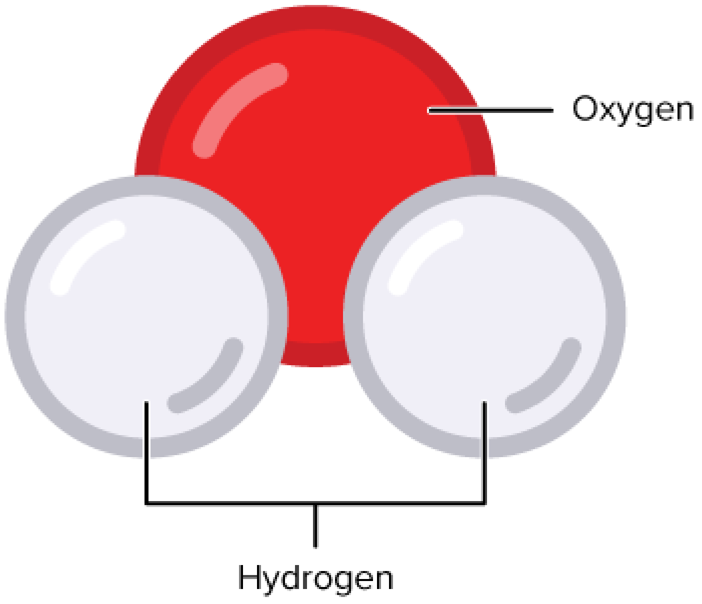
A compound found mainly in living things is known as an **organic compound**. Organic compounds make up the cell and other structures of organism and carry out life processes. Carbon is the main element in organic compounds, so carbon is essential to life on Earth. Without carbon, life as we know it could not exist.

DID YOU KNOW?

RNA was one of the first organic molecule that formed about 4 billion years ago. It may have formed the basis of early life.

Compounds

A **compound** is a substance that consists of two or more elements. A compound has a unique composition that is always the same. The smallest particle of a compound is called a molecule. Consider water as an example. A molecule of water always contains one atom of oxygen and two atoms of hydrogen. The composition of water is expressed by the chemical formula H_2O. A model of a water molecule is shown in the **Figure** below. Water is not an organic compound.



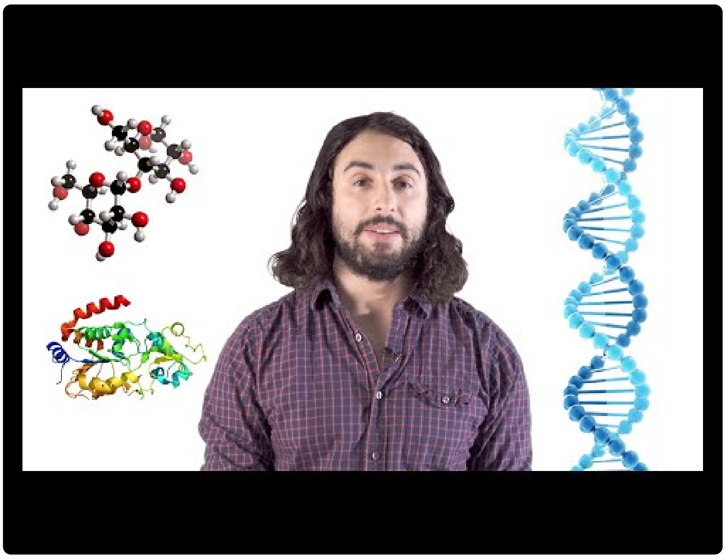
[Figure 2]

A water molecule always has this composition, one atom of oxygen and two atoms of hydrogen.

What causes the atoms of a water molecule to “stick” together? The answer is **chemical bond**. A **chemical bond** is a force that holds molecules together. Chemical bonds form when substances react with one another. A **chemical reaction** is a process that changes some chemical substances into others. A chemical reaction is needed to form a compound. Another chemical reaction is needed to separate the substances in a compound.

Carbon

Why is carbon so basic to life? The reason is carbon's ability to form stable bonds with many elements, including itself. This property allows carbon to form a huge variety of very large and complex molecules. In fact, there are nearly 10 million carbon-based compounds in living things! However, the millions of organic compounds can be grouped into just four major types: **carbohydrate**, **lipid**, **protein**, and **nucleic acid**. You can compare the four types in the **Table** below. Common structural examples of the four major types of organic compounds are included in the table. Notice the diversity of structures among the organic compounds listed.



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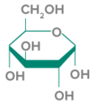
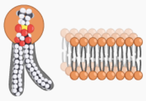
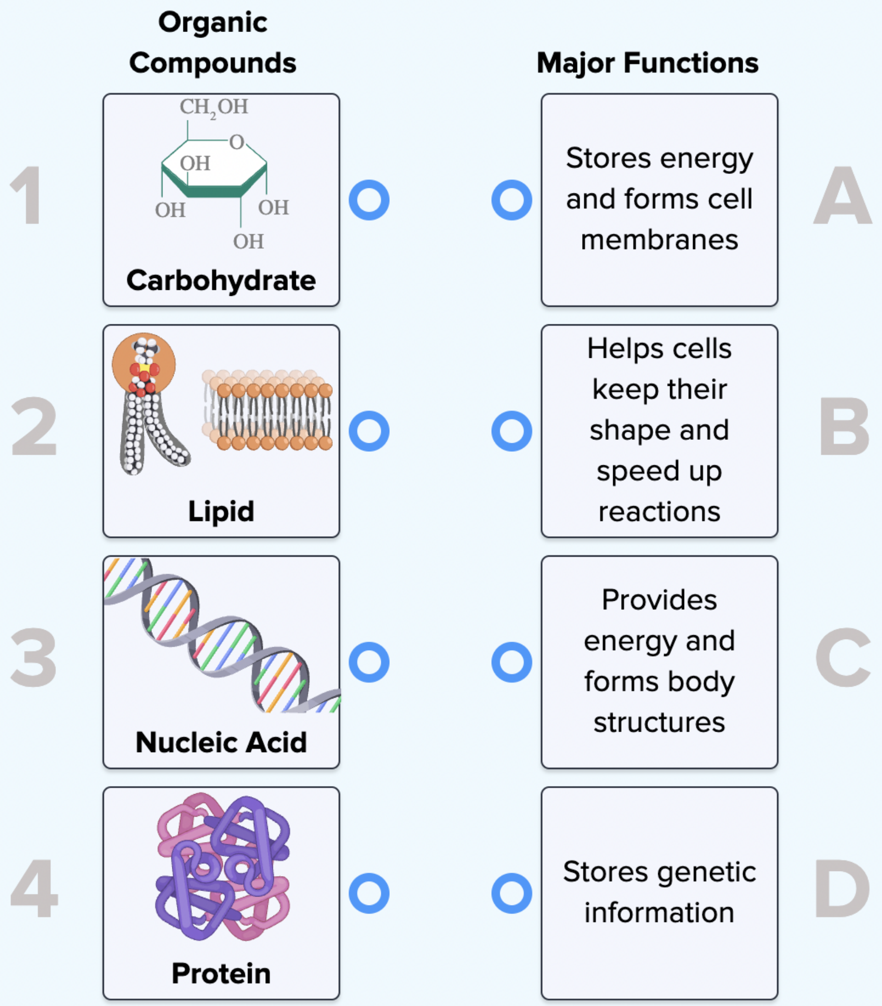
Type of Compound	Examples	Structure	Elements	Functions	Monomer
Carbohydrates	sugars, starches	 [Figure 3]	carbon, hydrogen, oxygen	provides energy to cells, stores energy, forms body structures	monosaccharide
Lipids	fats, oils	 [Figure 4]	carbon, hydrogen, oxygen	stores energy, forms cell membrane, carries messages	
Proteins	enzyme, antibody	 [Figure 5]	carbon, hydrogen, oxygen, nitrogen, sulfur	helps cells keep their shape, makes up muscles, speeds up chemical reactions, carries messages and materials	amino acid
Nucleic Acids	DNA, RNA	 [Figure 6]	carbon, hydrogen, oxygen, nitrogen, phosphorus	contains instructions for proteins, passes instructions from parents to offspring, helps make proteins	nucleotide

https://flexbooks.ck12.org/flx/render/embeddedobject/309291

Carbohydrates, proteins, and nucleic acids are large molecules known as **polymer** (also referred to as macromolecules) built from smaller molecules (**monomer**) through **dehydration reactions**. In a dehydration reaction, water is removed as two monomers are joined together. **hydrolysis** is a reaction where polymers are broken down; a water molecule is split, separating a monomer away from the polymer chain.

CAN YOU MATCH?

Try to match these organic compounds with their major functions.



Answers: 1-C, 2-A, 3-D, 4-B

Summary

- Carbon is the main element in organic compounds. Carbon can form stable bonds with many elements, including itself.
- There are four major types of organic compounds: carbohydrates, lipids, proteins, and nucleic acids.

- In a dehydration reaction, two monomers are joined together while in hydrolysis polymers are broken down, separating a monomer away from the polymer chain.

Review

1. What is a compound?
2. Explain why carbon is essential to all known life on Earth.
3. What are the four main types of organic compounds?
4. Which type(s) of organic compounds provide energy?
5. Which organic compound stores genetic information?
6. Examples of proteins include _______________.

Report Content Errors

1.10 Carbohydrates

FlexBooks 2.0 > Biology For High School Diploma > Carbohydrates

Last Modified: Aug 31, 2021

What you will learn

- The chemical structure and function of carbohydrates
- Examples of carbohydrates and where they are used
- Sugars used as biofuels

[Figure 1]

Sugar. Does this look like biological energy?

As a child, you may have been told that sugar is bad for you. Well, that's not exactly true. Essentially, carbohydrates are made of sugar, from a single sugar molecule to thousands of sugar molecules attached together. Why? One reason is to store energy. But that does not mean you should eat it by the spoonful.

Carbohydrates

Carbohydrates are the most common type of organic compound. A **carbohydrate** is an organic compound such as sugar or starch and is used to store energy. Like most organic compounds, carbohydrates are built of small, repeating units that form bonds with each other to make a larger molecule. In the case of carbohydrates, the small repeating units are called **monosaccharide**. Carbohydrates contain only carbon, hydrogen, and oxygen.

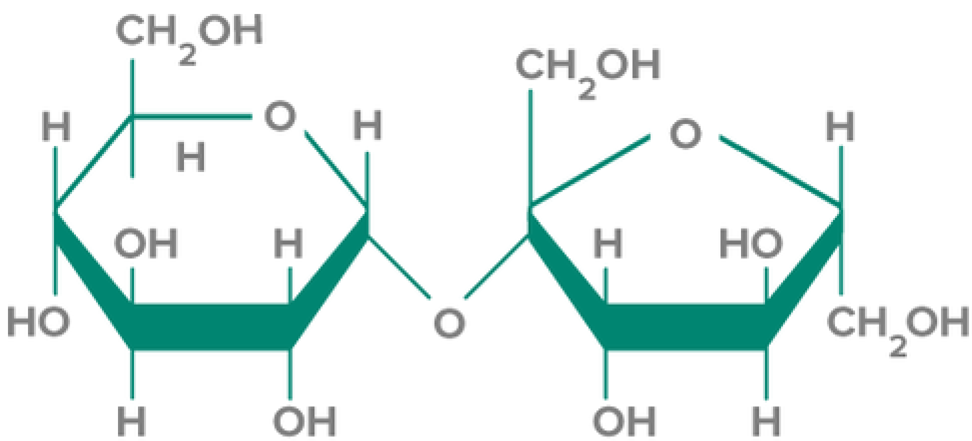
Monosaccharides and Disaccharides

A **monosaccharide**, the monomer of carbohydrates, is a **simple sugar** such as fructose or **glucose**. Fructose is found in fruit, whereas glucose generally results from the digestion of other carbohydrates. **Glucose** ($C_6H_{12}O_6$) is used for energy by the cell of most organism and is a product of photosynthesis.

DID YOU KNOW?

The brain is the only organ that is entirely dependent on glucose for its function. It cannot use any other molecule for its energy needs.

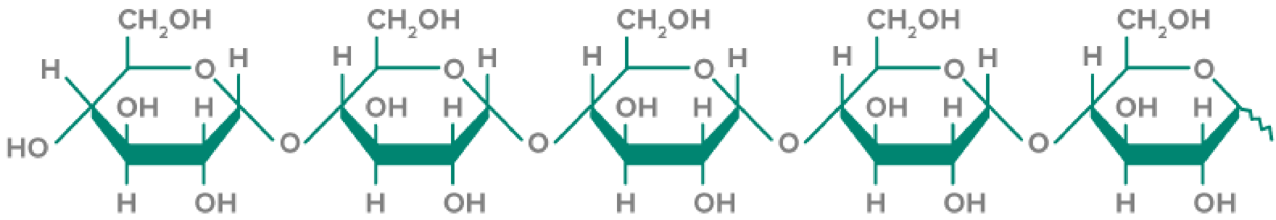
Another monosaccharide, fructose, has the same chemical formula as glucose, but the atoms are arranged differently. Molecules with the same chemical formula but with atoms in a different arrangement are called **isomer**. Compare the glucose and fructose molecules in the **Figure** below. Can you identify their differences? The only differences are the positions of some of the atoms. These differences affect the properties of the two monosaccharides.



[Figure 2]

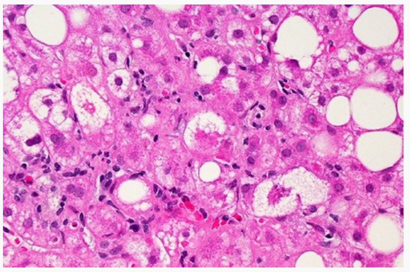
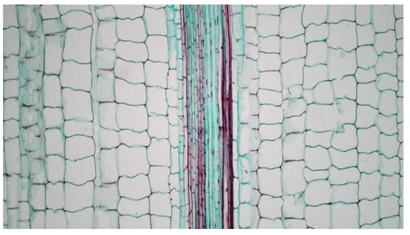
Sucrose Molecule. This sucrose molecule is a disaccharide. It is made up of two monosaccharides: glucose on the left and fructose on the right.

If two monosaccharides bond together, they form a carbohydrate called a **disaccharide**. An example of a disaccharide is sucrose (table sugar), which consists of the monosaccharides glucose and fructose (**Figure** above). Monosaccharides and disaccharides are also called simple sugars. They provide the major source of energy to living cells.



Polysaccharides

A **polysaccharide** is a complex carbohydrate that forms when simple sugars bind together in a chain. Polysaccharides may contain just a few simple sugars or thousands of them. Complex carbohydrates have two main functions: storing energy and forming structures of living things. Some examples of complex carbohydrates and their functions are shown in the **Table** below. Which type of complex carbohydrate does your own body use to store energy?

Name	Function	Example
Starch	Used by plants to store energy.	 [Figure 3] A potato stores starch in underground tubers.
Glycogen	Used by animal to store energy.	 [Figure 4] A human stores glycogen in liver cells.
cellulose	Used by plants to form rigid walls around cells.	 [Figure 5] Plants use cellulose for their cell wall.
chitin	Used by some animals to form an external skeleton.	 [Figure 6] A grasshopper uses chitin for its exoskeleton.

DID YOU KNOW?

Your blood group (A, B, AB, or O) is determined by the type of small carbohydrates attached to certain protein in the membranes of your red blood cell.

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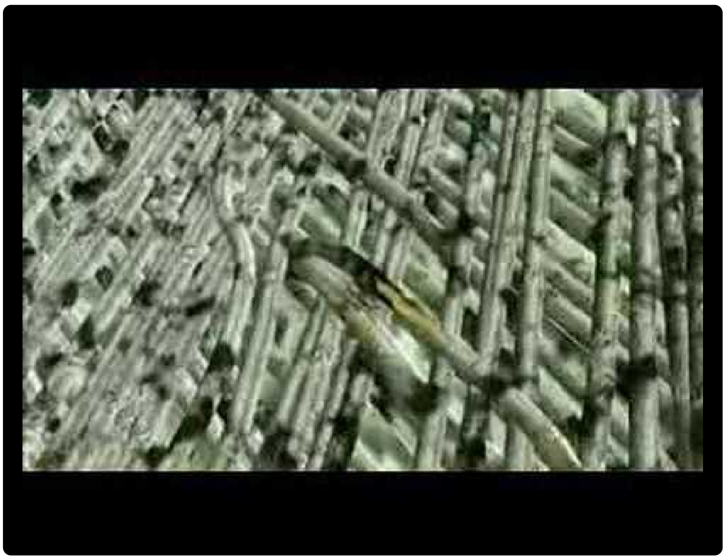
Biofuels: From Sugar to Energy

For years there's been a buzz, both positive and negative, about generating ethanol fuel from corn. Is this a good idea? Is it necessary? These questions need to be discussed. However, the Bay Area of California is rapidly becoming a world center for the next generation of green fuel alternatives. The joint BioEnergy Institute is developing methods to isolate biofuels from the sugars in cellulose.



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Summary

- Carbohydrates are organic compounds used to store energy.
- A monosaccharide, the monomer of carbohydrates, is a simple sugar, such as fructose or glucose.
- Complex carbohydrates have two main functions: storing energy and forming structures of living things.

Review

1. What is a carbohydrate?
2. List three facts about glucose.
3. Assume that you are trying to identify an unknown organic molecule. It contains only carbon, hydrogen, and oxygen and is found in the cell walls of a newly discovered plant species. What type of organic compound is it? Why?
4. Compare and contrast the structures and functions of simple sugars and complex carbohydrates.

Report Content Errors

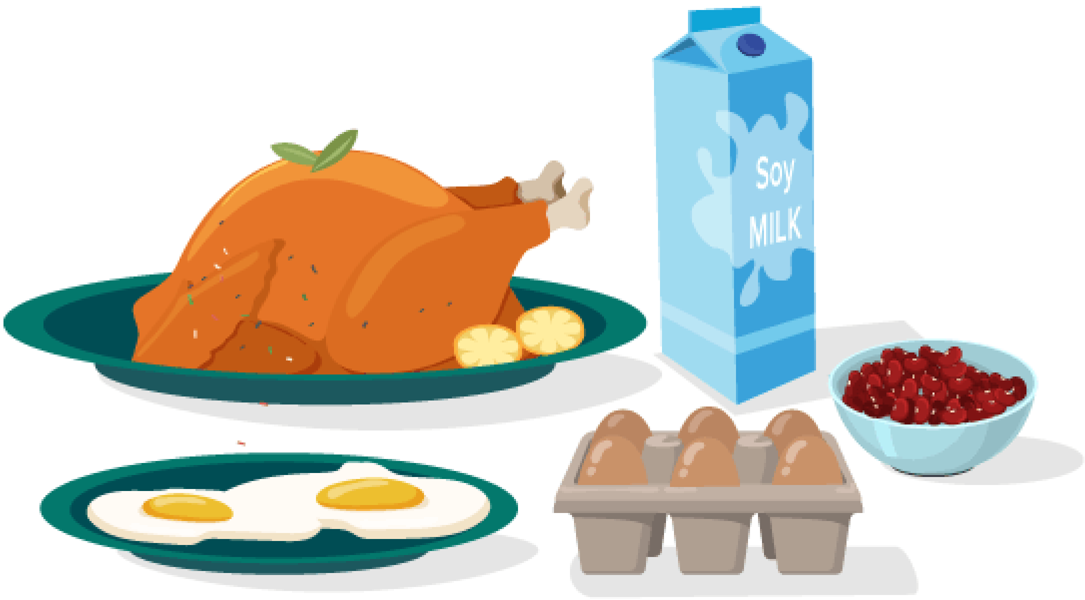
1.11 Proteins

FlexBooks 2.0 > Biology For High School Diploma > Proteins

Last Modified: Jan 18, 2022

What you will learn

- What are proteins
- Levels of protein structure
- Important functions of proteins



[Figure 1]

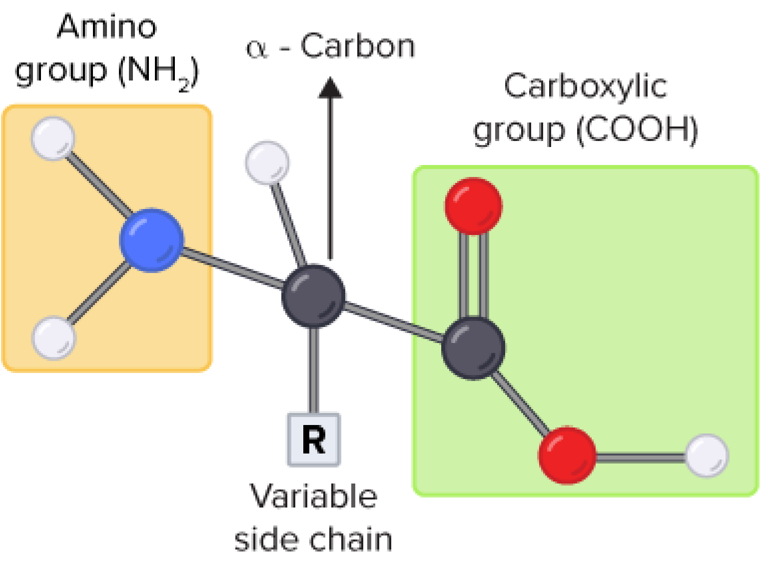
You may have been told proteins are good for you. Do these look good to you?

Proteins as food. To you, these may not look appetizing (or they might), but they do provide a nice supply of **amino acid**, the monomer of proteins. Proteins have many important roles, from transporting, signaling, receiving, and catalyzing to storing, defending, and allowing for movement. Where do you get the amino acids needed so your cell can make their own proteins? If you cannot make it, you must eat it.

Proteins

A **protein** is an organic compound made up of small molecules called **amino acids**, the monomers of proteins. There are 20 different amino acids commonly found in the proteins of living organism. Small proteins may contain just a few hundred amino acids, whereas large proteins may contain thousands of amino acids. The largest known proteins are titins, found in muscle, which are composed from over 27,000 amino acids.

The **Figure** below shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. For example, in the amino acid glycine, the side chain is simply hydrogen (H). In glutamic acid, in contrast, the side chain is CH2CH2COOH. Variable side chains give amino acids different chemical properties. The order of amino acids, together with the properties of the amino acids, determines the shape of the protein, and the shape of the protein determines the function of the protein.



[Figure 2]

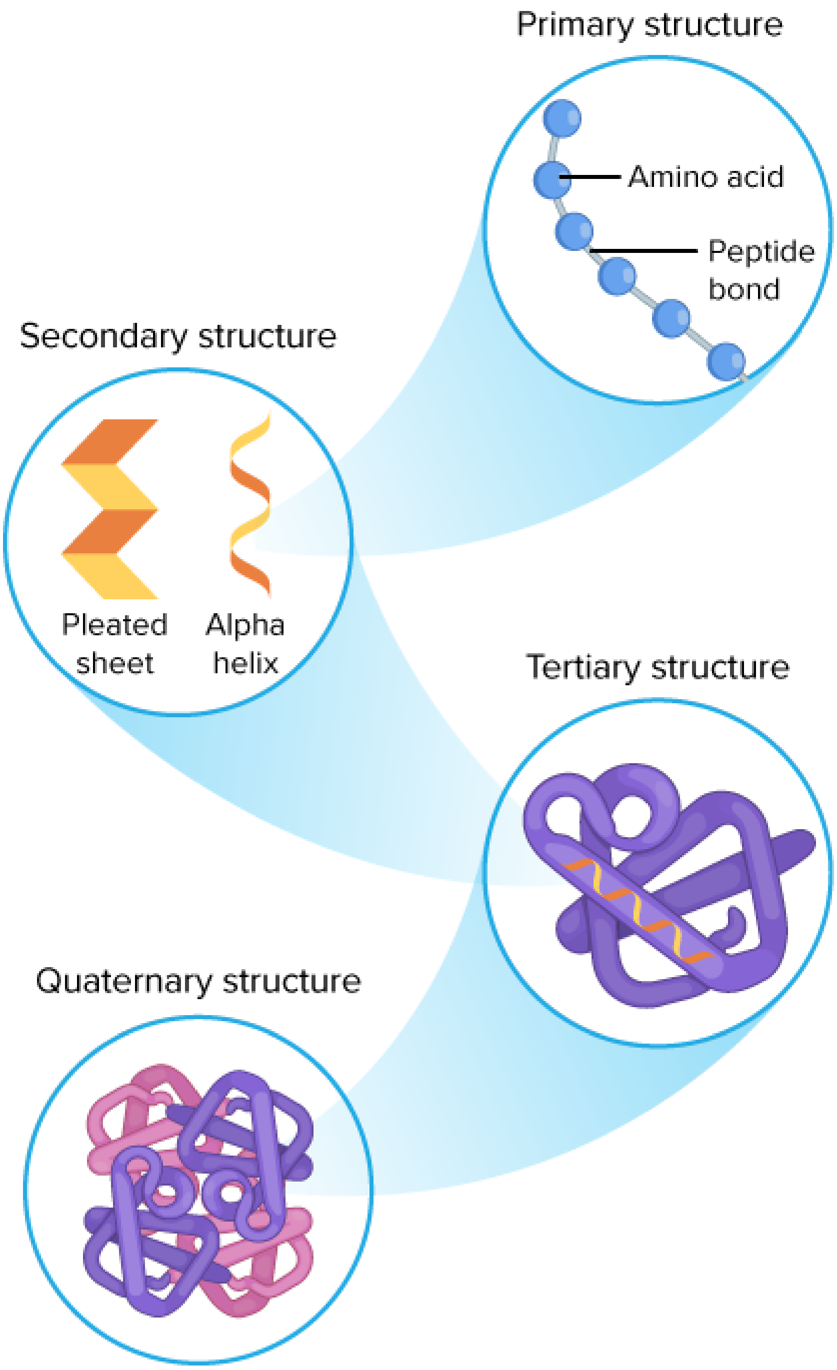
General Structure of Amino Acids. KEY: White = hydrogen (H), Blue = nitrogen (N), Dark Grey = carbon (C), Red = oxygen (O), R = variable side chain

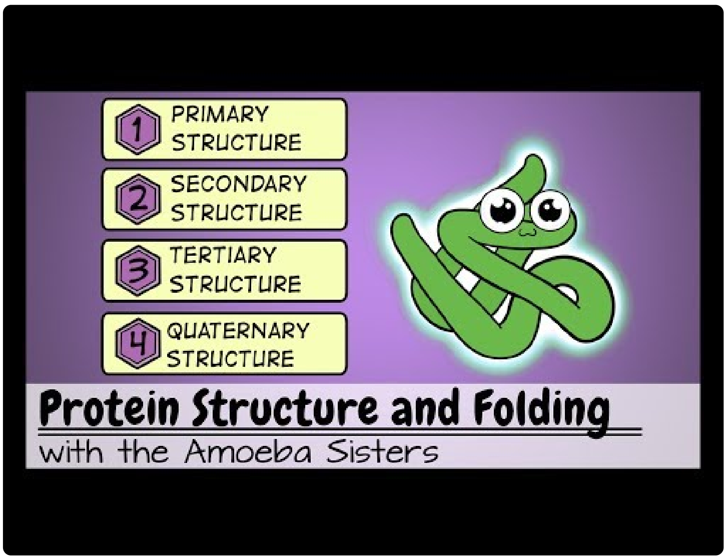
DID YOU KNOW?

Although there are hundreds of amino acids found in nature, only 20 amino acids are encoded by the standard genetic code in humans and other living organisms. Two more amino acids, selenocysteine and pyrrolysine, have been found to be incorporated during protein synthesis. This makes them the 21^{st} and 22^{nd} amino acids that you may find present in proteins.

Protein Structure

When amino acids bind together, they form a long chain called a **polypeptide**. A protein consists of one or more polypeptide chains. A protein may have up to four levels of structure. The lowest level, a protein's primary structure, is its sequence of amino acids. Higher levels of protein structure are described in the animation below. The complex structures of different proteins give them unique properties, which they need to carry out their various jobs in living organisms.





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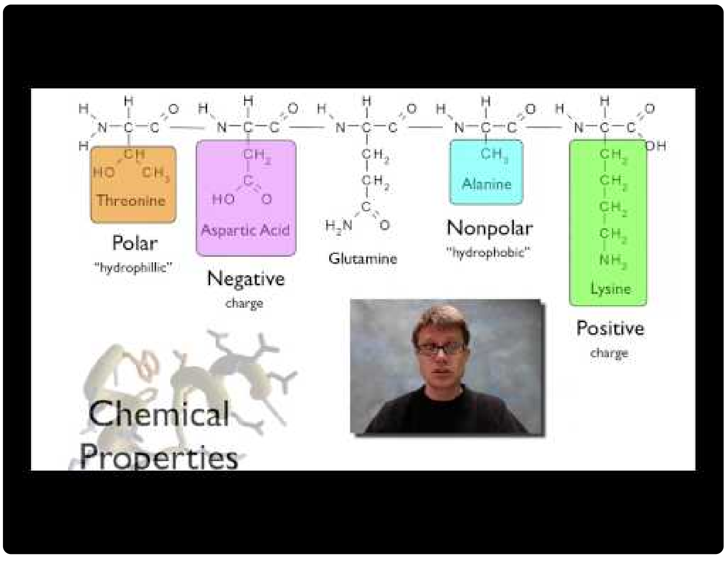
Functions of Proteins

Proteins play many important roles in living things. Some proteins help cells keep their shape (structural proteins), some, such as connective and motor proteins, make up muscle tissue, and some transport items in and out of cells (transport proteins). Some proteins act as signals, and other proteins receive those signals. **enzyme** are proteins that speed up chemical reaction in cells. Other proteins are **antibody**, which bind to foreign substances such as bacterium and target them for destruction. Still other proteins carry messages or transport materials. For example, human red blood cell contain a protein called **hemoglobin**, which binds with oxygen. Hemoglobin allows the blood to carry oxygen from the lung to cells throughout the body.



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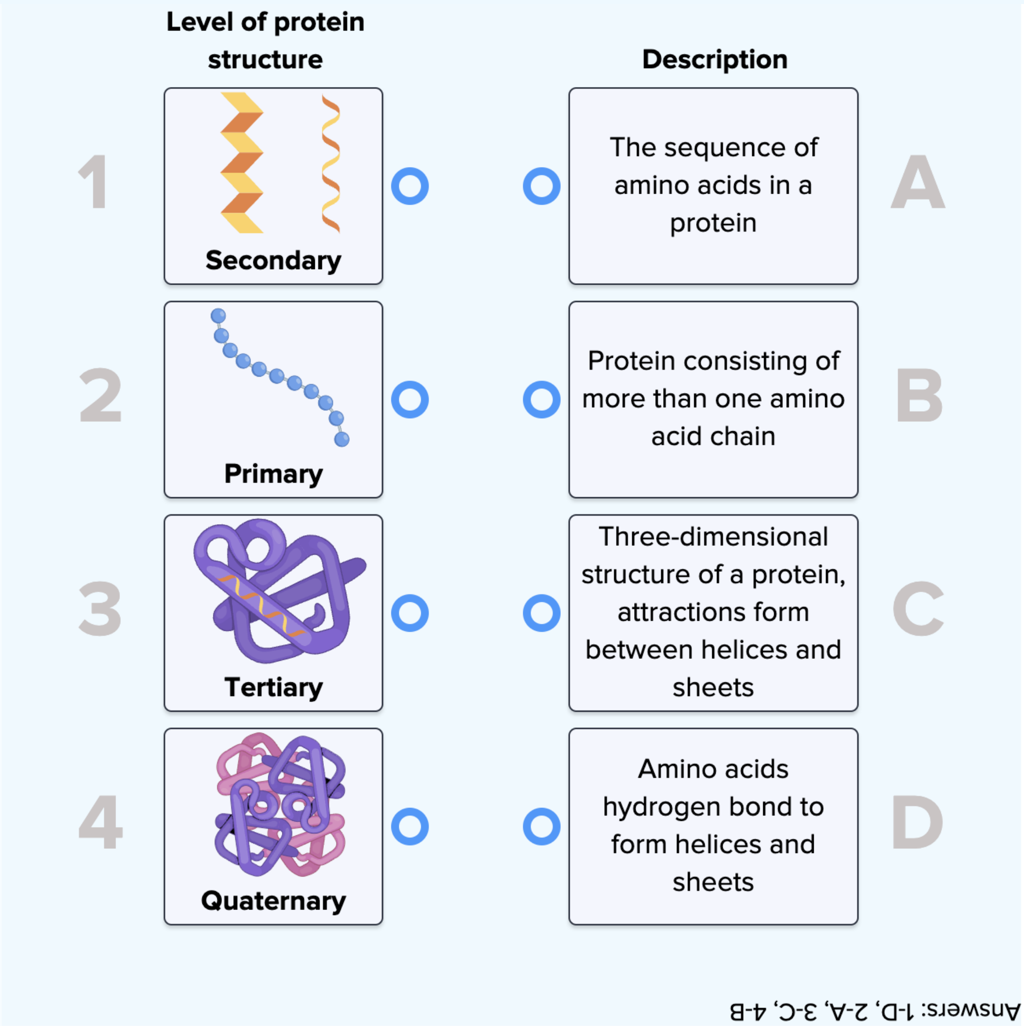
Proteins and Diet

Proteins in the diet are necessary for life. Dietary proteins are broken down into their component amino acids when food is digested. Cells can then use the components to build new proteins. Humans are able to synthesize all but eight of the twenty common amino acids. These eight amino acids, called essential amino acid, must be consumed in foods. Like dietary carbohydrate and lipid, dietary proteins can also be broken down to provide cells with energy.

CAN YOU MATCH?

Try matching the levels of protein structure with their description.



science Friday: The Medical Wonders of Worm Spit

How useful is worm spit? It turns out that worm spit, also known as silk, is a very useful material in medicine. In this video by Science Friday, Dr. David Kaplan describes how silk is used in a variety of medical applications.

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Summary

- Proteins are organic compounds made up of amino acids, the monomers of proteins.
- A protein may have up to four levels of structure. The complex structures of different proteins give them unique properties.
- Enzymes are proteins that speed up biochemical reactions in cells. Antibodies are proteins that target pathogens for destruction.

Review

1. Proteins are made out of _______________.
2. What determines the primary structure of a protein?
3. State two functions of proteins.
4. What are enzymes?
5. Describe the role of hemoglobin.

Report Content Errors

1.12 Lipids

FlexBooks 2.0 > Biology For High School Diploma > Lipids

Last Modified: Jan 18, 2022

What you will learn

- What are lipids
- Structure and function of saturated and **unsaturated fatty acid**
- Types of lipids
- Role of lipids in the human body

[Figure 1]

Oil. Does it mix with water? No. Biologically, why is this important?

Oil is a lipid. The property of chemically not being able to mix with water gives lipids some very important biological functions. Lipids form the outer membrane of cell. Why?

Lipids

A **lipid** is an organic compound such as fat or oil. organism use lipids to store energy, but lipids have other important roles as well. Lipids consist of repeating units called fatty acid. **Fatty acids** are organic compounds that have the general formula $CH_3(CH_2)_nCOOH$, where *n* usually ranges from 2 to 28 and is always an even number. There are two types of fatty acids: **saturated fatty acid** and unsaturated fatty acids.

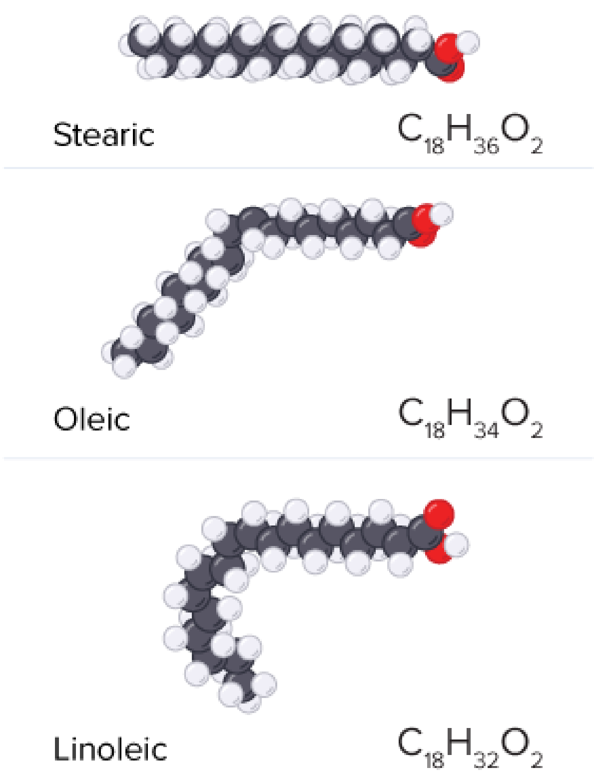
DID YOU KNOW?

Lipids are the highest long-term energy storage molecules. One gram of lipids yields 9 kcal of energy.

Saturated Fatty Acids

In **saturated fatty acids**, carbon atoms are bonded to as many hydrogen atoms as possible. This causes the molecules to form straight chains, as shown in the **Figure** below. The straight chains can be packed together very tightly, allowing them to store energy in a compact form. This explains why saturated fatty acids are solids at room temperature. animal use saturated fatty acids to store energy.

[Figure 2]



[Figure 3]

Fatty Acids structures and their examples. Saturated fatty acids have straight chains. Unsaturated fatty acids have bent chains.

Unsaturated Fatty Acids

In **unsaturated fatty acids**, some carbon atoms are not bonded to as many hydrogen atoms as possible. Instead, they are bonded to other groups of atoms. Wherever carbon binds with these other groups of atoms, it causes chains to bend (see the **Figure** above). The bent chains cannot be packed together very tightly, so unsaturated fatty acids are liquids at room temperature. Plants use unsaturated fatty acids to store energy. Some examples are shown in the **Figure** below.

[Figure 4]

[Figure 5]

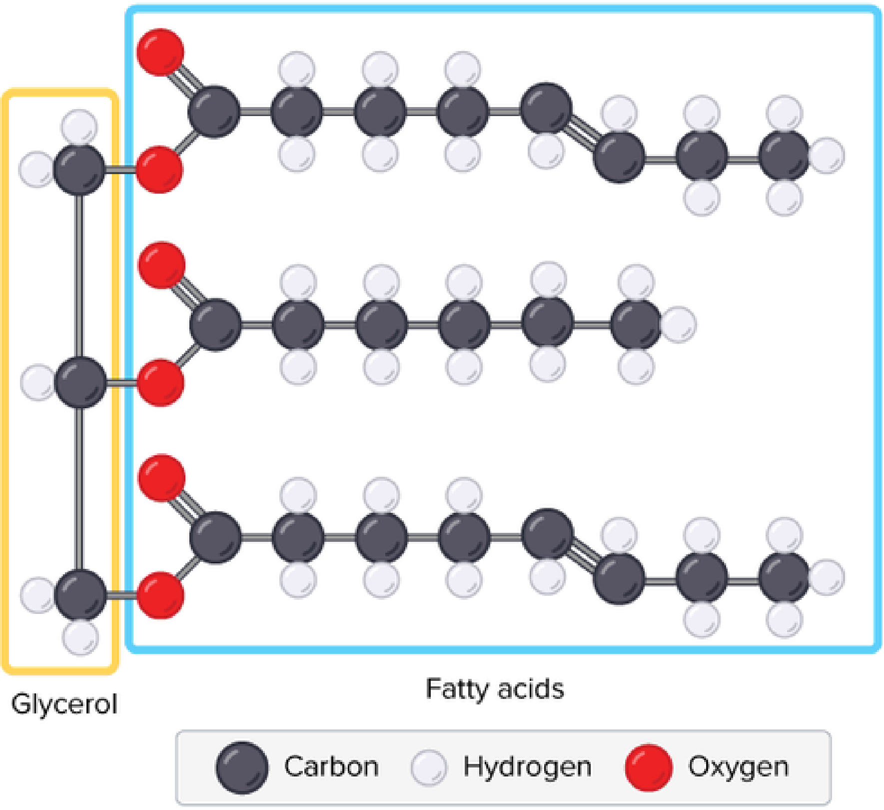
[Figure 6]

These plant products all contain unsaturated fatty acids.

Types of Lipids

Lipids may consist of fatty acids alone, or they may contain other molecules as well. For example, some lipids contain alcohol or phosphate groups. They include

1. **Triglycerides**: the main form of stored energy in animals.
2. **Phospholipids**: the major components of cell membrane.
3. **Steroids**: serve as chemical messengers and have other roles.



[Figure 7]

Triglyceride Molecule. The left part of this triglyceride molecule represents glycerol. Each of the three long chains on the right represents a different fatty acid.

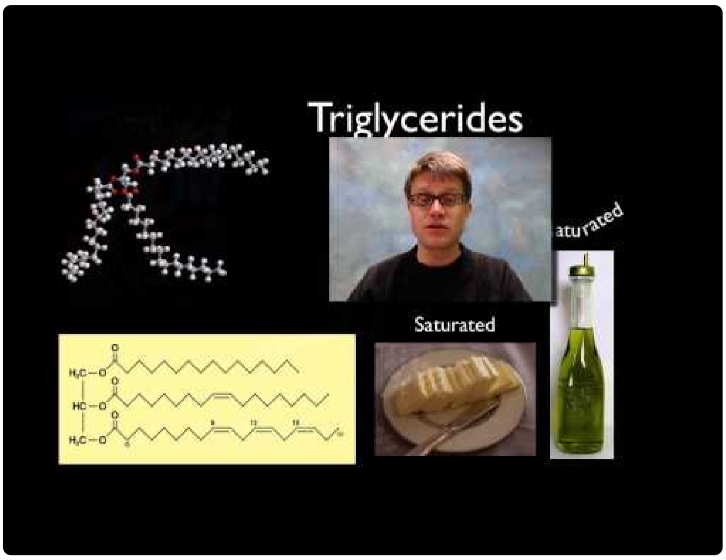
Lipids and Diet

Humans need lipids for many vital functions, such as storing energy and forming cell membranes. Lipids can also supply cells with energy. In fact, a gram of lipids supplies more than twice as much energy as a gram of carbohydrate or protein. Lipids are necessary in the diet for most of these functions. Although the human body can manufacture most of the lipids it needs, there are others, called **essential fatty acid**, that must be consumed in food. Essential fatty acids include omega-3 and omega-6 fatty acids. Both of these fatty acids are needed for important biological processes, not just for energy.

DID YOU KNOW?

The acidic environment of the stomach helps digest lipids by activating the enzyme lipase. Lipase breaks down lipids into glycerol and fatty acids.

Although some lipids in the diet are essential, excess dietary lipids can be harmful. Because lipids are very high in energy, eating too many may lead to unhealthy weight gain. A high-fat diet may also increase lipid levels in the blood. This, in turn, can increase the risk for health problems such as cardiovascular disease. The dietary lipids of most concern are saturated fatty acids, trans fats, and cholesterol. For example, cholesterol is the lipid mainly responsible for narrowing artery and causing the disease atherosclerosis.



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Summary

- Organisms use lipids to store energy. There are two types of fatty acids: saturated fatty acids and unsaturated fatty acids.
- Animals use saturated fatty acids to store energy. Plants use unsaturated fatty acids to store energy.
- Phospholipids are the major components of cell membranes.
- Excess dietary lipids can be harmful.

Review

1. What is a lipid? Give three examples.
2. Butter is a fat that is a solid at room temperature. What type of fatty acid does butter contain? How do you know?
3. Explain why molecules of saturated and unsaturated fatty acids have different shapes.
4. Which lipid is the main component of cell membranes?

Report Content Errors

1.13 Nucleic Acids

FlexBooks 2.0 > Biology For High School Diploma > Nucleic Acids

Last Modified: Jan 25, 2022

What you will learn

- Nucleic acids and their structure
- Role of nucleic acids

[Figure 1]

You may have heard that something is "encoded in your DNA." What does that mean?

Nucleic acids. Essentially the "instructions" or the "code" of life. Deoxyribonucleic acid, or **DNA**, carries the unique code to make the protein that give you your traits. Half of this code comes from your biological mother and a half from your biological father. Therefore, every person that has ever lived - except for identical twins - has his or her own unique sequence of code - or instructions - or DNA.

Nucleic Acids

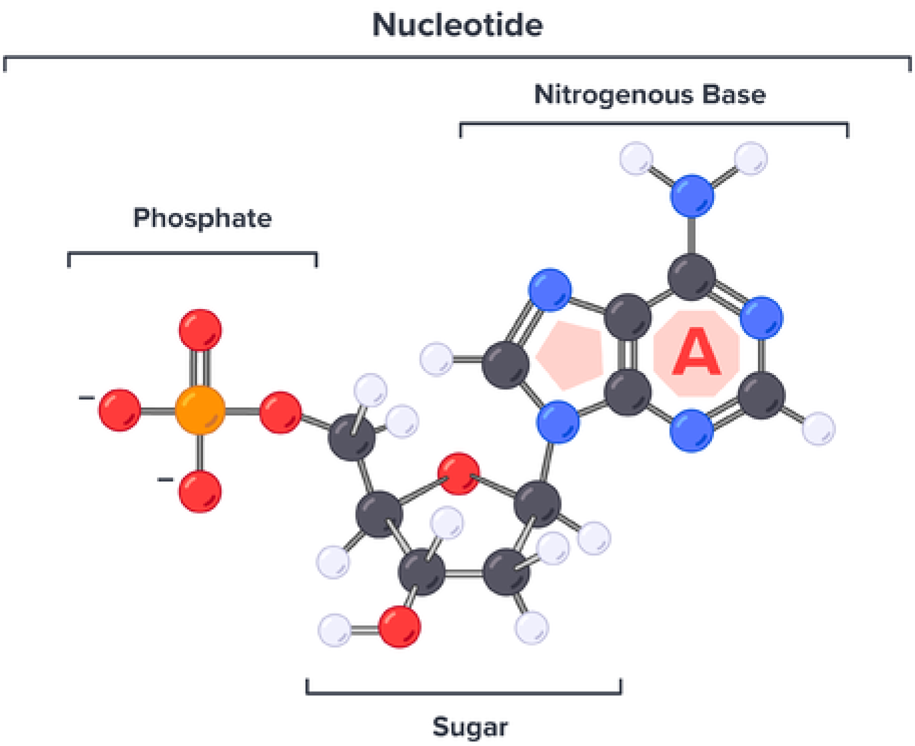
A **nucleic acid** is an organic compound, such as DNA or **RNA**, that is built of monomer called **nucleotide**. Many nucleotides bind together to form a chain called a **polynucleotide**. The nucleic acid **DNA** (deoxyribonucleic acid) consists of two polynucleotide chains. The nucleic acid **RNA** (ribonucleic acid) consists of just one polynucleotide chain. Adenosine Triphosphate (ATP) is another important nucleic acid. ATP is described as the "energy currency" of the cell or the "molecular unit of currency." One molecule of ATP contains three phosphate groups.

Structure of Nucleic Acids

Each nucleotide consists of three smaller molecules as shown in the **Figure** below:

1. sugar
2. phosphate group
3. nitrogen base

If you look at the **Figure** below, you will see that the sugar of one nucleotide binds to the phosphate group of the next nucleotide. These two molecules alternate to form the backbone of the nucleotide chain. This backbone is known as the *sugar-phosphate backbone.*



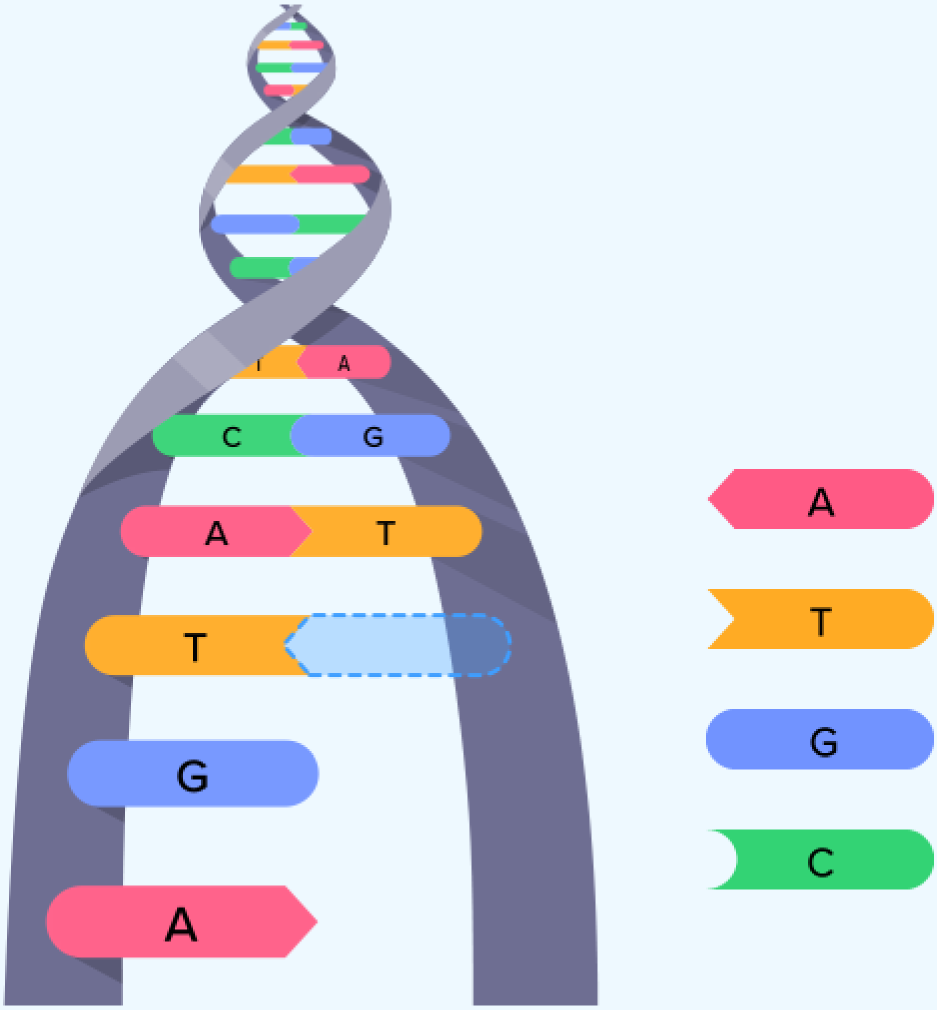
[Figure 2]

Structure of a nucleotide

The nitrogen bases in a nucleic acid stick out from the backbone. There are four different types of bases: cytosine (C), adenine (A), guanine (G), and either thymine (T) in DNA, or uracil (U) in RNA. In DNA, bonds form between bases on the two nucleotide chains and hold the chains together. Each type of base binds with just one other type of base: cytosine always binds with guanine, and adenine always binds with thymine. These pairs of bases are called **complementary base pair**.

CAN YOU BUILD?

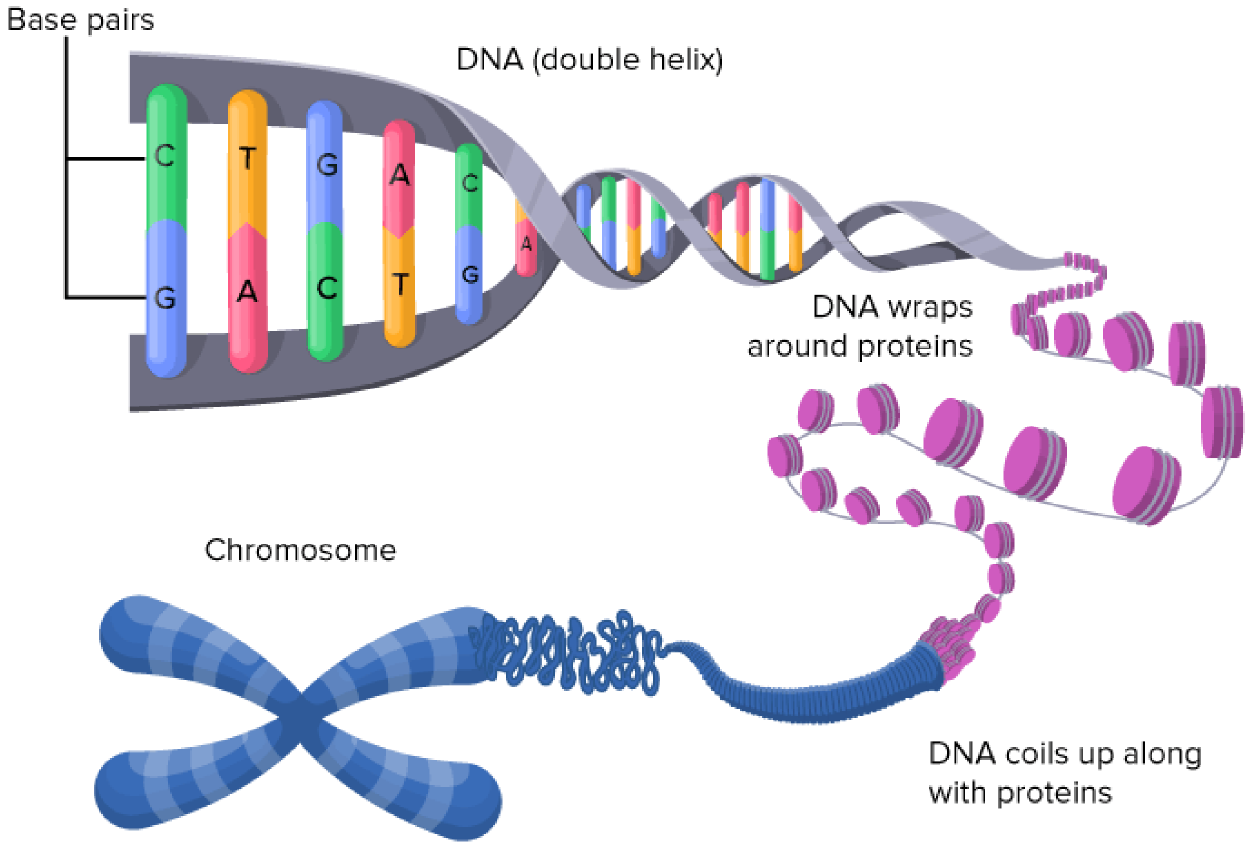
Try to bond the nitrogen bases on the right, with the complementary base. Start by dragging the nitrogen bases on the right.



DID YOU KNOW?

Although there are about 8.7 million known species of living organism on Earth, their genetic information is only made of four letters A, T, G, and C.

The binding of complementary bases allows DNA molecules to take their well-known shape, called a **double helix**, which is shown in the **Figure** below. A double helix is like a twisted ladder. The double helix shape forms naturally and is very strong, making the two polynucleotide chains difficult to break apart.



[Figure 3]

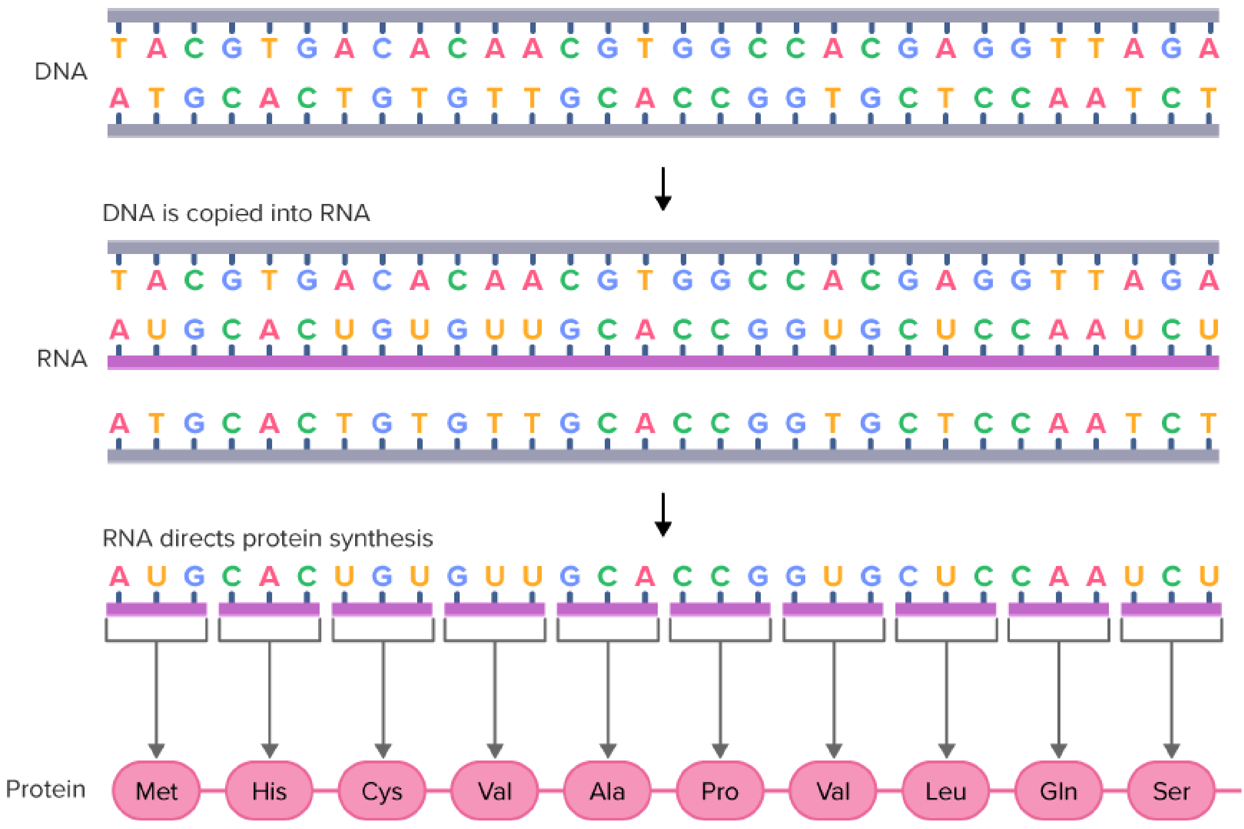
DNA Molecule. Bonds between complementary bases help form the double helix of a DNA molecule. The letters A, T, G, and C stand for the bases adenine, thymine, guanine, and cytosine. The sequence of these four bases in DNA is a code that carries instructions for making proteins. Shown is how the DNA winds into a chromosome.

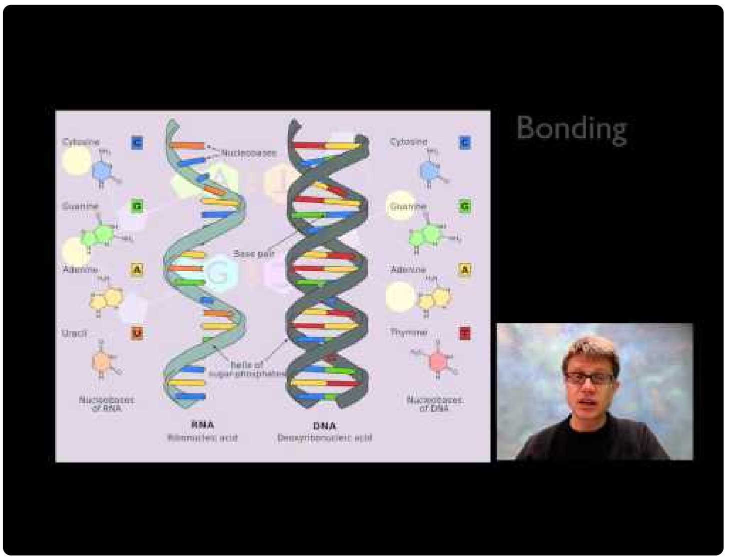
DID YOU KNOW?

Due to one less carbon in its sugar component, DNA is a more stable molecule than RNA. This property is useful in keeping the genetic information safe.

Roles of Nucleic Acids

DNA is also known as the hereditary material or genetic information. It is found in gene, and its sequence of bases makes up a code. Between 'starts' and 'stops', the code carries instructions for the correct sequence of amino acid in a protein. DNA and RNA have different functions relating to the genetic code and proteins. Like a computer code, DNA contains the genetic instructions for the correct sequence of amino acids in proteins. RNA uses the information in DNA to assemble the correct amino acids and help make the protein. The information in DNA is passed from parent cell to daughter cell whenever cells divide. The information in DNA is also passed from parents to offspring when organisms reproduce. This is how inherited characteristics are passed from one generation to the next.





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Summary

- DNA, RNA, and ATP are nucleic acids. Polynucleotides like DNA and RNA are built of monomers called nucleotides.
- The bases of DNA are adenine, guanine, cytosine, and thymine. In RNA, thymine is replaced by uracil.
- In DNA, A always binds to T, and G always binds to C.
- The shape of the DNA molecule is known as a double helix.
- DNA contains the genetic instructions for the correct sequence of amino acids in proteins. RNA uses the information in DNA to assemble the correct amino acids and help make the protein.

Review

1. Identify the three parts of a nucleotide.
2. What is DNA?
3. What are complementary base pairs? Give an example.
4. Describe the shape of DNA.
5. How are DNA and RNA related to proteins?

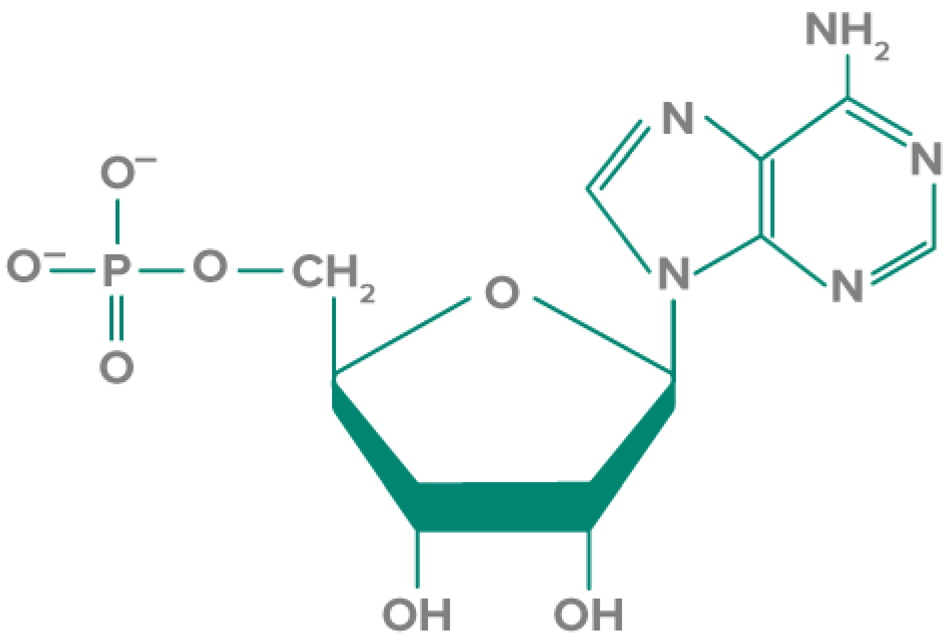
1.14 Biochemical Reactions

FlexBooks 2.0 > Biology For High School Diploma > Biochemical Reactions

Last Modified: Mar 04, 2022

What you will learn

- **chemical reaction** and biochemical reactions
- **reactant** and products in a chemical reaction
- How to write a **chemical equation**
- Conservation of matter in chemical reactions



[Figure 1]

Understanding chemistry is essential to fully understand biology. Why?

A general understanding of chemistry is necessary to understand biology. Essentially, our cell are just thousands of chemicals — made of element like carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur — in just the right combinations. And these chemicals combine through chemical reactions.

Chemical Reactions

The element chlorine (Cl) is a greenish poison. Would you eat chlorine? Of course not, but you often eat a compound containing chlorine. In fact, you probably eat this chlorine compound just about every day. Do you know what it is? It's table salt. Table salt is sodium chloride (NaCl), which forms when chlorine and sodium (Na) combine in certain proportions. How does chlorine, a toxic green chemical, change into harmless white table salt? It happens in a chemical reaction.

A **chemical reaction** is a process that changes some chemical substances into others. A substance that starts a chemical reaction is called a **reactant**, and a substance that forms as a result of a chemical reaction is called a **product**. During a chemical reaction, the reactants are used up to create the products. Chemical reactions that take place inside living things are called **biochemical reactions**.

An example of a chemical reaction is the burning of methane. In this chemical reaction, the reactants are methane (CH_4) and oxygen (O_2), and the products are carbon dioxide (CO_2) and water (H_2O). A chemical reaction involves the breaking and forming of chemical bond. When methane burns, bonds break in the methane and oxygen molecules, and new bonds form in the molecules of carbon dioxide and water.

Chemical Equations

A chemical reaction can be represented by a **chemical equation**. For example, the burning of methane can be represented by the chemical equation

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

The arrow in a chemical equation separates the reactants from the products and shows the direction in which the reaction proceeds. If the reaction could occur in the opposite direction as well, two arrows pointing in opposite directions would be used. The number 2 in front of O_2 and H_2O shows that two oxygen molecules and two water molecules are involved in the reaction. (With no number in front of a chemical symbol, just one molecule is involved.)

Conservation of Matter

In a chemical reaction, the quantity of each element does not change; there is the same amount of each element in the products as there was in the reactants. This is because matter is always conserved. The conservation of matter is reflected in a reaction's chemical equation. The same number of atoms of each element appears on each side of the arrow. For example, in the chemical equation for the burning of methane, there are four hydrogen atoms on each side of the arrow. Can you find all four of them on each side of the equation?

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Summary

- A chemical reaction is a process that changes some chemical substances into others. During a chemical reaction, the reactants are used up to create the products.
- In a chemical reaction, matter is always conserved.

Review

1. Define a chemical reaction.
2. Describe the roles of reactants and products in chemical reactions.
3. How does a chemical equation show that matter is always conserved in a chemical reaction?
4. Knowing that water (H_2O) forms from hydrogen (H_2) and oxygen (O_2), write a chemical equation for the formation of water from these two elements.

Report Content Errors

1.15 Energy and Biochemical Reactions

FlexBooks 2.0 > Biology For High School Diploma > Energy and Biochemical Reactions

Last Modified: Jan 18, 2022

What will you learn

- How **energy** is involved in a chemical reaction
- Endothermic and **exothermic reaction**

[Figure 1]

What is energy? Where does your energy come from? Can energy be recycled?

This team of ants is breaking down a dead tree. A classic example of teamwork. And all that work takes energy. In fact, each chemical reaction - the chemical reactions that allow the cell in those ants to do the *work* - needs energy to get started. And all that energy comes from the food the ants eat. Whatever eats the ants gets their energy from the ants. Energy passes through an ecosystem in one direction only.

Chemical Reactions and Energy

Chemical reactions always involve energy. **Energy** is a property of matter that is defined as the ability to do work. When methane burns, for example, it releases energy in the form of heat and light. Other chemical reactions absorb energy rather than release it.

Exothermic Reactions

A chemical reaction that releases energy (as heat) is called an **exothermic reaction**. This type of reaction can be represented by a general chemical equation:

reactant → Products + Heat

In addition to methane burning, another example of an exothermic reaction is chlorine combining with sodium to form table salt. This reaction also releases energy.

DID YOU KNOW?

cellular respiration is a series of exothermic reactions that occur in order to release energy from food molecules.

Endothermic Reaction

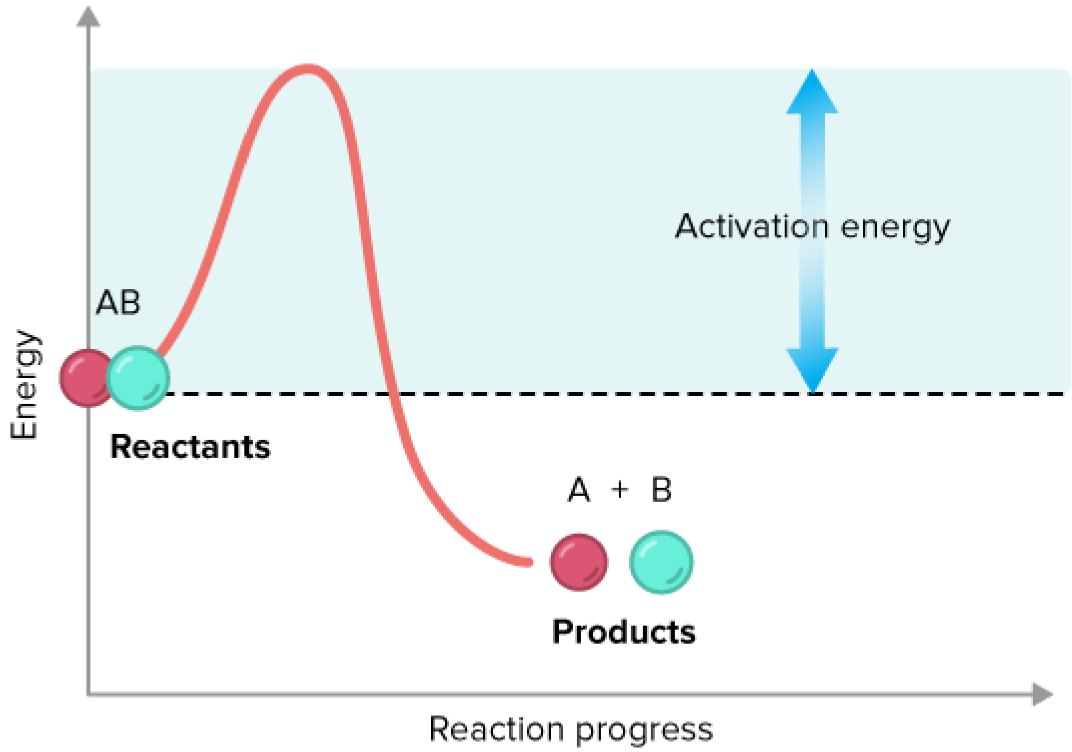
A chemical reaction that absorbs energy is called an **endothermic reaction**. This type of reaction can also be represented by a general chemical equation:

Reactants + Heat → Products

Did you ever use a chemical cold pack? The pack cools down because of an endothermic reaction. When a tube inside the pack is broken, it releases a chemical that reacts with water inside the pack. This reaction absorbs heat energy and quickly cools down the pack.

Activation Energy

All chemical reactions need energy to get started. Even reactions that release energy need a boost of energy in order to begin. The energy needed to start a chemical reaction is called **activation energy**. Activation energy is like the push a child needs to start going down a playground slide. The push gives the child enough energy to start moving, but once she starts, she keeps moving without being pushed again. Activation energy is illustrated in the **Figure** below.



[Figure 2]

Activation energy provides the "push" needed to start a chemical reaction. Is the chemical reaction in this figure an exothermic or endothermic reaction?

Why do all chemical reactions need energy to get started? In order for reactions to begin, reactant molecules must bump into each other, so they must be moving, and movement requires energy. When reactant molecules bump together, they may repel each other because of intermolecular forces pushing them apart. Overcoming these forces so the molecules can come together and react also takes energy.

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Summary

- Chemical reactions always involve energy.
- A chemical reaction that releases energy is an exothermic reaction, and a chemical reaction that absorbs energy is an endothermic reaction.
- The energy needed to start a chemical reaction is the activation energy.

Review

1. What is an exothermic reaction?
2. What is the general chemical equation for an endothermic reaction?
3. What is the activation energy?
4. Why do all chemical reactions require activation energy?

Report Content Errors

1.16 Types of Biochemical Reactions

FlexBooks 2.0 > Biology For High School Diploma > Types of Biochemical Reactions

Last Modified: Mar 04, 2022

What you will learn

- **biochemical reaction** and their role in **metabolism**
- The types of biochemical reactions

[Figure 1]

What do you get when you cross biology and chemistry?

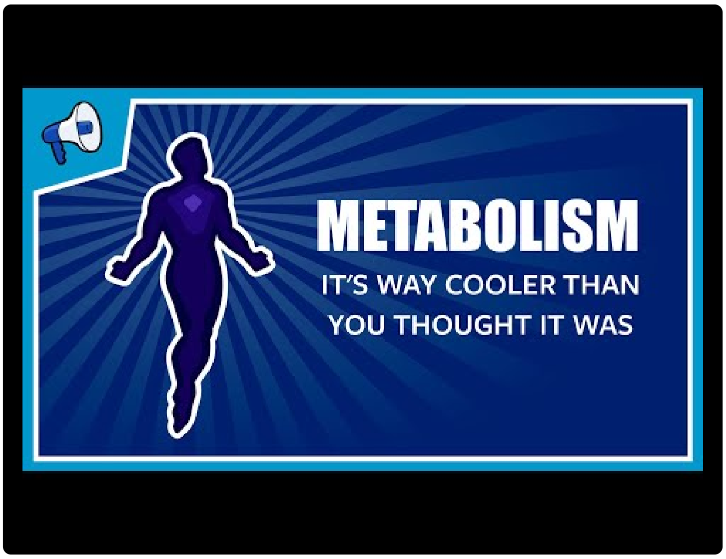
Hummingbirds, with their tiny bodies and high levels of activity, have the highest metabolic rates of any animal — roughly a dozen times that of a pigeon and a hundred times that of an elephant. The metabolic rate, or rate of metabolism, has to do with the amount of energy the organism uses. And that energy is used to drive the chemical reaction in cell — or the biochemical reactions. And, of course, it is all the biochemical reactions that allow the cells to function properly, and maintain life.

Biochemical Reactions

Biochemical reactions are chemical reactions that take place inside the cells of living things. The field of **biochemistry** demonstrates that knowledge of chemistry, as well as biology, is needed to fully understand the life processes of organisms at the level of the cell. The sum of all the biochemical reactions in an organism is called **metabolism**. It includes both exothermic and endothermic reactions.

Types of Biochemical Reactions

exothermic reaction in organisms are called **catabolic reaction**. These reactions break down molecules into smaller units and release energy. An example of a catabolic reaction is the breakdown of glucose, which releases energy that cells need to carry out life processes. Endothermic reactions in organisms are called **anabolic reactions**. These reactions build up bigger molecules from smaller ones. An example of an **anabolic reaction** is the joining of amino acid to form a protein. Which type of reactions—catabolic or anabolic—do you think occur when your body digests food?



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Summary

- Biochemical reactions are chemical reactions that take place inside the cells of organisms.
- Catabolic reactions break down big molecules into smaller units.
- Anabolic reactions build up bigger molecules from smaller ones.

Review

1. What are biochemical reactions?
2. What is metabolism?
3. Describe catabolic reactions?
4. What is an example of a biochemical reaction?

Report Content Errors

1.17 Enzymes

FlexBooks 2.0 > Biology For High School Diploma > Enzymes

Last Modified: Feb 08, 2022

What you will learn

- How enzymes catalyze biochemical reaction
- Importance of enzymes

[Figure 1]

What is a biological catalyst?

This super fast train can obviously reach great speeds. And there's a lot of technology that helps this train go fast. Speaking of helping things go fast brings us to enzymes. Life could not exist without enzymes. Essentially, enzymes are biological **catalyst** that speed up biochemical reactions.

Enzymes

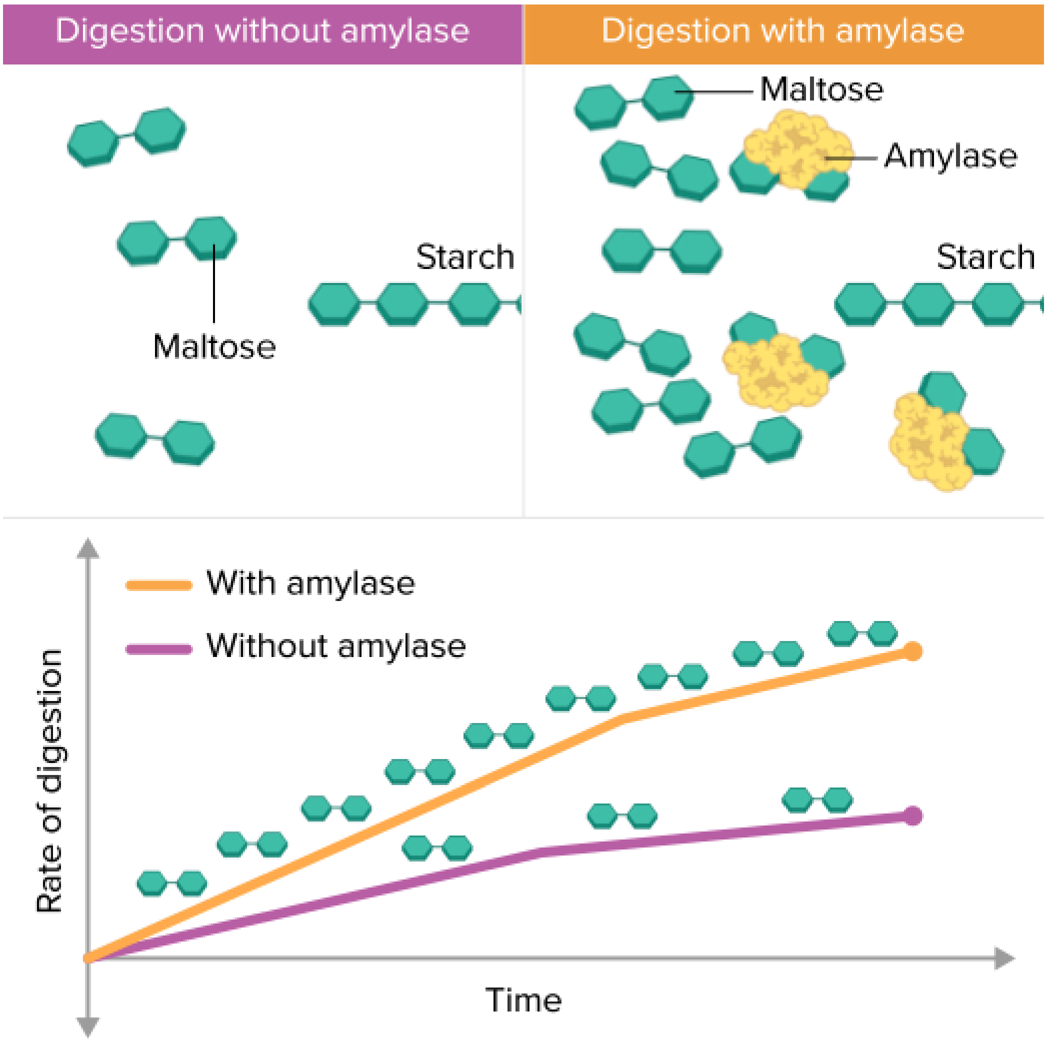
Enzymes and Biochemical Reactions

Most chemical reaction within organism would be impossible under the conditions in cell. For example, the body temperature of most organisms is too low for reactions to occur quickly enough to carry out life processes. reactant may also be present in such low concentrations that it is unlikely they will meet and collide. Therefore, the rate of most biochemical reactions must be increased by a catalyst. A **catalyst** is a chemical that speeds up chemical reactions. In organisms, catalysts are called **enzymes**. Essentially, enzymes are biological catalysts.

Like other catalysts, enzymes are not reactants in the reactions they control. They help the reactants interact but are not used up in the reactions. Instead, they may be used over and over again. Unlike other catalysts, enzymes are usually highly specific for particular chemical reactions. They generally catalyze only one or a few types of reactions.

Enzymes are extremely efficient in speeding up reactions. They can catalyze up to several million reactions per second. As a result, the difference in rates of biochemical reactions with and without enzymes may be enormous. A typical biochemical reaction might take hours or even days to occur under normal cellular conditions without an enzyme, but less than a second with an enzyme.

How does an enzyme affect the rate of a biochemical reaction?



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DID YOU KNOW?

The first enzyme, diastase, was discovered by French chemist Anselme Payen in 1833. This enzyme, now known as amylase, belongs to the group of enzymes that catalyze the breakdown of starch to maltose.

Importance of Enzymes

Enzymes are involved in most of the biochemical reactions that take place in organisms. About 4,000 such reactions are known to be catalyzed by enzymes, but the number may be even higher. Enzymes allow reactions to occur at the rate necessary for life.

In animal, an important function of enzymes is to help digest food. Digestive enzymes speed up reactions that break down large molecules of carbohydrate, protein, and fats into smaller molecules the body can use. Without digestive enzymes, animals would not be able to break down food molecules quickly enough to provide the energy and nutrient they need to survive.

science Friday: Stained Glass Conservation

Stained glass from the Middle Ages is often hundreds of years old. Unfortunately, many of these relics are in need of cleaning and maintenance. In this video by Science Friday, conservator Mary Higgins discusses the methods used to protect the stained glass.

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DID YOU KNOW?

Carbonic anhydrase is one of the fastest known enzymes present in the human body. It can produce up to 600,000 molecules of product per second. It catalyzes the conversion between carbon dioxide and bicarbonate ion and maintains the pH, acid-base homeostasis in blood, and regulates fluid balance.

Summary

- Enzymes are biological catalysts. They speed up biochemical reactions.
- Enzymes are involved in most of the chemical reactions that take place in organisms.

Review

1. What are enzymes?
2. Are enzymes reactants? Explain your answer.

3. What happens to an enzyme after a biochemical reaction?
4. Explain why organisms need enzymes to survive.

Report Content Errors

1.18 Enzyme Function

FlexBooks 2.0 > Biology For High School Diploma > Enzyme Function

Last Modified: Jan 18, 2022

What will you learn

- How do **enzyme** work
- What is the role of the **active site** of an enzyme
- Factors that affect enzyme activity

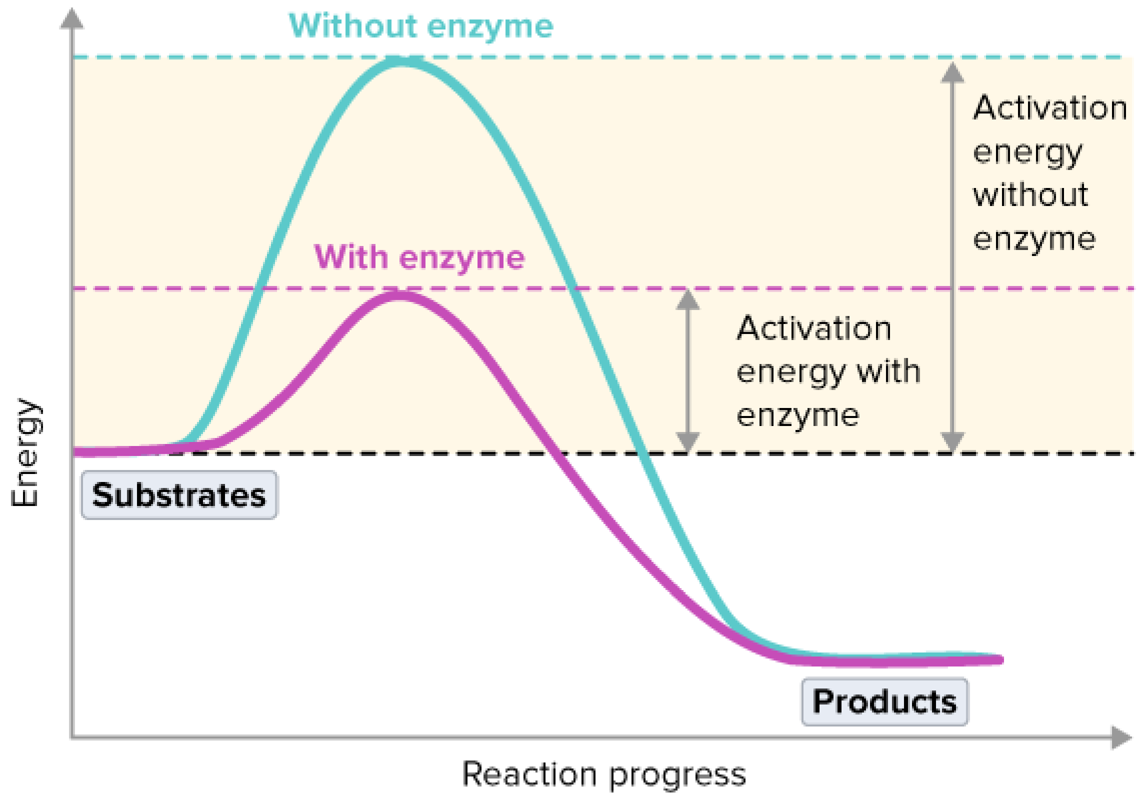
[Figure 1]

Do cells have one enzyme with lots of functions, or many enzymes, each with just one function?

Enzymes. Vital protein necessary for life. So how do enzymes work? How do they catalyze just one specific biochemical reaction? In a puzzle, only two pieces will fit together properly. Understanding that is one of the main steps in understanding how enzymes work.

Enzyme Function

How do **enzymes** speed up biochemical reactions so dramatically? Like all catalyst, enzymes work by lowering the **activation energy** of chemical reaction. Activation energy is the energy needed to start a chemical reaction. This is illustrated in the **Figure** below. The biochemical reaction shown in the figure requires about three times as much activation energy without the enzyme as it does with the enzyme.



[Figure 2]

The enzyme speeds up the reaction by lowering the activation energy needed for the reaction to start. Compare the activation energy with and without the enzyme.

Enzymes generally lower activation energy by reducing the energy needed for reactant to come together and react. For example:

- Enzymes bring reactants together so they don't have to expend energy moving about until they collide at random. Enzymes bind both reactant molecules (called the **substrate**), tightly and specifically, at a site on the enzyme molecule called the **active site**.
- By binding reactants at the active site, enzymes also position reactants correctly, so they do not have to overcome intermolecular forces that would otherwise push them apart. This allows the molecules to interact with less energy.
- Enzymes may also allow reactions to occur by different pathways that have lower activation energy.

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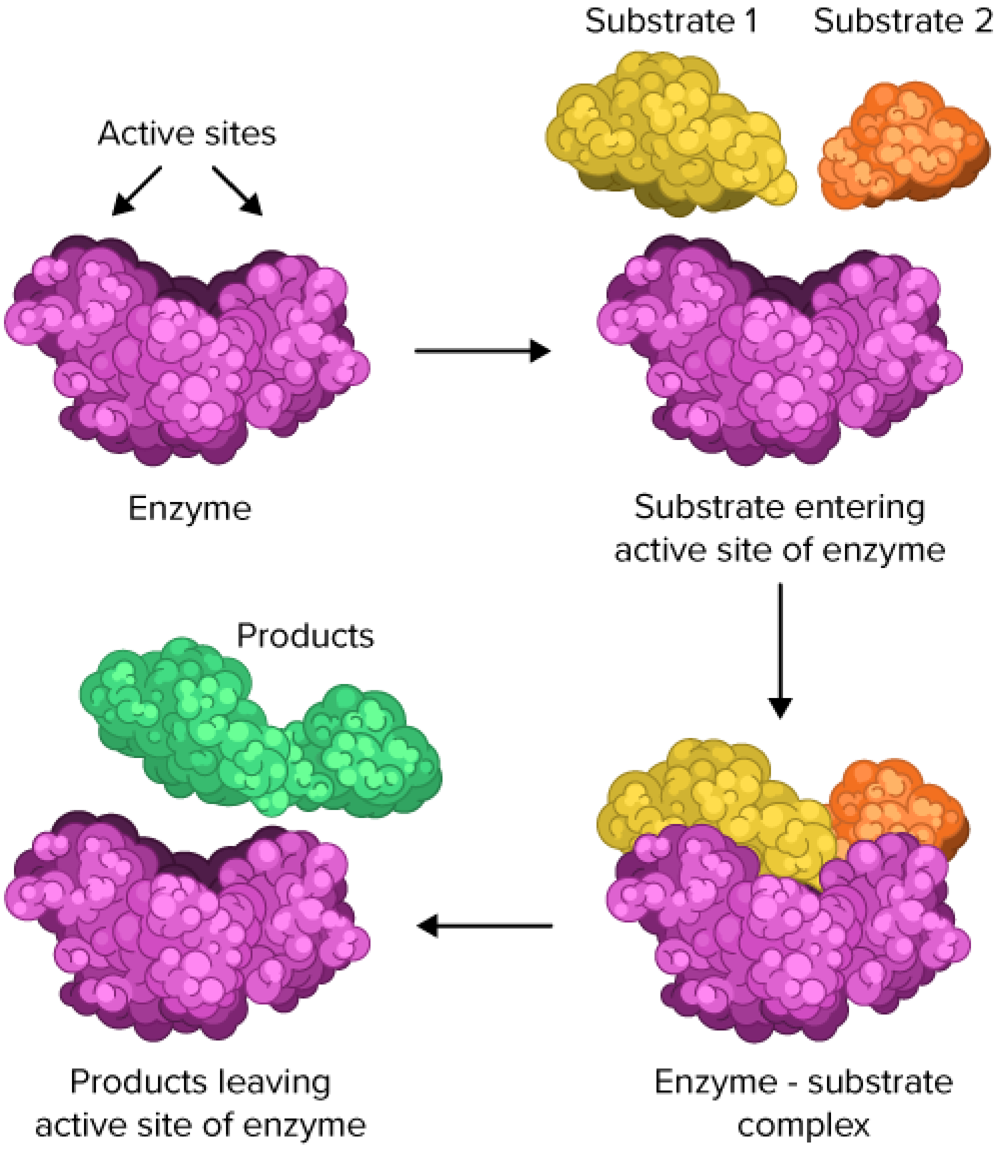
DID YOU KNOW?

Enzymes are crucial to metabolic reactions. Almost all metabolic reactions are catalyzed by enzymes and it is estimated to be around 75,000 different enzymes in the human body.

The active site is specific for the reactants of the biochemical reaction the enzyme catalyzes. Similar to puzzle pieces fitting together, the active site can only bind certain substrates.

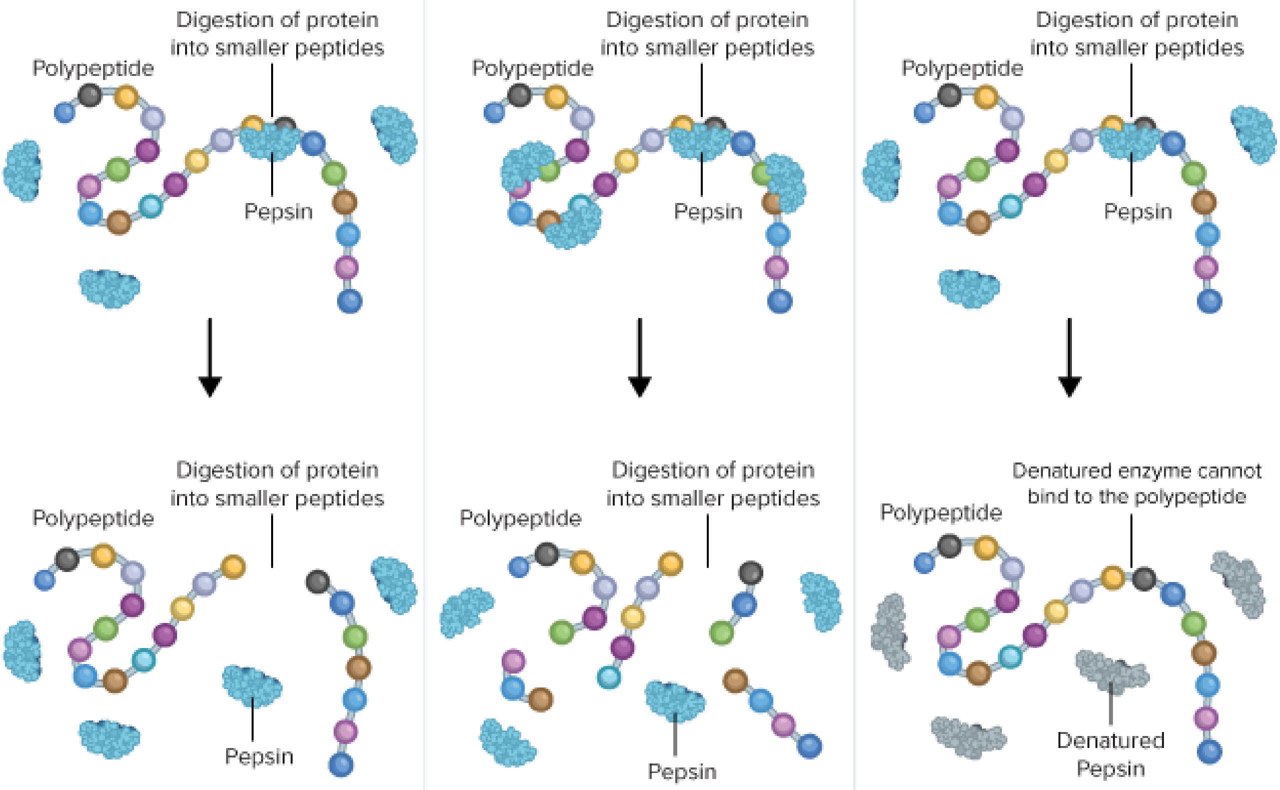


The activities of enzymes also depend on the surrounding conditions such as the temperature and the pH. For example, some enzymes work best at acidic pHs, while others work best in neutral environments.

- Digestive enzymes secreted in the acidic environment (low pH) of the stomach help break down proteins into smaller molecules. The main digestive enzyme in the stomach is pepsin, which works best at a pH of about 1.5. These enzymes would not work optimally at other pHs. Trypsin is another enzyme in the digestive system, which breaks protein chains in food into smaller parts. Trypsin works in the small intestine, which is not an acidic environment. Trypsin's optimum pH is about 8.
- Biochemical reactions are optimal at physiological temperatures. For example, most biochemical reactions work best at the normal body temperature of 98.6˚F. Many enzymes lose function at lower and higher temperatures compared to their optimum temperature. At higher temperatures, an enzyme's shape deteriorates, also known as denaturing. Only when the temperature comes back to normal does the enzyme regain its shape and normal activity.

Explore the effect of pH on the activity of the pepsin enzyme

Sub-optimal conditions of pH and temperature lowers the enzyme activity.	Enzymes work best within specific pH and temperature ranges.	Extreme high pH and temperatures denature the enzyme active site and make it non-functional.



pH range	4-5	1-3	>6
Temperature	<25°C	30-40°C	>45°C

Summary

- Enzymes work by lowering the activation energy needed to start biochemical reactions.
- The activities of enzymes depend on the temperature and the pH of the surroundings.

Review

1. How do enzymes speed up biochemical reactions?
2. Where is the active site located? Explain the role of the active site?

3. Complete this sentence: The activities of enzymes depends on the ____________ and the ____________ of the surroundings.
4. Distinguish between the conditions needed for the proper functioning of pepsin and trypsin.

Report Content Errors

1.19 Water and Life

FlexBooks 2.0 > Biology For High School Diploma > Water and Life

Last Modified: Jan 18, 2022

What you will learn

- The distribution of water on Earth
- The chemical structure and properties of water
- How water is important for all life processes

[Figure 1]

Dihydrogen oxide, or dihydrogen monoxide. Does this chemical sound dangerous?

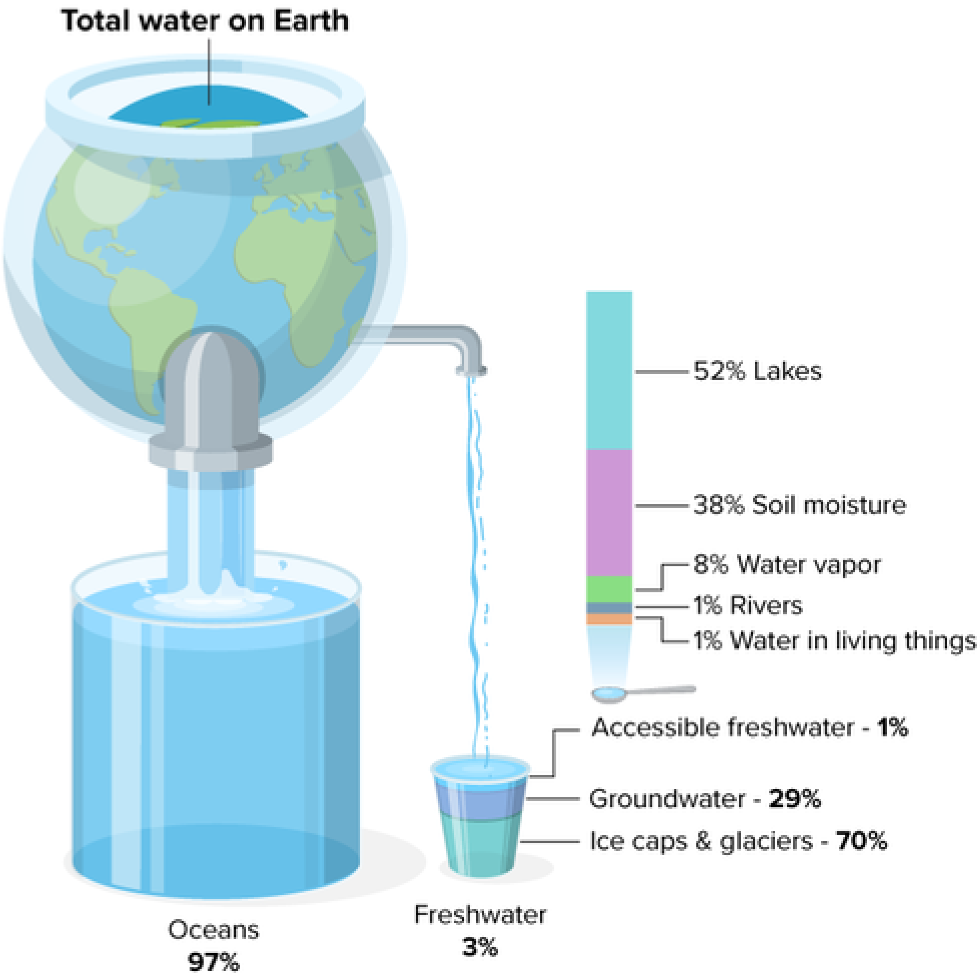
Another name for this compound is...water. Water can create some absolutely beautiful sights. Iguassu Falls is the largest series of waterfalls on the planet, located in Brazil, Argentina, and Paraguay. And water is necessary for life. The importance of water to life cannot be emphasized enough. All life needs water. Life started in water. Essentially, without this simple three atom molecule, life would not exist.

Water

Water, like carbon, has a special role in living things. It is needed by all known forms of life. Water is a simple molecule, containing just three atoms. Nonetheless, water's structure gives it unique properties that help explain why it is vital to all living organism.

Water, Water Everywhere

Water is a common chemical substance on planet Earth. In fact, Earth is sometimes called the "water planet" because almost 75% of its surface is covered with water. If you look at the **Figure** below, you will see where Earth's water is found. The term *water* generally refers to its liquid state, and water is a liquid over a wide range of temperatures on Earth. However, water also occurs on Earth as a solid (ice) and as a gas (water vapor).



[Figure 2]

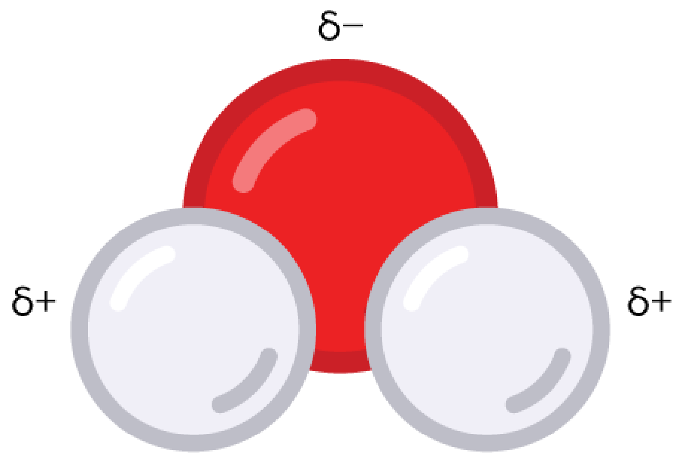
Most of the water on Earth consists of saltwater in the oceans. What percent of Earth's water is freshwater? Where is most of the freshwater found?

Structure and Properties of Water

No doubt, you are already aware of some of the properties of water. For example, you probably know that water is tasteless and odorless. You also probably know that water is transparent, which means that light can pass through it. This is important for organisms that live in the water, because some of them need sunlight to make food.

Chemical Structure of Water

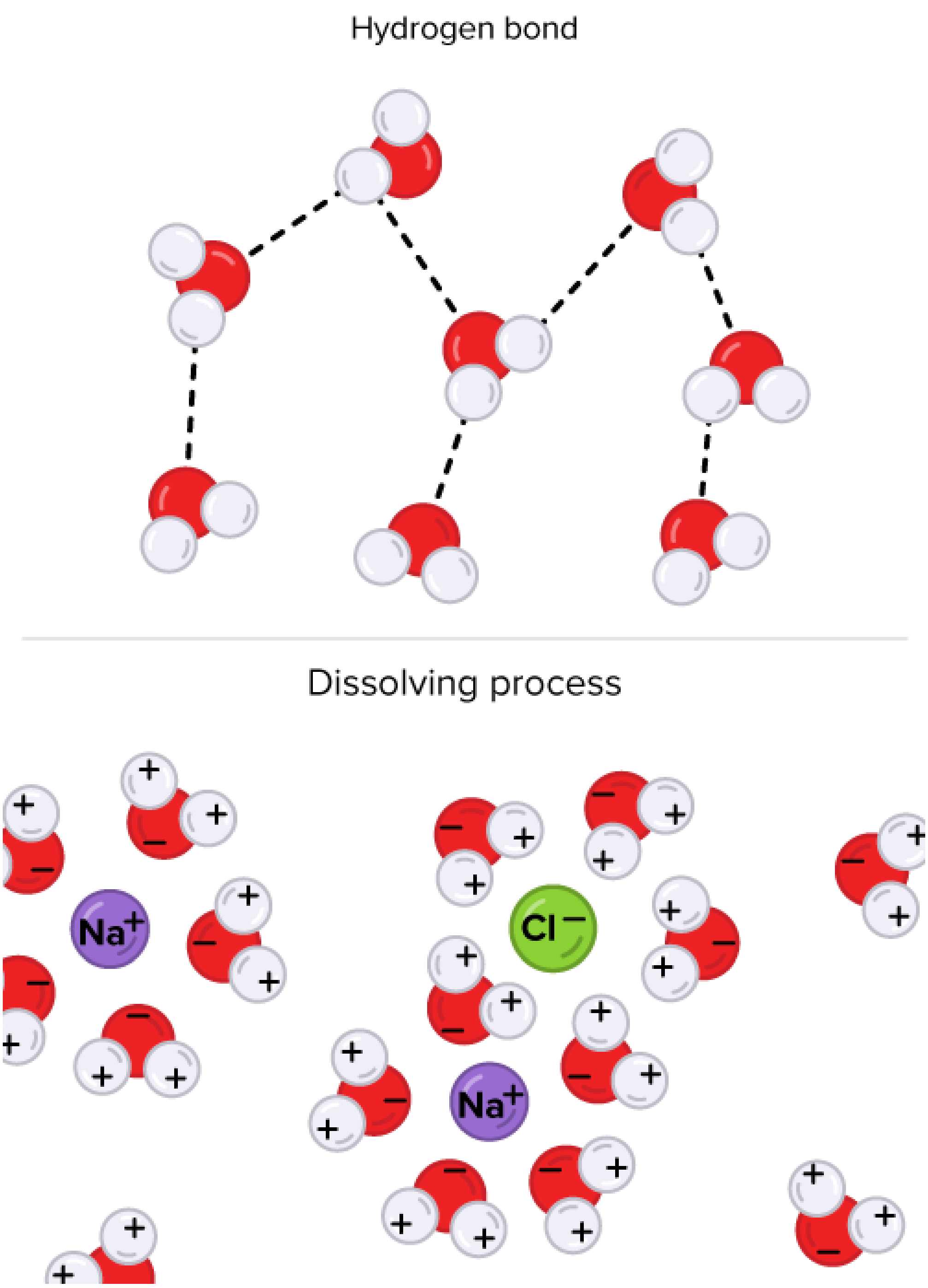
To understand some of water's properties, you need to know more about its chemical structure. As shown in the **Figure** below, each molecule of water consists of one atom of oxygen (red) and two atoms of hydrogen (white). The oxygen atom in a water molecule attracts negatively-charged electrons more strongly than the hydrogen atoms do. As a result, the oxygen atom has a slightly negative charge, and the hydrogen atoms have a slightly positive charge. A difference in electrical charge between different parts of the same molecule is called **polarity**, making water a **polar molecule**.



[Figure 3]

Opposites attract when it comes to charged molecules. In the case of water, the positive (hydrogen) end of one water molecule is attracted to the negative (oxygen) end of a nearby water molecule. Because of this attraction, weak bonds form between adjacent water molecules. The type of bond that forms between molecules is called a **hydrogen bond**. Bonds between molecules are not as strong as bonds within molecules. There are just many more hydrogen bonds in water (between water molecules) than there are covalent bonds within a molecule. The hydrogen bonds may not be strong, but in water they are strong enough to hold together nearby molecules.

Because of its polarity, water readily dissolves many substances including ionic compounds like table salt (NaCl). Water molecules stabilize the Na^+ and Cl^- ion that are formed after the ionic bond between them breaks.

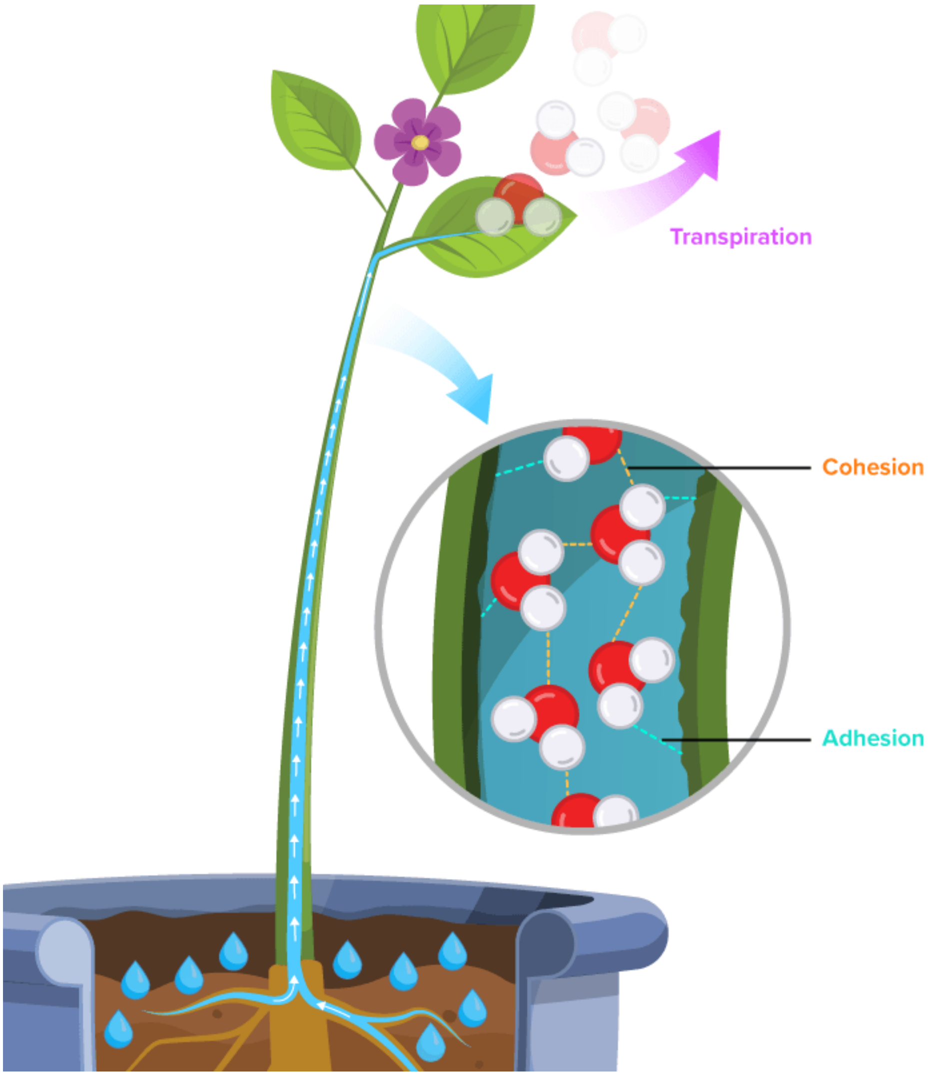


Properties of Water

Hydrogen bonds between water molecules explain some of water's properties. For example, hydrogen bonds explain why water molecules tend to stick together. This property is known as **cohesion**. Have you ever watched water drip from a leaky faucet or from a melting icicle? If you have, then you know that water always falls in drops rather than as separate molecules.

Another important physical property of water is **adhesion**. In terms of water, adhesion is the bonding of a water molecule to another substance, such as the sides of a leaf's vein. This process happens because hydrogen bonds are special in that they break and reform with great frequency. This constant rearranging of hydrogen bonds allows a percentage of all the molecules in a given sample to bond to another substance. This grip-like characteristic that water molecules form causes capillary action, the ability of a liquid to flow against gravity in a narrow space. An example of capillary action is when you place a straw into a glass of water. The water seems to climb up the straw before you even place your mouth on the straw.

Adhesion, cohesion and capillary action are necessary to the survival of most organisms. It is the mechanism that is responsible for water transport in plants through roots and stem (see **Figure** below), and in animal through small blood vessel.



[Figure 4]

Evaporation of water through transpiration causes the movement of water in plants. Water moves up the stem by cohesion and adhesion.

Hydrogen bonds cause water to have a relatively high boiling point of 100°C (212°F). Because of its high boiling point, most water on Earth is in a liquid state rather than in a gaseous state. Water in its liquid state is needed by all living things. Hydrogen bonds also cause water to expand when it freezes. This, in turn, causes ice to have a lower density (mass/volume) than liquid water. The lower density of ice means that it floats on water. For example, in cold climates, ice floats on top of the water in lakes. This allows lake animals such as fish to survive the winter by staying in the water under the ice.

Water and Life

The human body is about 70% water (not counting the water in body fat, which varies from person to person). The body needs all this water to function normally. Just why is so much water required by human beings and other organisms? Water can dissolve many substances that organisms need, and it is necessary for many biochemical reaction. The examples below are among the most important biochemical processes that occur in living things, but they are just two of many ways that water is involved in biochemical reactions.

- Photosynthesis—In this process, cell use the energy in sunlight to change carbon dioxide and water to glucose and oxygen. Water is a reactant in this process. The reactions of photosynthesis can be represented by the chemical equation

$$6CO_2 + 6H_2O + \text{Energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

- Cellular respiration—In this process, cells break down glucose in the presence of oxygen and release carbon dioxide, water (a product), and energy. The reactions of cellular respiration can be represented by the chemical equation

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Water is involved in many other biochemical reactions. As a result, just about all life processes depend on water. Clearly, life as we know it could not exist without water.

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Summary

- Water is needed by all known forms of life.
- Due to the difference in the distribution of charge, water is a polar molecule.
- Hydrogen bonds hold adjacent water molecules together.
- Water has several important properties including cohesion, adhesion and a relatively high boiling point.
- Water is involved in many biochemical reactions. As a result, just about all life processes depend on water.

Review

1. Where is most of Earth's water found?
2. What percent of Earth's water is freshwater?
3. What is polarity? Describe the polarity of water.
4. How could you demonstrate to a child that solid water is less dense than liquid water?
5. Explain how water's polarity is related to its boiling point.
6. Explain why metabolism in organisms depends on water.

Report Content Errors

1.20 Acids and Bases

FlexBooks 2.0 > Biology For High School Diploma > Acids and Bases

Last Modified: Jan 18, 2022

What you will learn

- The properties of acids and bases
- How acids and bases are important in living organism

[Figure 1]

Acids and bases. Why are these important in biology?

It comes back to a number of biological processes. For example, enzyme work best at specific levels of acids or bases. Take your stomach, a very acidic environment. The enzymes that work in that environment could not work in your mouth. What would your food taste like if your mouth was also a very acidic environment?

Acids and Bases

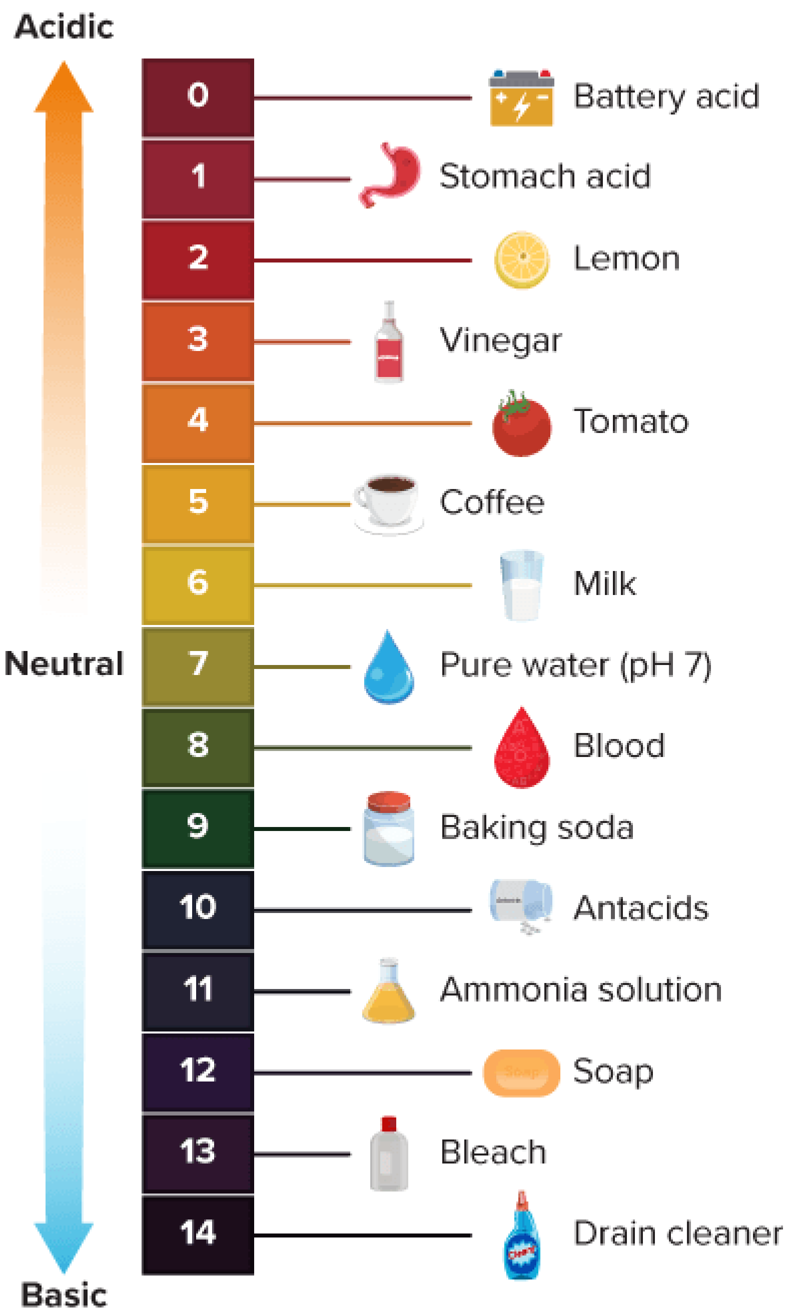
Water is the main ingredient of many solutions. A **solution** is a mixture of two or more substances that has the same composition throughout. Some solutions are acids and some are bases. To understand acids and bases, you need to know more about pure water. In pure water (such as distilled water), a tiny fraction of water molecules naturally breaks down to form ion. An **ion** is an electrically charged atom or molecule. The breakdown of water is represented by the chemical equation

$2\ H_2O \rightarrow H_3O^+ + OH^-$

The products of this reaction are a hydronium ion (H_3O^+) and a hydroxide ion (OH^-). The hydroxide ion, which has a negative charge, forms when a water molecule gives up a positively charged hydrogen ion (H^+). The hydronium ion, which has positive charge, forms when another water molecule accepts the hydrogen ion.

Acidity and pH

The concentration of hydronium ions in a solution is known as **acidity**. In pure water, the concentration of hydronium ions is very low; only about 1 in 10 million water molecules naturally breaks down to form a hydronium ion. As a result, pure water is essentially neutral. Acidity is measured on a scale called **pH**, as shown in **Figure** below. Pure water has a pH of 7, so the point of neutrality on the pH scale is 7.



[Figure 2]

Acidity and the pH scale: Water has a pH of 7, so this is the point of neutrality on the pH scale. Acids have a pH less than 7, and bases have a pH greater than 7. Approximate pH of examples are shown.

Acids

If a solution has a higher concentration of hydronium ions than pure water, it has a pH lower than 7. A solution with a pH lower than 7 is called an **acid**. As the hydronium ion concentration increases, the pH value decreases. Therefore, the more acidic a solution is, the lower its pH value is. Did you ever taste vinegar? Like other acids, it tastes sour. Stronger acids can be harmful to organisms. For example, stomach acid would eat through the stomach if it were not lined with a layer of mucus. Strong acids can also damage materials, even hard materials such as glass.

Bases

If a solution has a lower concentration of hydronium ions than pure water, it has a pH higher than 7. A solution with a pH higher than 7 is called a **base**. Bases, such as baking soda, have a bitter taste. Like strong acids, strong bases can harm organisms and damage materials. For example, lye can burn the skin, and bleach can remove the color from clothing.

Check your understanding!

PROGRESS 0 / 4

1.

Which of the following statement(s) about pH of a solution is true?

SELECT ALL THAT APPLY

a pH represents the acidity of a solution.

b pH scale is a 14 point scale.

c pH values are based on the hydroxide ion concentration.

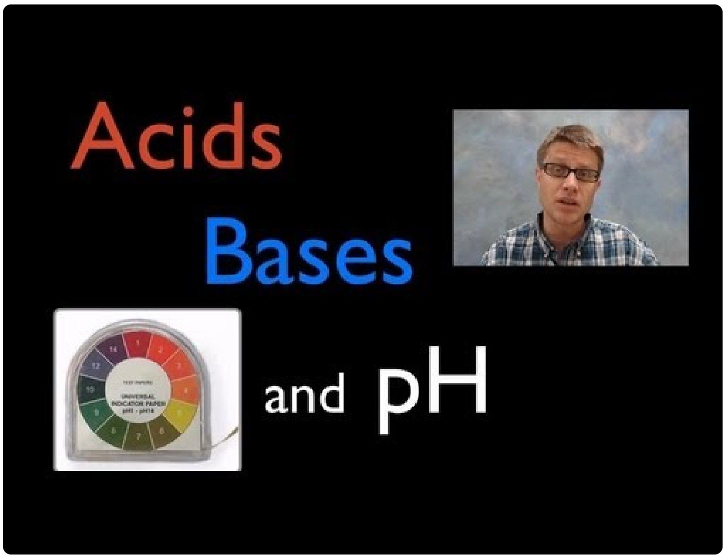
Check It

Hint

https://www.ck12.org/assessment/ui/embed.html?test/view/611607f665749a6400513e5e&

Acids and Bases in Organisms

Acids and bases are important in living things because most enzymes can do their job only at a certain level of acidity. cell secrete acids and bases to maintain the proper pH for enzymes to work. For example, every time you digest food, acids and bases are at work in your digestive system. Consider the acidic environment of the stomach. The acidic environment helps with the digestion of food. The enzyme pepsin, which helps break down protein in the stomach can only function optimally in the low pH environment. The stomach secretes a strong acid that allows pepsin to work, and the stomach to do its job. However, when stomach contents enter the small intestine, the acid must be neutralized. This is because enzymes in the small intestine need a basic environment in order to work. An organ called the pancreas secretes a strong base into the small intestine, and this base neutralizes the acid.



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DID YOU KNOW?

A bee sting is made up of various components that make the bee venom slightly acidic in nature with a pH between 5 to 5.5.

Summary

- A solution is a mixture of two or more substances that has the same composition throughout. Some solutions are acids, some are bases.
- Pure water has a pH of 7, so the point of neutrality on the pH scale is 7.
- Acids have a higher concentration of hydronium ions than pure water, and a pH lower than 7.

- Bases have a lower concentration of hydronium ions than pure water, and a pH higher than 7.
- Acids and bases are important in living organisms because most enzymes function best at a specific pH.

Review

1. What is the pH of a neutral solution?
2. Distinguish between an acid and a base.
3. Describe an example of an acid or a base that is involved in human digestion.
4. Assume that you test an unknown solution and find that it has a pH of 7.2. What type of solution is it? How do you know?
5. Are the following acids or bases?

   a. milk

   b. coffee

   c. soap

1.21 REFERENCES

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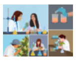	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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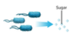	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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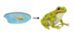
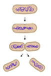
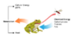
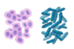
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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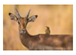	**Credit:** matrishva **Source:** https://pixabay.com/photos/impala-oxpecker-bird-antelope-5873636/ **License:** Pixabay License
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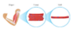	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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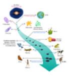	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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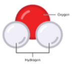
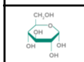
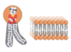
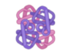
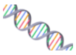
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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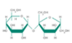	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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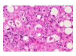	**Credit:** Dr. David Kleiner, National Cancer Institute/NIH **Source:** https://www.flickr.com/photos/132318516@N08/48904411988 **License:** Public Domain

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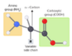	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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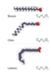	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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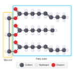	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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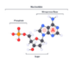	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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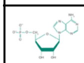	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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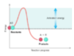	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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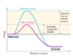	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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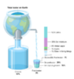
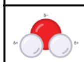
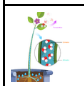
	**Credit:** CK12 Foundation **Source:** CK12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK12 Foundation **Source:** CK12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK12 Foundation **Source:** CK12 Foundation **License:** CK-12 Curriculum Materials License
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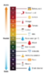	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

CHAPTER 2

Cell Biology

Chapter Outline

2.1 Parts of the Cell

FlexBooks 2.0 > Biology For High School Diploma > Parts of the Cell

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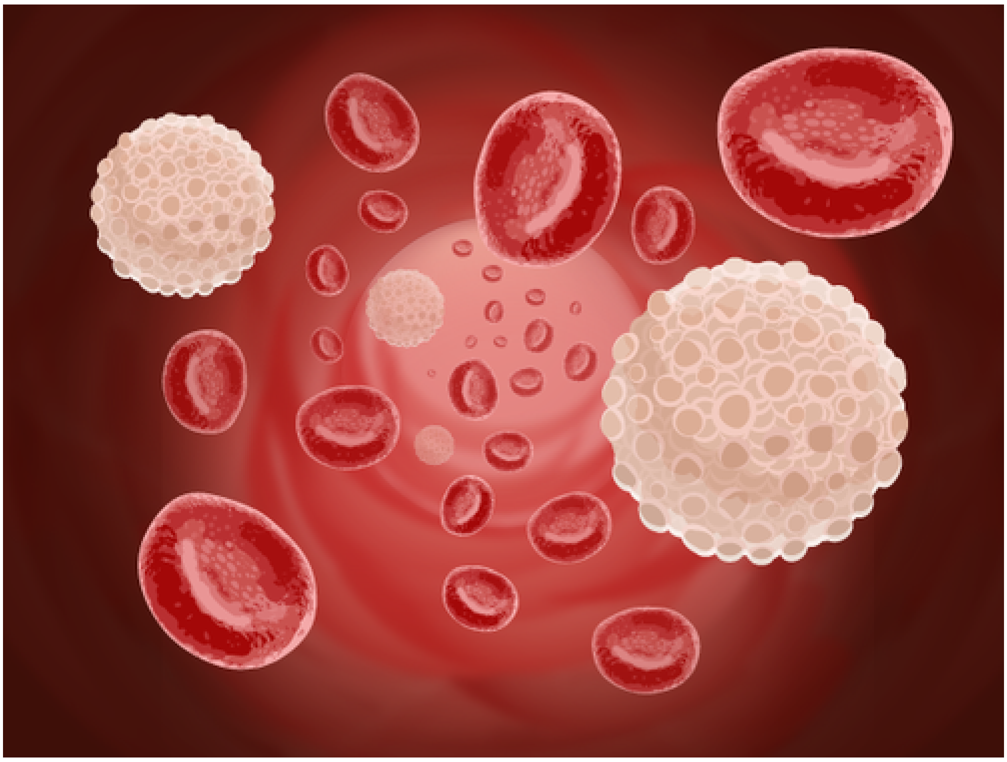
What you will learn

- How and when cell were discovered
- The cell theory
- How diverse are cells
- What parts are common among all living cells



[Figure 1]

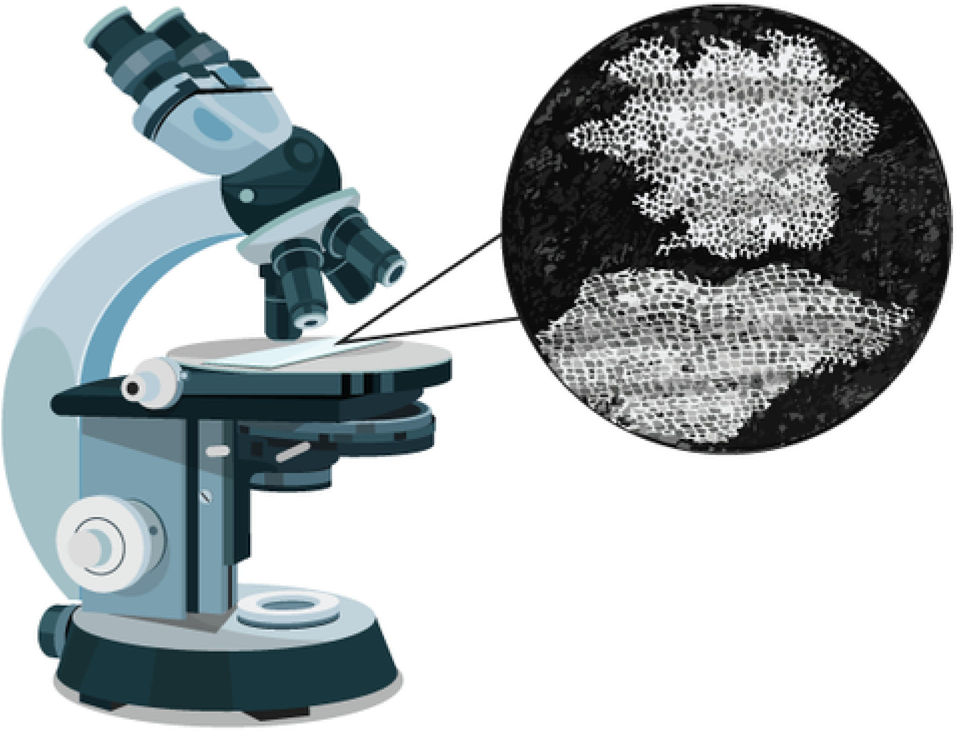
What do a bacterial cell and one of your cells have in common?

There are many different types of cells, but they all have certain parts in common. As this image of human blood shows, cells come in different shapes and sizes. The shapes and sizes directly influence the function of the cell. Yet, all cells - cells from the smallest bacterium to those in the largest whale - do some similar functions, so they do have parts in common.

Common Parts of Cells

Discovery of Cells

The first time the word *cell* was used to refer to these tiny units of life was in 1665 by a British scientist named Robert Hooke. Hooke was one of the earliest scientists to study living things under a microscope. The microscopes of his day were not very strong, but Hooke was still able to make an important discovery. When he looked at a thin slice of cork under his microscope, he was surprised to see what looked like a honeycomb, made up of many tiny units, which Hooke called cells.



[Figure 2]

Illustration of cork cells. What type of material is cork? Do you know where cork comes from?

Soon after Robert Hooke discovered cells in cork, Anton van Leeuwenhoek in Holland made other important discoveries using a microscope. Leeuwenhoek made his own microscope lenses, and he was so good at it that his microscope was more powerful than other microscopes of his day. In fact, Leeuwenhoek's microscope was almost as strong as modern light microscopes.

Using his microscope, Leeuwenhoek discovered tiny animal such as rotifers. Leeuwenhoek also discovered human blood cells. He even scraped plaque from his own teeth and observed it under the microscope. What do you think Leeuwenhoek saw in the plaque? He saw tiny living things with a single cell that he named *animalcules* ("tiny animals"). Today, we call Leeuwenhoek's animalcules bacteria.

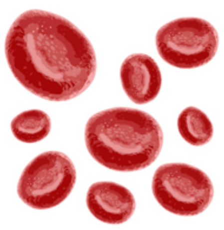
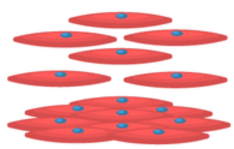
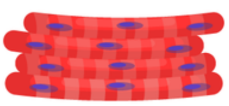
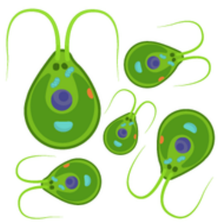
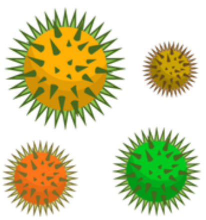
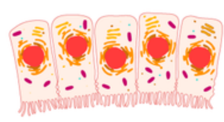
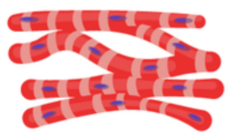
The Cell Theory

The cell theory is one of the fundamental theory of biology. For two centuries after the discovery of the microscope by Robert Hooke and Anton van Leeuwenhoek, biologists found cells everywhere. Biologists in the early part of the 19^{th} century suggested that all living things were made of cells, but the role of cells as the primary building block of life was not discovered until 1839 when two German scientists, Theodor Schwann, a zoologist (studies animals), and Matthias Jakob Schleiden, a botanist (studies plants), suggested that cells were the basic unit of structure and function of all life. Later, in 1858, the German doctor Rudolf Virchow observed that cells divide to produce more cells. He proposed that all cells arise only from other cells. The collective observation of all three scientists form the cell theory, which states that:

- all organism are made up of one or more cells,
- all the life functions of an organism occur within cells,
- all cells come from preexisting cells.

Cell Diversity

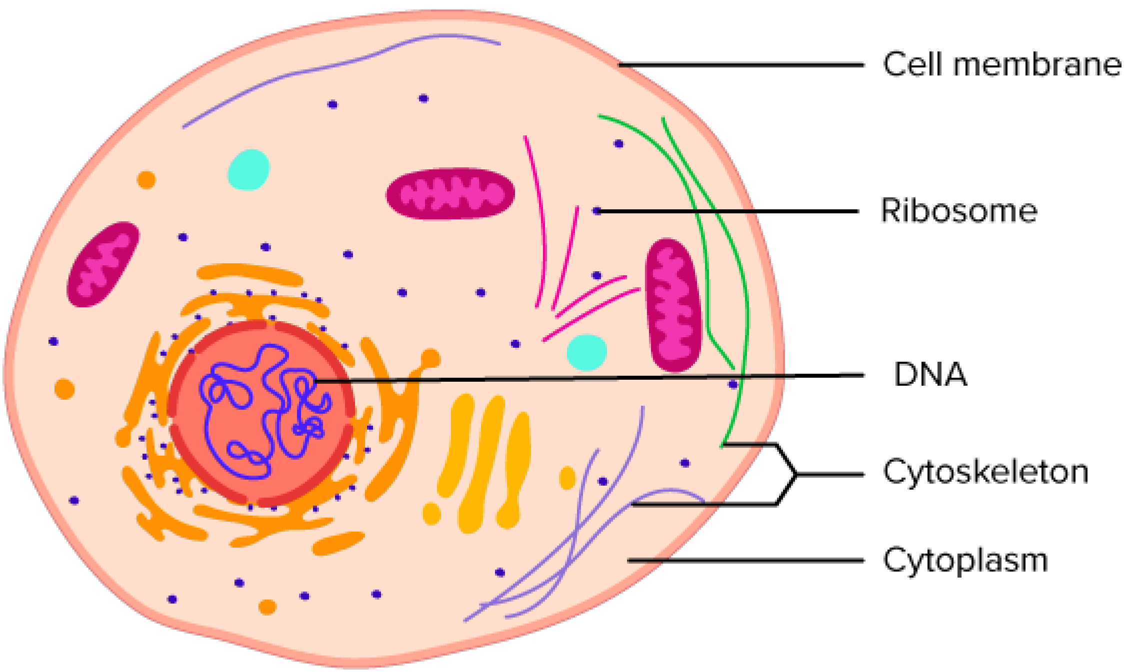
Cells with different functions often have different shapes. The cells pictured in the **Figure** below are just a few examples of the many different shapes that cells may have. Each type of cell in the figure has a shape that helps it do its job. For example, the job of the nerve cell is to carry messages to other cells. The nerve cell has many long extensions that reach out in all directions, allowing it to pass messages to many other cells at once. Do you see the tail-like projections on the alga cells? Algae live in water, and their tails help them swim. pollen grains have spikes that help them stick to insects such as bees. How do you think the spikes help the pollen grains do their job? (*Hint:* Insects pollinate flower.)

 [Figure 3]	 [Figure 4]	 [Figure 5]	 [Figure 6]	 [Figure 7]
red blood cell	Bacteria	bone cell	smooth muscle cells	skeletal muscle cells
 [Figure 8]	 [Figure 9]	 [Figure 10]	 [Figure 11]	 [Figure 12]
Algae	Pollen grains	Nerve cell	Columnar epithelial cells	cardiac muscle cells

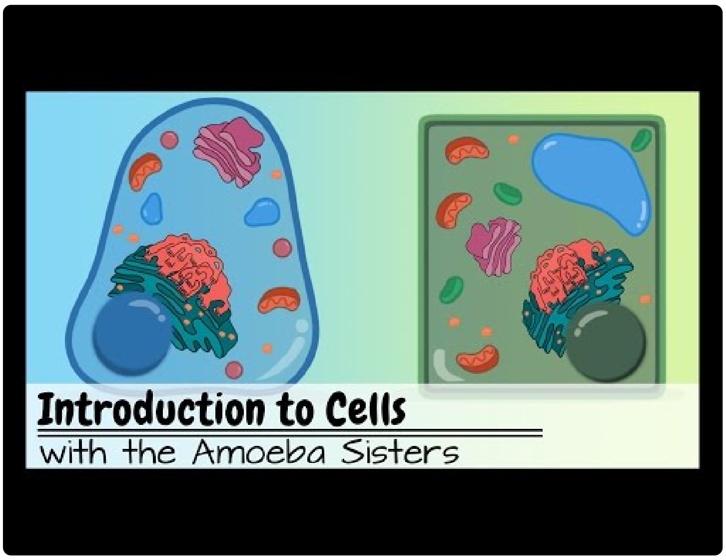
Common Parts of a Cell

Although cells are diverse, all cells have certain parts in common. The parts include a plasma membrane, **cytoplasm**, ribosome, cytoskeleton, and **DNA**.

1. The **cell membrane** (also called the **plasma membrane**) is a thin coat of lipid that surrounds a cell. It forms the physical boundary between the cell and its environment, so you can think of it as the ‘‘skin’’ of the cell.
2. **Cytoplasm** refers to all of the cellular material inside the cell membrane, other than the nucleus. Cytoplasm is made up of a watery substance called **cytosol** and contains other cell structures such as ribosomes.
3. **Ribosomes** are structures in the cytoplasm where protein are made.
4. The **cytoskeleton** consists of filaments and tubules that crisscross the cytoplasm and help maintain the cell’s shape.
5. **DNA** is a nucleic acid found in cells. It contains the genetic instructions that cells need to make proteins.



These parts are common to all cells, from organisms as different as bacteria and human beings. How did all known organisms come to have such similar cells? The similarities show that all life on Earth has a common evolutionary history.



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Summary

- The cell theory is one of the fundamental theories of biology. It states that all organisms are made up of one or more cells, all the life functions of an organism occur within cells, and all cells come from preexisting cells.
- Cells come in many different shapes. Cells with different functions often have different shapes.
- Although cells come in diverse shapes, all cells have certain parts in common. These parts include the cell membrane, cytoplasm, ribosomes, cytoskeleton, and DNA.

Review

1. Who coined the term *cell*, in reference to the tiny structures seen in living organisms?
2. Who identified *animalcules*? What are *animalcules*?
3. What are the three main parts of the cell theory?
4. List the four parts common to all cells.
5. What are the cell structures where proteins are made?
6. What is the role of DNA?

Report Content Errors

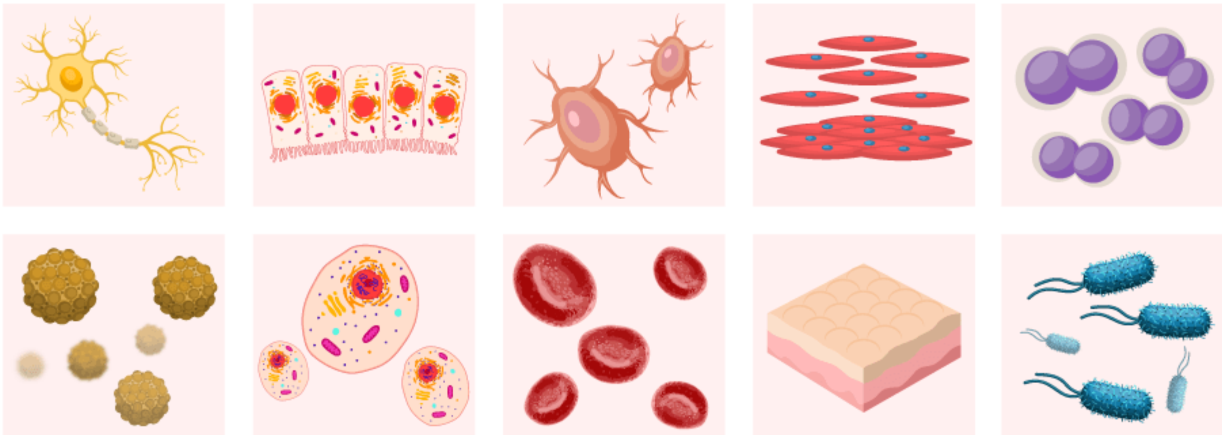
2.2 Prokaryotic and Eukaryotic Cells

FlexBooks 2.0 > Biology For High School Diploma > Prokaryotic and Eukaryotic Cells

Last Modified: Jan 18, 2022

What you will learn

- The two types of cell: prokaryotic and eukaryotic
- How **eukaryotic cell** differ in structure from **prokaryotic cell**



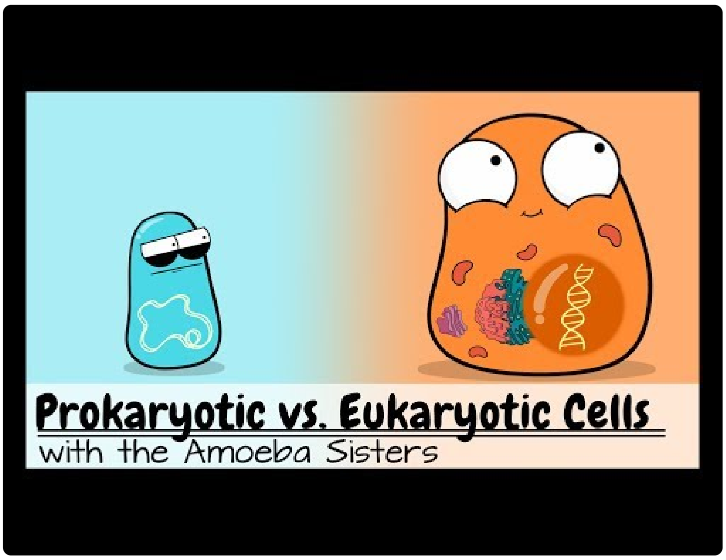
[Figure 1]

How many different types of cells are there?

There are many different types of cells. For example, in you there are blood cells and skin cells and bone cells, and even bacterium. Here we have drawings of bacteria and animal cells. Can you tell which depicts various types of bacteria? However, all cells - whether from bacteria, human, or any other organism - will be one of two general types. In fact, all cells other than bacteria will be one type, and bacterial cells will be the other. And it all depends on how the cell stores its DNA.

Two Types of Cells

There is a basic cell structure that is present in many but not all living cells: the **nucleus**. The **nucleus** of a cell is a structure in the cytoplasm that is surrounded by a membrane (the nuclear membrane) and contains, and protects, most of the cell's DNA. Based on whether they have a nucleus, there are two basic types of cells: prokaryotic cells and eukaryotic cells.



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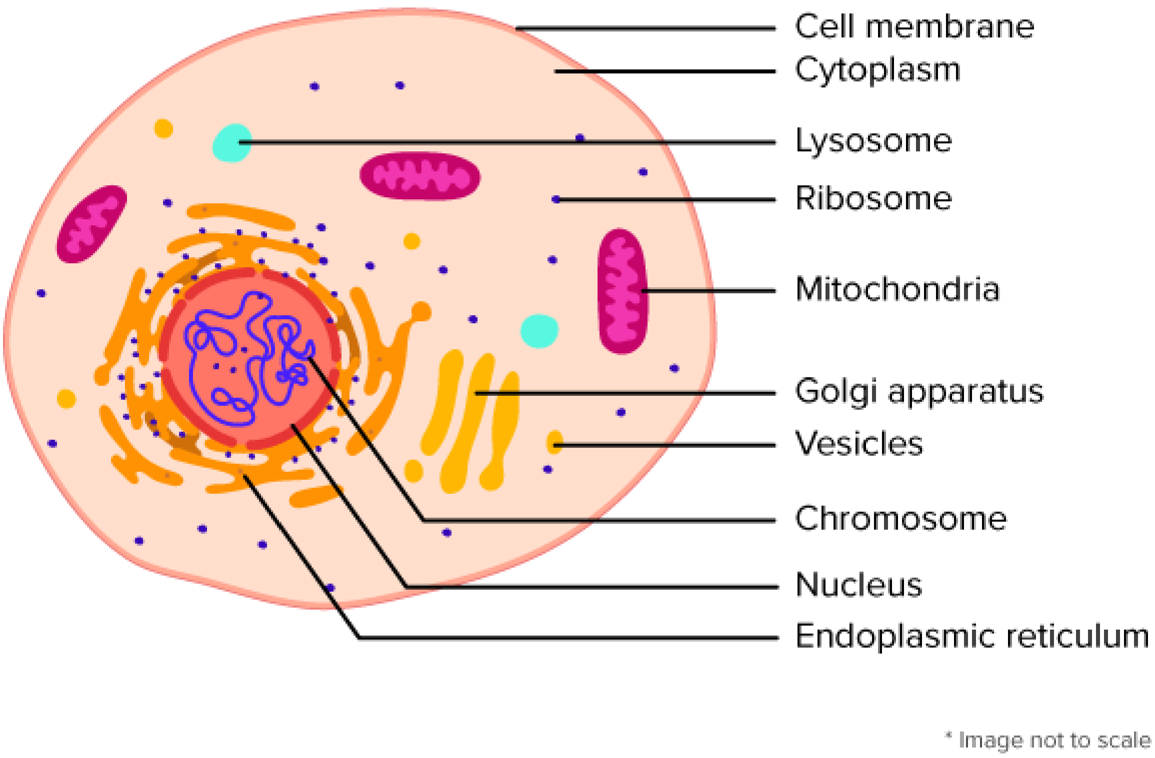
Eukaryotic Cells

Eukaryotic cells are cells that contain a nucleus. Eukaryotic cells are usually larger than prokaryotic cells, and they are found mainly in multicellular organism. Organisms with eukaryotic cells are called **eukaryote**, and include fungus, animals, protist, and plants.

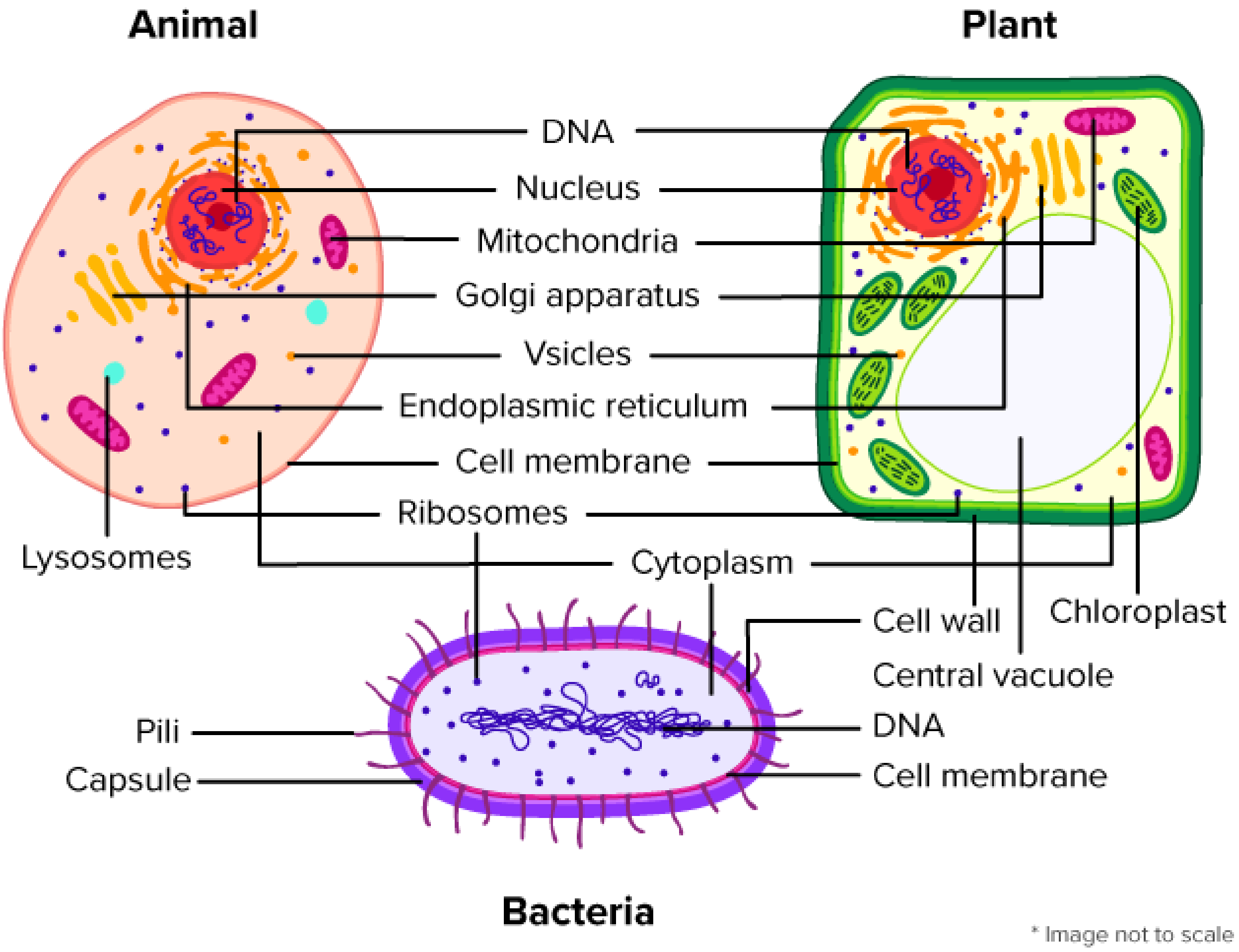
Eukaryotic cells also contain other **organelle** besides the nucleus. An **organelle** is a structure within the cytoplasm that performs a specific job in the cell. Organelles called mitochondrion, for example, provide energy to the cell, and organelles called vacuole store substances in the cell. Organelles allow eukaryotic cells to carry out more functions than prokaryotic cells can. This allows eukaryotic cells to have greater cell specificity than prokaryotic cells. ribosome, the cellular structures where protein are made, are found in both eukaryotic and prokaryotic cells.



In some ways, a cell resembles a plastic bag full of Jell-O. Its basic structure is a cell membrane filled with cytoplasm. Like Jell-O containing mixed fruit, the cytoplasm of the cell also contains various structures, such as a nucleus and other organelles.

Prokaryotic Cells

Prokaryotic cells are cells without a nucleus. The DNA in prokaryotic cells is in the cytoplasm rather than enclosed within a nuclear membrane. Prokaryotic cells are found in single-celled organisms, such as bacteria. Organisms with prokaryotic cells are called **prokaryote**. They were the first type of organisms to evolve and are still the most common organisms today.



DID YOU KNOW?

Mature red blood cell (RBCs) do not have a nucleus present. RBCs contain hemoglobin protein that binds to oxygen and helps in the transport of oxygen throughout the body. In the absence of a nucleus, mature RBCs can accommodate more hemoglobin to carry oxygen.

Summary

- Prokaryotic cells are cells without a nucleus.
- Eukaryotic cells are cells that contain a nucleus.
- Eukaryotic cells have other organelles besides the nucleus.

Review

1. What is the cell nucleus?
2. What is the main difference between prokaryotic and eukaryotic cells?
3. Give an example of a prokaryotic cell.
4. Define organelle.
5. What is the advantage of having organelles?

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2.3 Phospholipid Bilayer

FlexBooks 2.0 > Biology For High School Diploma > Phospholipid Bilayer

Last Modified: Sep 30, 2021

What you will learn

- Structure of the **cell membrane**
- Role of the phospholipid bilayer in the cell membrane function

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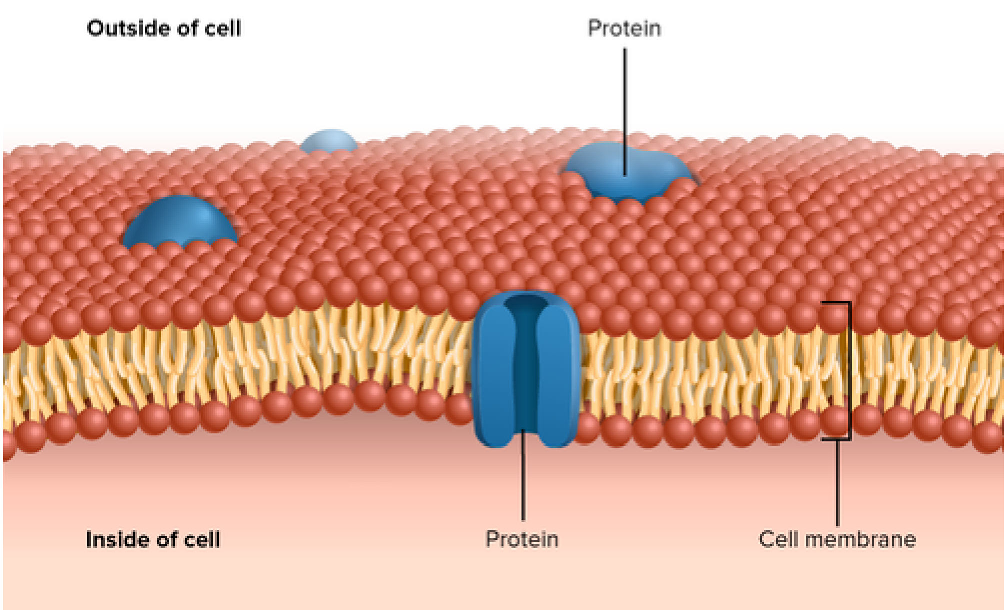


[Figure 1]

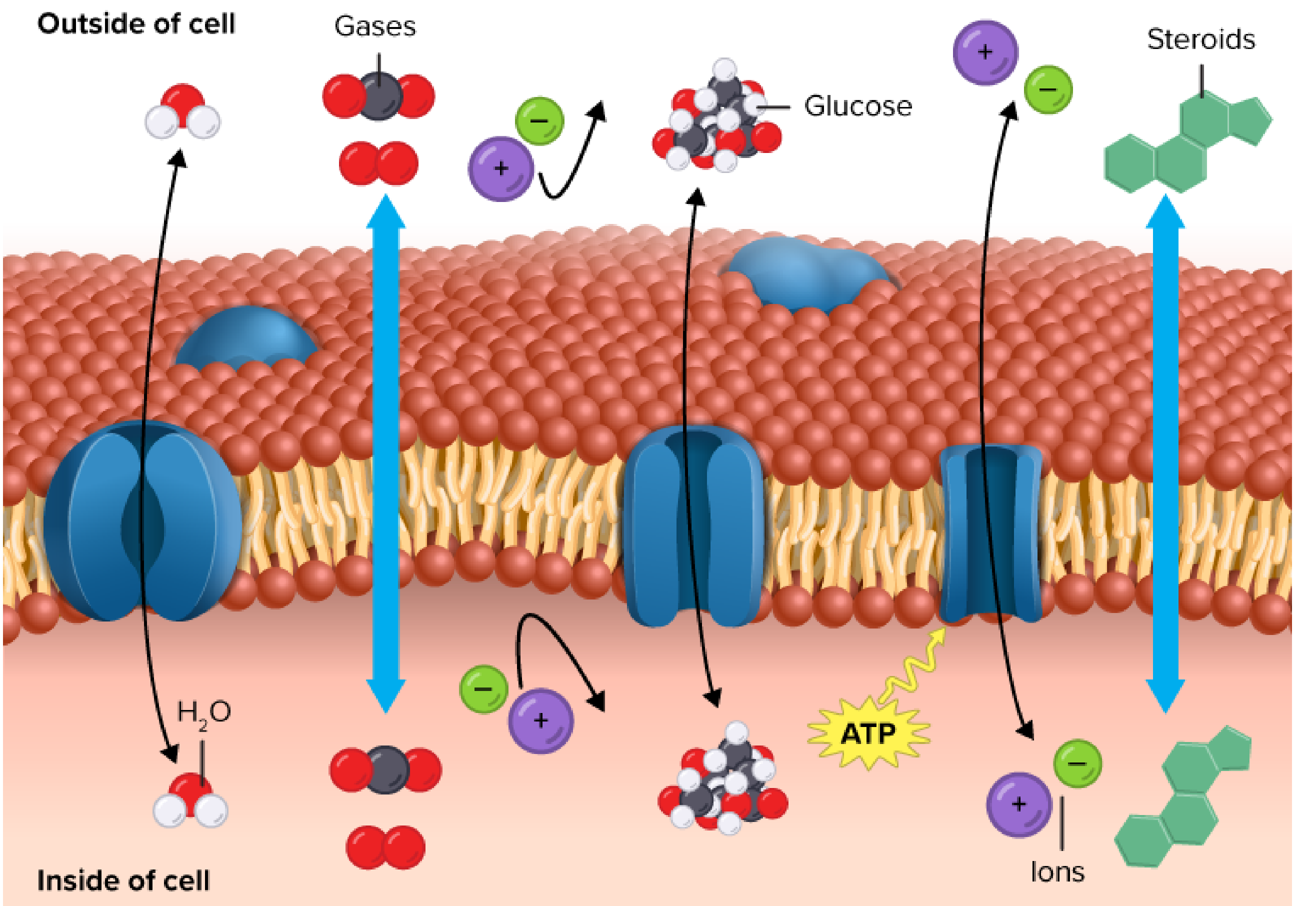
All cells have a cell membrane. This membrane surrounds the cell. So what is its role?

Can molecules enter and leave the cell? Yes. Can anything or everything enter or leave? No. So, what determines what can go in or out? Is it the nucleus? The DNA? Or the cell membrane?

The Cell Membrane

The **cell membrane** (also known as the **plasma membrane**) forms a barrier between the cytoplasm inside the cell and the environment outside the cell. It protects and supports the cell and also controls everything that enters and leaves the cell. It allows only certain substances to pass through, while keeping others in or out. The ability to allow only certain molecules in or out of the cell is referred to as selective permeability or **semipermeability**.

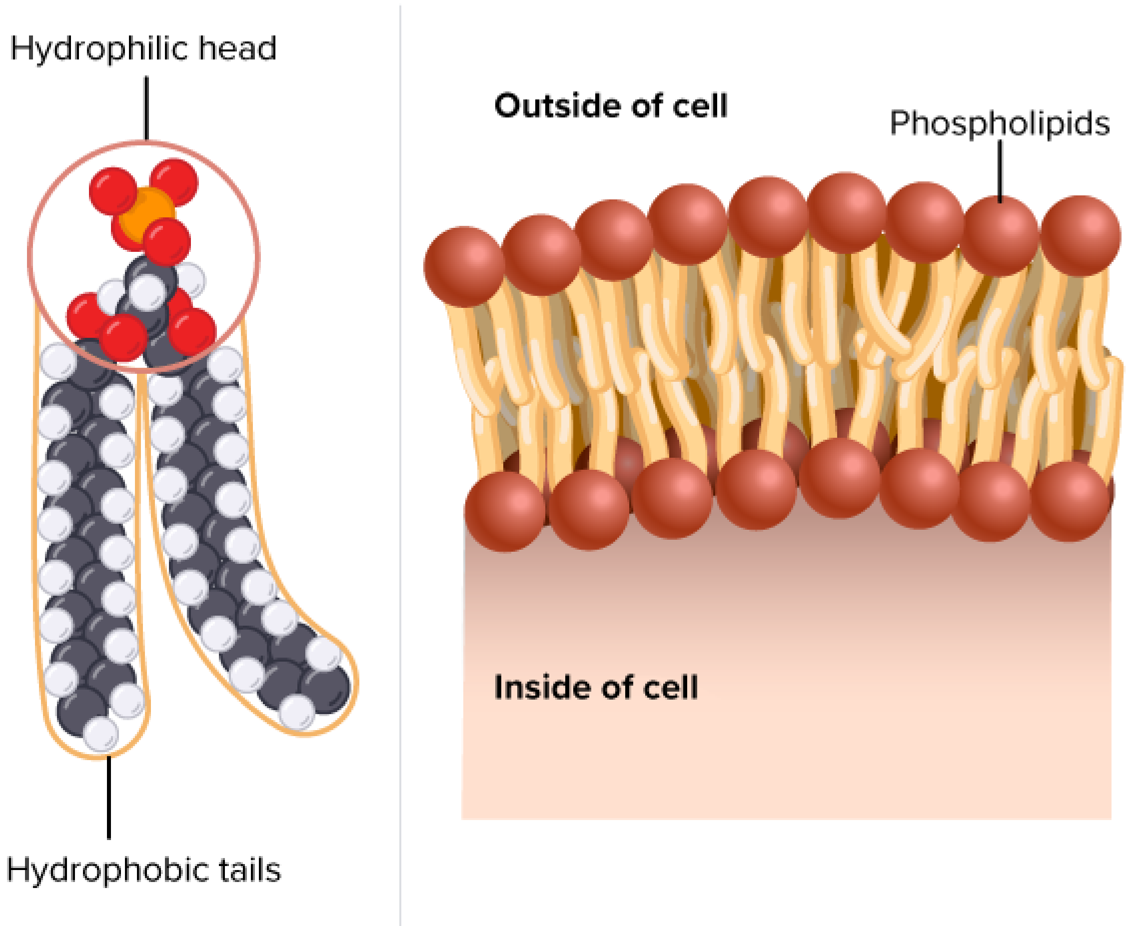
To understand how the cell membrane controls what crosses into or out of the cell, you need to know its composition.



A Phospholipid Bilayer

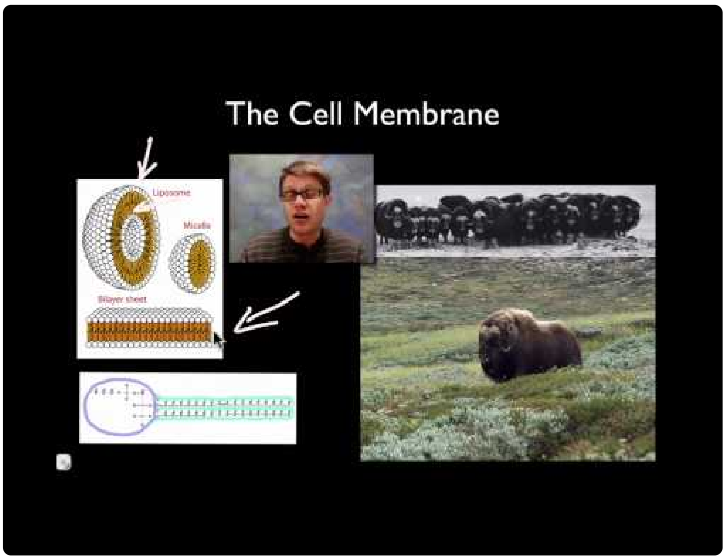
The cell membrane is composed mainly of phospholipids, which consist of fatty acid and alcohol. The phospholipids in the cell membrane are arranged in two layers, called a **phospholipid bilayer**. Each phospholipid molecule has a head and two tails. The head "loves" water (**hydrophilic**) and the tails "hate" water (**hydrophobic**). The water-hating tails are on the interior of the membrane, whereas the water-loving heads point outwards, toward either the cytoplasm or the fluid that surrounds the cell.

Molecules that are hydrophobic can easily pass through the cell membrane, if they are small enough, because they are water-hating like the interior of the membrane. Small lipid and steroids are hydrophobic and can readily cross the membrane. Molecules that are hydrophilic, on the other hand, cannot pass through the cell membrane—at least not without help—because they are water-loving like the exterior of the membrane, and are therefore excluded from the interior of the membrane. Hydrophilic molecules such as glucose and ion like Na+ and K+ need the help of special protein to cross the membrane.



DID YOU KNOW?

In 1925, Gortner and Grendel studied human red blood cell to measure the amount of lipids in the cell membrane. Their observation suggested that the cell membrane could be a double layer of lipids.



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Science Friday: Candy Corn in Space

Candy corn is a very tasty treat. In this video by science Friday, astronaut Don Pettit uses Candy Corn to demonstrate the effects of hydrophobic and hydrophilic interactions.

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Summary

- The cell membrane forms a barrier between the cytoplasm and the environment outside the cell. The cell membrane has selective permeability.
- The cell membrane is primarily composed of phospholipids arranged in a bilayer, with the hydrophobic tails on the interior of the membrane, and the hydrophilic heads pointing outwards.

Review

1. Describe the role of the cell membrane.
2. What is meant by semipermeability?
3. Describe the composition of the cell membrane.
4. Explain why hydrophobic molecules can easily cross the cell membrane, while hydrophilic molecules cannot.

Report Content Errors

2.4 Membrane Proteins

FlexBooks 2.0 > Biology For High School Diploma > Membrane Proteins

Last Modified: Jan 18, 2022

What will you learn

- Types of membrane proteins
- The **Fluid Mosaic Model** of the cell membrane
- Different types of extensions of the cell membrane and their role in cell movement

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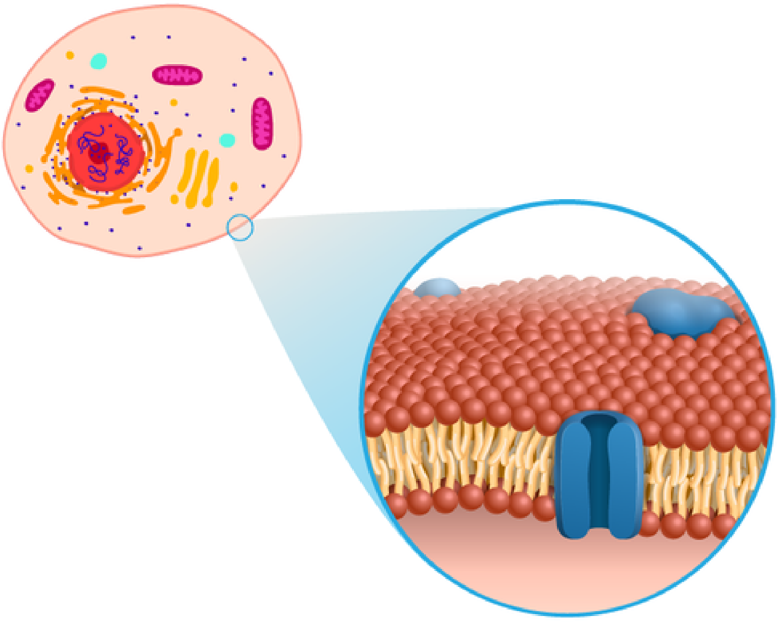


[Figure 1]

Can anything or everything move in or out of the cell?

No. It is the semipermeable cell membrane that determines what can enter and leave the cell. So, if not everything can cross the membrane, how do certain things get across?

Membrane Proteins

The cell membrane contains molecules other than phospholipids, primarily other lipid and protein. The yellow molecules between the phospholipid tails in the **Figure** below, for example, are the lipid cholesterol. Molecules of cholesterol help the cell membrane keep its shape. Many of the proteins in the cell membrane assist other substances in crossing the membrane.

The cell membranes also contain certain types of proteins. A membrane protein is a protein molecule that is attached to, or associated with, the membrane of a cell or an organelle. Membrane proteins can be put into two groups based on how the protein is associated with the membrane.

integral membrane protein are permanently embedded within the cell membrane. They have a range of important functions. Such functions include channeling or transporting molecules across the membrane. Other integral proteins act as cell receptors. Integral membrane proteins can be classified according to their relationship with the bilayer:

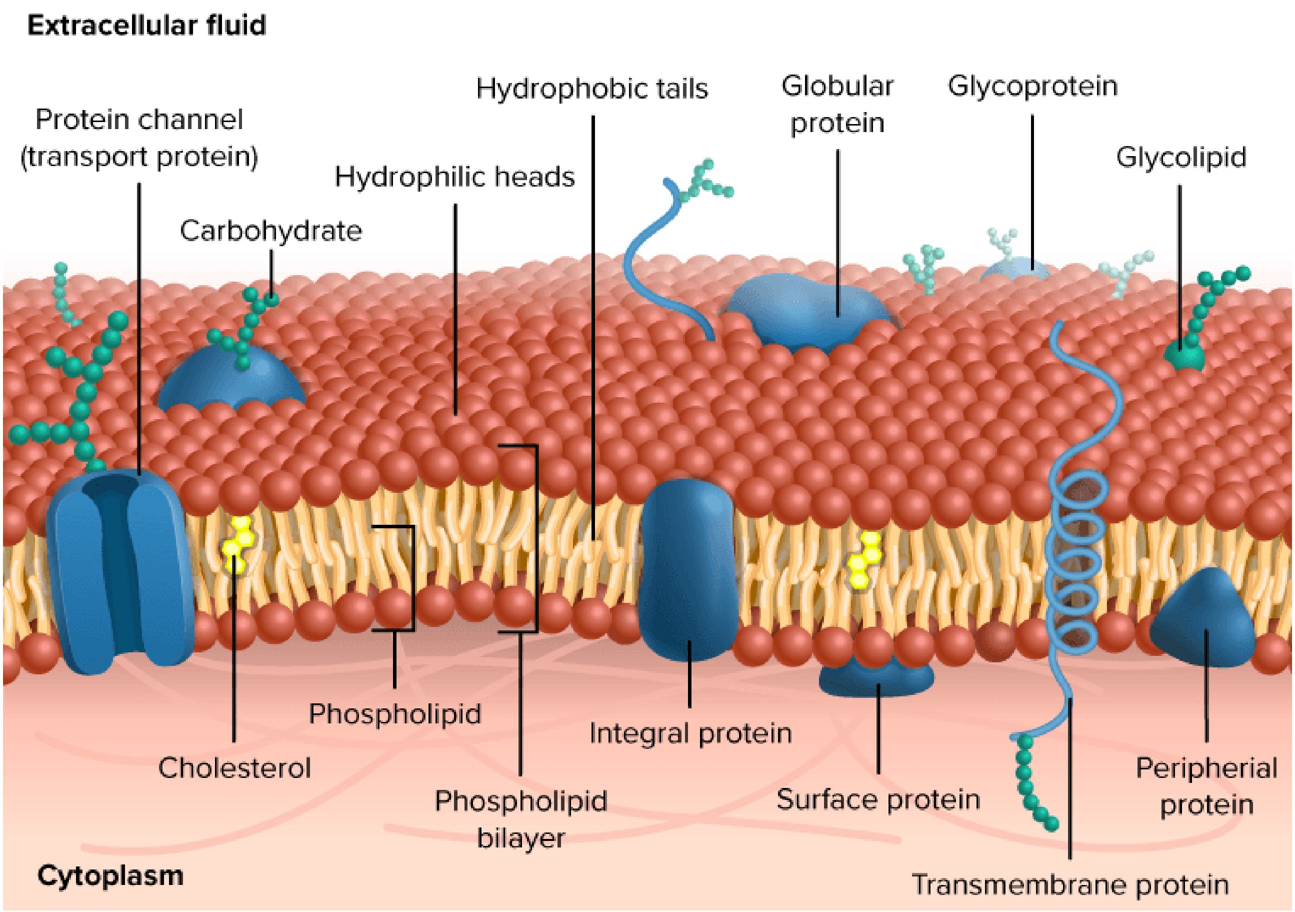
- Transmembrane proteins span the entire cell membrane. Transmembrane proteins are found in all types of biological membranes.
- Integral monotopic proteins are permanently attached to the membrane from only one side.

Some integral membrane proteins are responsible for cell adhesion (sticking of a cell to another cell or surface). On the outside of cell membranes and attached to some of the proteins are carbohydrate chains that act as labels that identify the cell type. Shown in the **Figure** below are two different types of membrane proteins and associated molecules.

DID YOU KNOW?

Glycoproteins and glycolipids have a carbohydrate chain that acts as a label to identify the cell type. Specifically, A, B, O blood groups result from having different carbohydrate chains on the cell surface of red blood cell.

peripheral membrane protein are proteins that are only temporarily associated with the membrane. They can be easily removed, which allows them to be involved in cell signaling. Peripheral proteins can also be attached to integral membrane proteins, or they can stick into a small portion of the lipid bilayer by themselves. Peripheral membrane proteins are often associated with ion channel and transmembrane receptors. Most peripheral membrane proteins are hydrophilic.



[Figure 2]

Some of the membrane proteins make up a major transport system that moves molecules and ions through the polar phospholipid bilayer.

DID YOU KNOW?

Phospholipase is an enzyme that breaks down various bonds in the polar head group of phospholipids. These enzymes are important to help break down damaged or aged cell membranes. This enzyme represents an example of a peripheral membrane protein.

The Fluid Mosaic Model

In 1972, S.J. Singer and G.L. Nicolson proposed the now widely accepted **Fluid Mosaic Model** of the structure of cell membranes. The model proposes that integral membrane proteins are embedded in the phospholipid bilayer, as seen in the **Figure** above. Some of these proteins extend all the way through the bilayer, and some only partially across it. These membrane proteins act as transport protein and receptors proteins.

Their model also proposed that the membrane behaves like a fluid, rather than a solid. The proteins and lipids of the membrane move around the membrane, much like buoys in water. Such movement causes a constant change in the "mosaic pattern" of the cell membrane.

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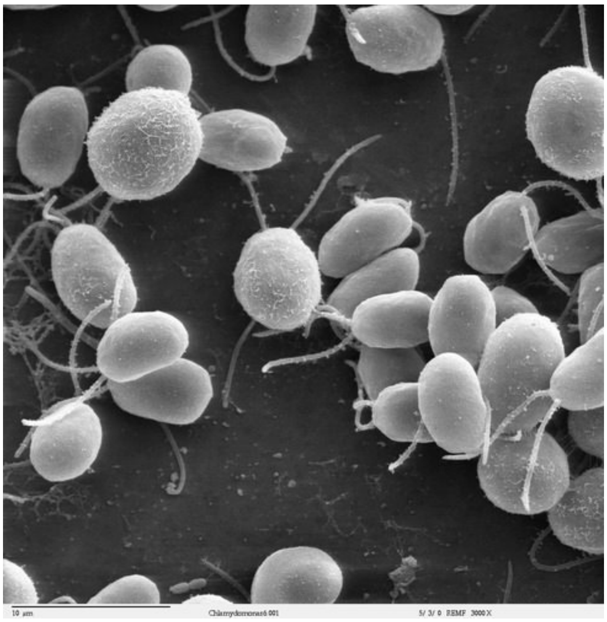
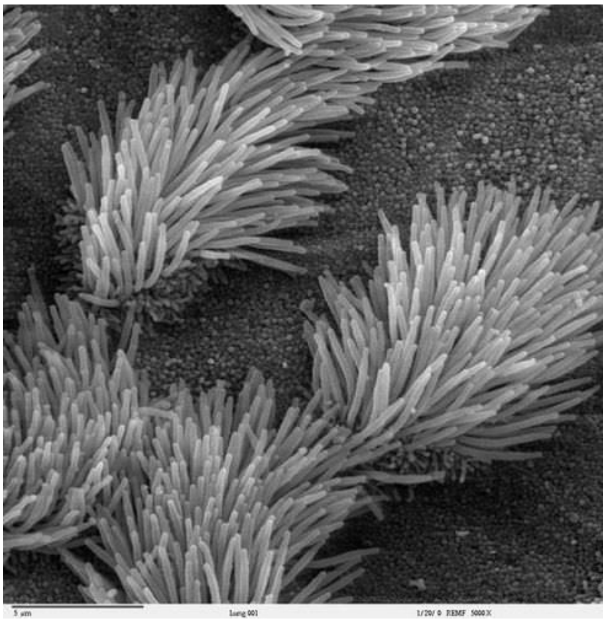
Extensions of the Cell Membrane

The cell membrane may have extensions, such as whip-like **flagellum** or brush-like **cilia**. In single-celled organism, like those shown in the **Figure** below, the membrane extensions may help the organisms move. In multicellular organism, the extensions have other functions. For example, the cilia on human lung cells sweep foreign particles and mucus toward the mouth and nose.

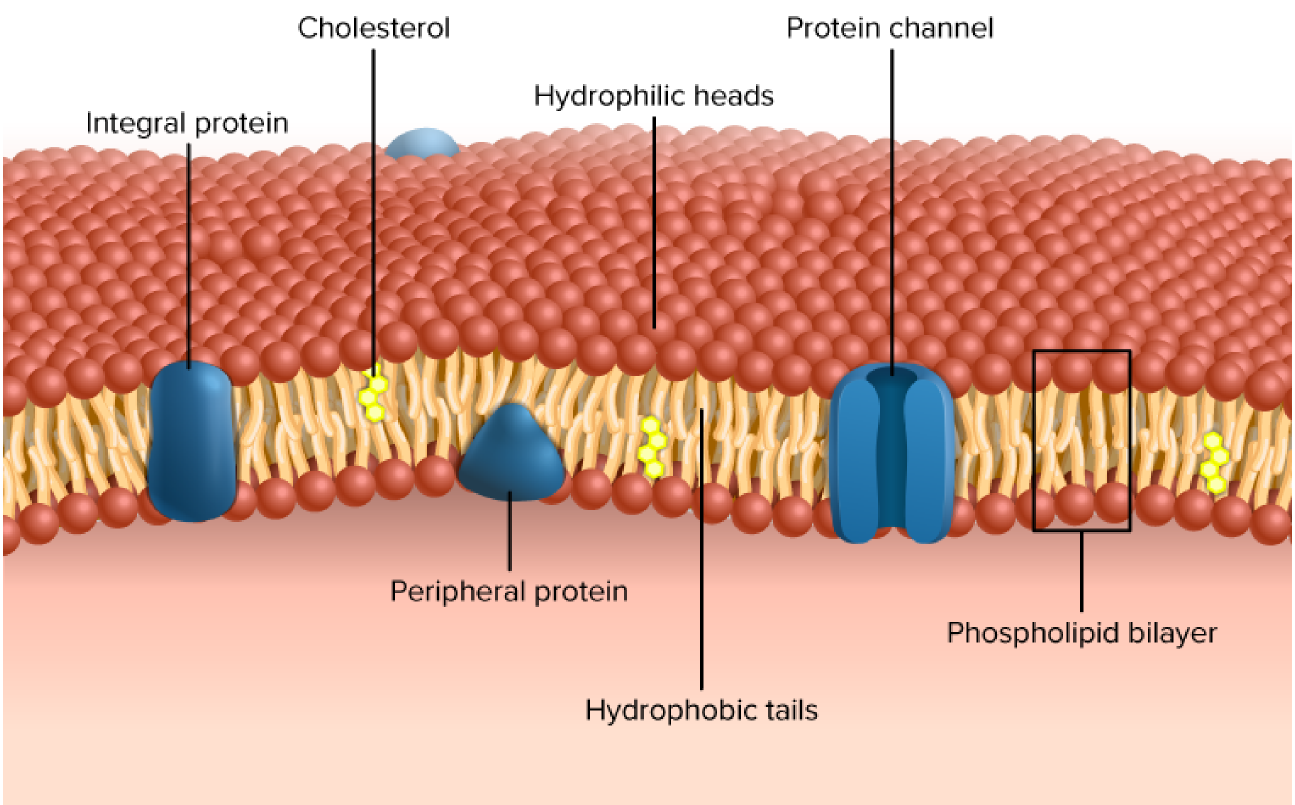


[Figure 3]



[Figure 4]

Flagella in Chlamydomonas and Cilia in Bronchiolar epithelium. Flagella and Cilia are extensions of the cell membrane of many cells.



Summary

- The cell membrane has many proteins that assist other substances in crossing the membrane.
- The Fluid Mosaic Model depicts the biological nature of the cell membrane.
- Cilia and flagella are extensions of the cell membrane.

Review

1. What is the main difference between the two main types of proteins associated with the cell membrane?
2. What are two functions of integral membrane proteins?
3. Discuss the Fluid Mosaic Model.
4. What are flagella and cilia?

Report Content Errors

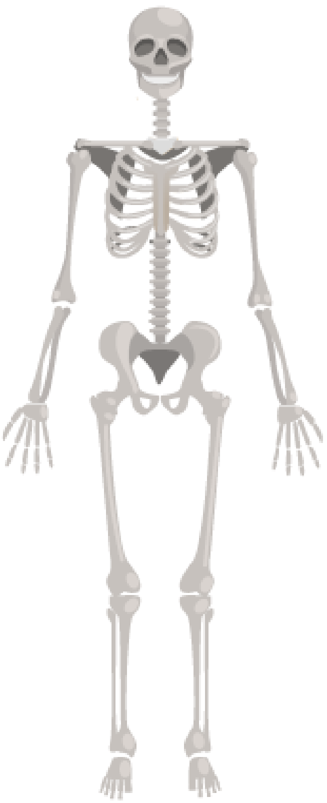
2.5 Cytoplasm and Cytoskeleton

FlexBooks 2.0 > Biology For High School Diploma > Cytoplasm and Cytoskeleton

Last Modified: Sep 30, 2021

What you will learn

- Structure and function of the **cytoplasm**
- Structure and function of the **cytoskeleton**
- Three main types of cytoskeleton fibers



[Figure 1]

Does a cell have, or even need, a "skeleton"?

What do you get if you take some tubing, and make the tubes smaller and smaller and smaller? You get very small tubes, or microtubes. Very small tubes, or **microtubule**, together with **microfilament**, form the basis of the "skeleton" inside the cell.

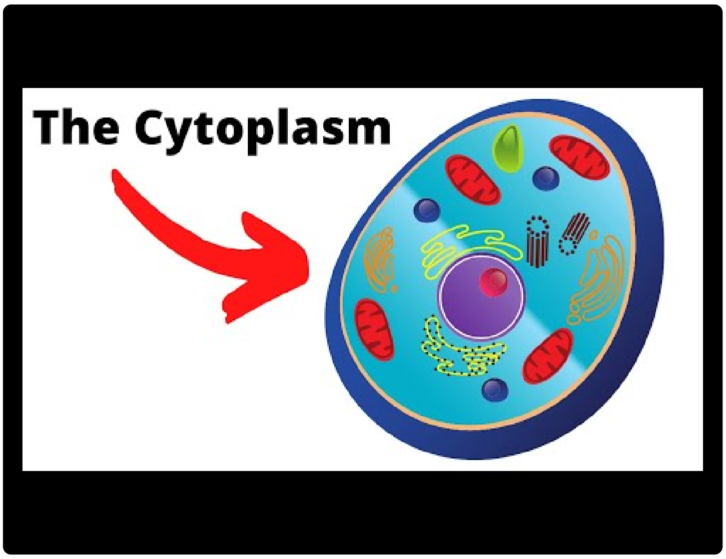
The Cytoplasm and Cytoskeleton

The **cytoplasm** consists of everything inside the cell membrane of the cell, excluding the nucleus in a eukaryotic cell. It includes the watery, gel-like material called **cytosol**, as well as various structures. The water in the cytoplasm makes up about two-thirds of the cell's weight and gives the cell many of its properties.

Functions of the Cytoplasm

The cytoplasm has several important functions, including:

1. suspending cell organelle.
2. pushing against the plasma membrane to help the cell keep its shape.
3. providing a site for many of the biochemical reaction of the cell.



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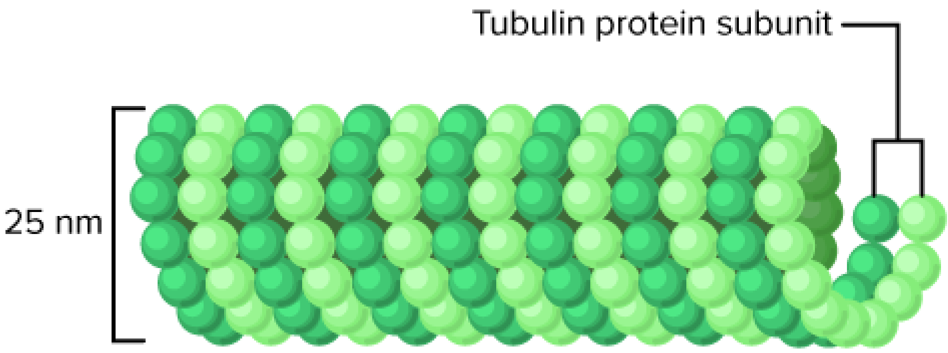
The Cytoskeleton

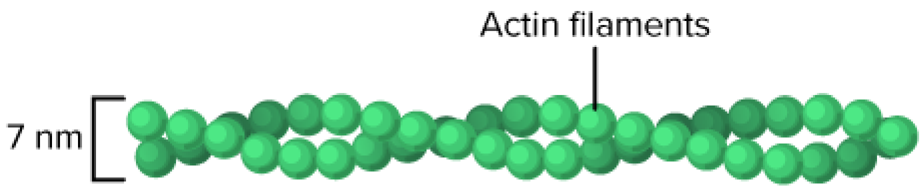
The **cytoskeleton** is a cellular "scaffolding" or "skeleton" that crisscrosses the cytoplasm. All eukaryotic cells have a cytoskeleton, and recent research has shown that prokaryotic cell also have a cytoskeleton. The eukaryotic cytoskeleton is made up of a network of long, thin protein fibers and has many functions. It helps to maintain cell shape. It holds organelles in place, and for some cells, it enables cell movement. The cytoskeleton also plays important roles in both the intracellular movement of substances and in cell division. Certain proteins act like a path that vesicle and organelles move along within the cell. The threadlike proteins that make up the cytoskeleton continually rebuild to adapt to the cell's constantly changing needs. Three main kinds of cytoskeleton fibers are microtubules, intermediate filament, and microfilaments.

- **Microtubules**, shown in the **Figure** below, are hollow cylinders and are the thickest of the cytoskeleton structures. They are most commonly made of filaments which are polymer of alpha and beta **tubulin**, and radiate outwards from an area near the nucleus called the centrosome. **Tubulin** is the protein that forms microtubules. Two forms of tubulin, alpha and beta, form dimers (pairs) which come together to form the hollow cylinders. The cylinders are twisted around each other to form the microtubules. Microtubules help the cell keep its shape as shown in the **Figure** below. They hold organelles in place and allow them to move around the cell, and they form the mitotic spindle during cell division. Microtubules also make up parts of cilia and flagellum, the organelles that help a cell move.



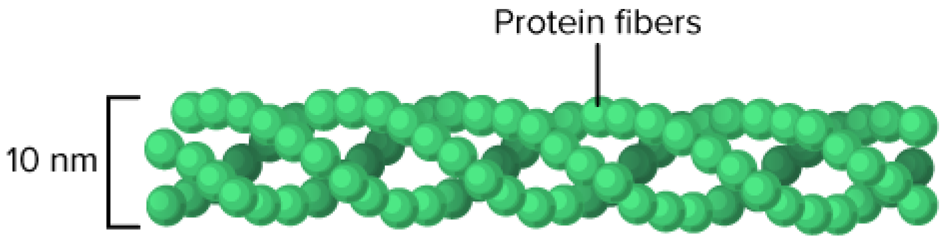
[Figure 2]

- **Microfilaments**, shown in the **Figure** below, are made of two thin **actin** chains that are twisted around one another. Microfilaments are mostly concentrated just beneath the cell membrane, where they support the cell and help the cell keep its shape. Microfilaments form cytoplasmatic extensions, such as pseudopodia and microvilli, which allow certain cells to move. The actin of the microfilaments interacts with the protein myosin to cause contraction in muscle cells. Microfilaments, as shown in the **Figure** below, are found in almost every cell, and are numerous in muscle cells and in cells that move by changing shape, such as phagocyte (white blood cell that search the body for bacterium and other invaders).

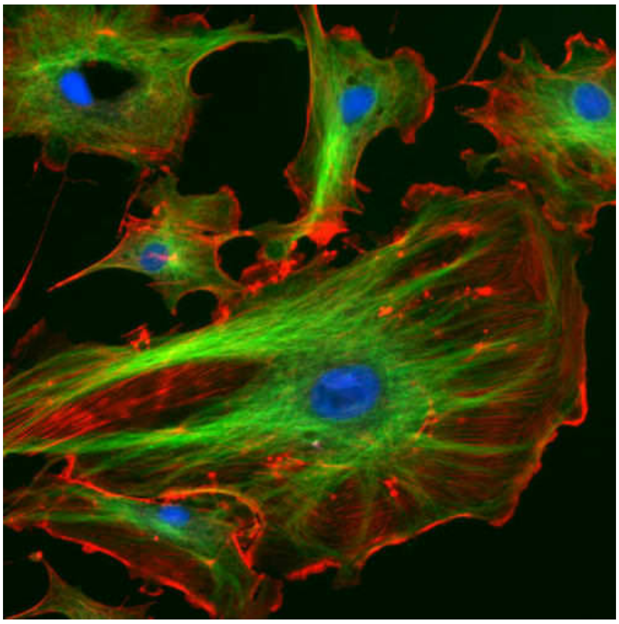


[Figure 3]

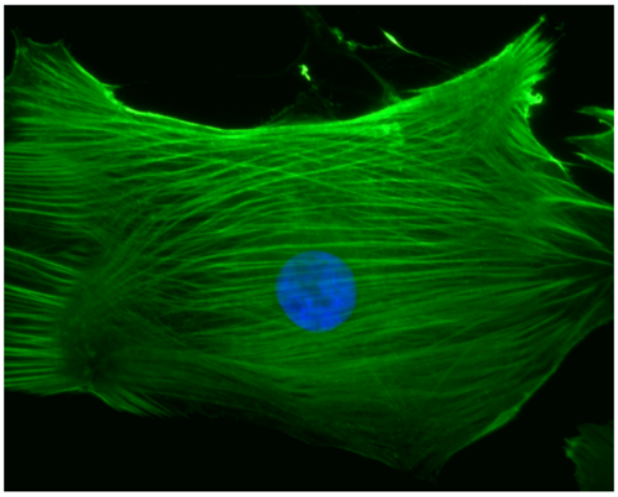
- **Intermediate filaments**, shown in the **Figure** below, differ in make-up from one cell type to another. Intermediate filaments organize the inside structure of the cell by holding organelles and providing strength. They are also structural components of the nuclear envelope. Intermediate filaments made of the protein keratin are found in skin, hair, and nails cells.



[Figure 4]



[Figure 5]



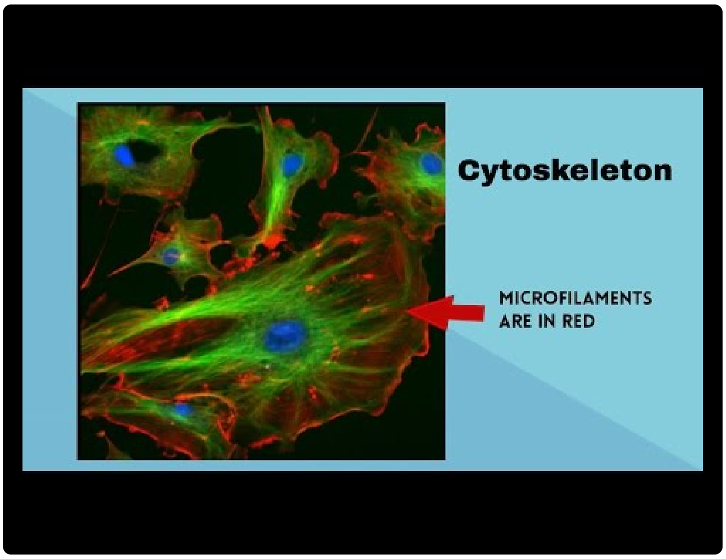
[Figure 6]

The eukaryotic cytoskeleton.

(Left) Microfilaments are shown in red, microtubules in green, and the nuclei are in blue. By linking regions of the cell together, the cytoskeleton helps support the shape of the cell.
(Right) Microscopy of microfilaments (actin filaments), shown in green, inside cells. The nucleus is shown in blue.

Cytoskeleton Structure

	Microtubules	Intermediate Filaments	Microfilaments
Fiber Diameter	About 25 nm	8 to 11 nm	Around 7 nm
Protein Composition	Tubulin, with two subunits, alpha and beta tubulin	One of different types of proteins such as lamin, vimentin, and keratin	Actin
Shape	Hollow cylinders made of two protein chains twisted around each other	Protein fiber coils twisted into each other	Two actin chains twisted around one another
Main Functions	Organelle and vesicle movement; form mitotic spindles during cell reproduction; cell motility (in cilia and flagella)	Organize cell shape; positions organelles in cytoplasm structural support of the nuclear envelope and sarcomere; involved in cell-to-cell and cell-to-matrix junctions	Keep cellular shape; allows movement of certain cells by forming cytoplasmatic extensions or contraction of actin fibers; involved in some cell-to-cell or cell-to-matrix junctions



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DID YOU KNOW?

Colchicine is an alkaloid isolated from the plant autumn crocus. This alkaloid prevents the assembly of the microtubules and does not allow the formation of spindle fibers during cell division. This stops the cell in the metaphase stage and blocks cell division. Since colchicine does not stop DNA replication it allows doubling of chromosome when applied to meristematic tissue in plants.

Check your understanding!

PROGRESS 0 / 4

1. Which of the following statement(s) are true about cytoskeleton fibers?

SELECT ALL THAT APPLY

a Microfilaments are made up of the protein actin.

b Intermediate filaments are made up of a variety of proteins.

c Microfilaments are involved in many cellular events that involve movement.

d Cytoskeletal fibers are polymers of carbohydrates.

Check It

Hint

https://www.ck12.org/assessment/ui/embed.html?test/view/613067df8ca10b06403e7c99&

Summary

- The cytoplasm consists of everything inside the cell membrane of the cell, excluding the nucleus in a eukaryotic cell.
- The cytoskeleton is a cellular "skeleton" that crisscrosses the cytoplasm. The three main cytoskeleton fibers are microtubules, intermediate filaments, and microfilaments.
- Microtubules are the thickest of the cytoskeleton structures and are most commonly made of filaments which are polymers of alpha and beta tubulin.
- Intermediate filaments organize the inside structure of the cell by holding organelles and providing strength.
- Microfilaments are the thinnest of the cytoskeleton structures and are made of two thin actin chains that are twisted around one another.

Review

1. What is the difference between cytoplasm and cytosol?
2. List two roles of the cytoplasm.
3. Name the three main types of cytoskeleton fibers.
4. List two functions of the eukaryotic cytoskeleton.

Report Content Errors

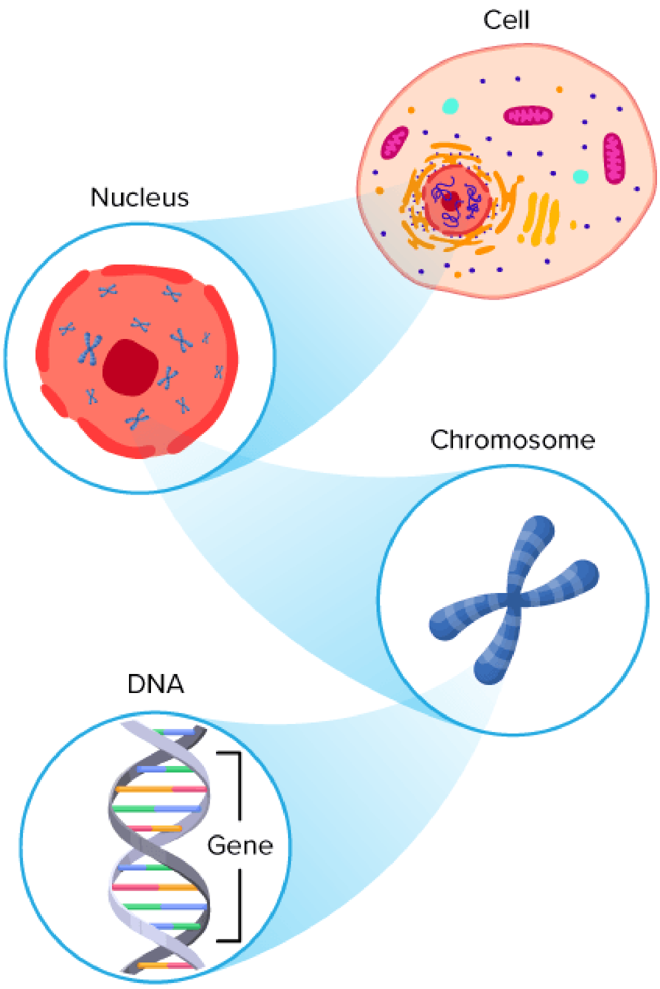
2.6 Nucleus

FlexBooks 2.0 > Biology For High School Diploma > Nucleus

Last Modified: Nov 23, 2021

What you will learn

- How DNA is organized inside the nucleus
- The role of the nucleus
- The structure and function of the **nuclear envelope**
- The role of the **nucleolus** in the assembly of **ribosome**



[Figure 1]

Where does the DNA live?

The answer depends on if the cell is prokaryotic or eukaryotic. The main difference between the two types of cells is the presence of a nucleus. And in eukaryotic cell, DNA lives in the nucleus.

The Nucleus

The **nucleus** is a membrane-enclosed organelle found in most eukaryotic cells. The nucleus is the largest organelle in the cell and contains most of the cell's genetic information (mitochondrion also contain DNA, called mitochondrial DNA, but it makes up just a small percentage of the cell's overall DNA content). The genetic information, which contains the information for the structure and function of the organism, is found encoded in DNA in the form of **gene**. A **gene** is a short segment of DNA that contains information to encode an RNA molecule into a protein strand. DNA in the nucleus is organized in long linear strands that are attached to different proteins. These proteins help the DNA coil up for better storage in the nucleus. Think how a string gets tightly coiled up if you twist one end while holding the other end. These long strands of coiled-up DNA and proteins are called **chromosome.** Each chromosome contains many genes. The function of the nucleus is to maintain the integrity of these genes and to control the activities of the cell by regulating **gene expression**. **Gene expression** is the process by which the information in a gene is "decoded" by various cell molecules to produce a functional gene product, such as a protein molecule.

DID YOU KNOW?

Every cell in the human body has 3 meters of DNA packed inside its nucleus, except gamete which have half the amount of DNA.

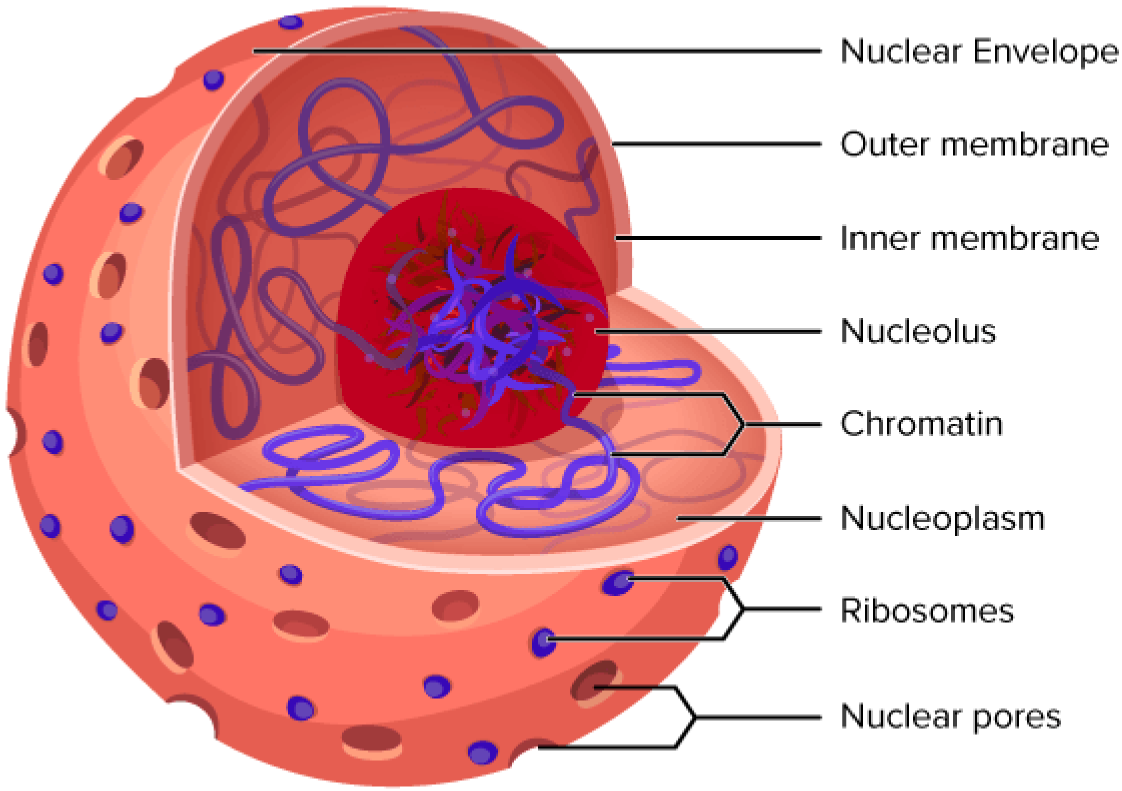
The degree of DNA coiling determines whether the chromosome strands are short and thick or long and thin. Between cell divisions, the DNA in chromosomes is more loosely coiled and forms long, thin strands called **chromatin**. Before the cell divides, the chromatin coil up more tightly and form chromosomes. Only chromosomes stain clearly enough to be seen under a microscope. The word chromosome comes from the Greek word *chroma* (color), and *soma* (body), due to its ability to be stained strongly by dyes.

The Nuclear Envelope

The **nuclear envelope** is a double membrane of the nucleus that encloses the genetic material. It separates the contents of the nucleus from the cytoplasm. The nuclear envelope is made of two lipid bilayers, an inner membrane and an outer membrane. The outer membrane is continuous with the rough endoplasmic reticulum. Many tiny holes called **nuclear pore** are found in the nuclear envelope. These nuclear pores help to regulate the exchange of materials (such as RNA and proteins) between the nucleus and the cytoplasm.

The Nucleolus

The nucleus of many cells also contains a non-membrane-bound organelle called a **nucleolus**, shown in the **Figure** below. The nucleolus is mainly involved in the assembly of ribosomes. **Ribosomes** are cellular parts made of protein and ribosomal RNA (rRNA), and they build cellular proteins in the cytoplasm. The function of the rRNA is to provide a way of decoding the genetic messages within another type of RNA (called mRNA), into amino acid. After being made in the nucleolus, ribosomes are exported to the cytoplasm, where they direct protein synthesis.

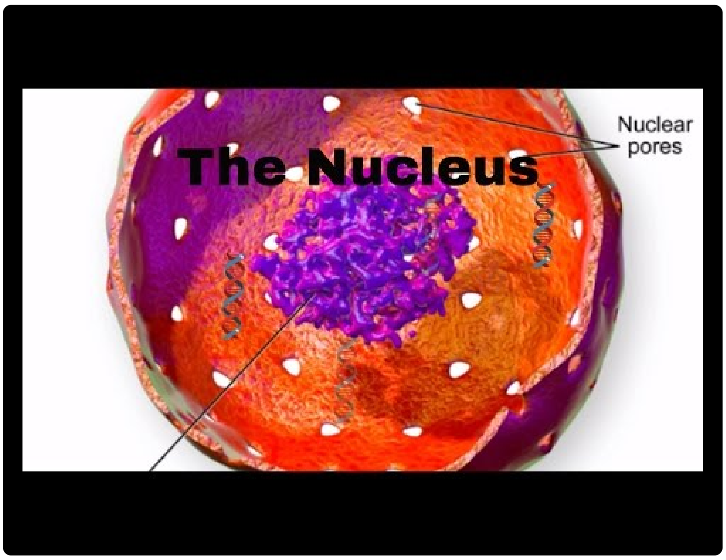


[Figure 2]

The eukaryotic cell nucleus. Visible in this diagram are the ribosome-studded double membranes of the nuclear envelope, the DNA (as chromatin), and the nucleolus. Within the nucleus is a viscous liquid called nucleoplasm, similar to the cytoplasm found outside the nucleus. The chromatin (which is normally invisible), is visible in this figure only to show that it is spread throughout the nucleus.

DID YOU KNOW?

A single mammalian cell may contain up to 10 million ribosomes.



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Summary

- The nucleus is a membrane-enclosed organelle, found in most eukaryotic cells, which stores the genetic material (DNA).
- The nucleus is surrounded by a double lipid bilayer, the nuclear envelope, which is embedded with nuclear pores.
- The nucleolus is inside the nucleus and is where ribosomes are made.

Review

1. What is the role of the nucleus of a eukaryotic cell?
2. Describe the nuclear membrane.
3. What are nuclear pores?
4. What is the role of the nucleolus?

Report Content Errors

2.7 Ribosomes and Mitochondria

FlexBooks 2.0 > Biology For High School Diploma > Ribosomes and Mitochondria

Last Modified: Feb 26, 2022

What you will learn

- The structure of **ribosome** and their role in protein synthesis
- Why **mitochondrion** are known as the "power plants" of the cell and how they meet the energy needs of the cell

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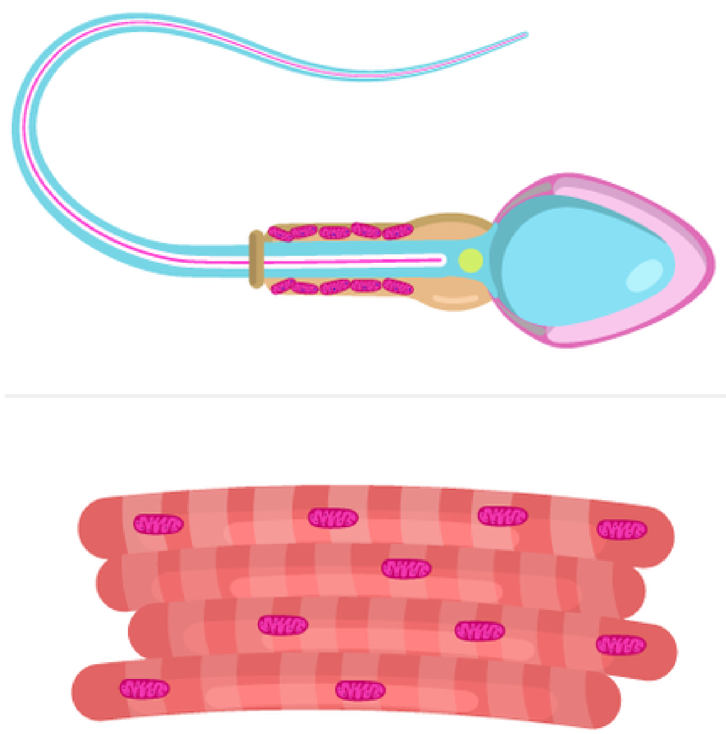


[Figure 1]

Sperm cells and muscle cells need lots of energy. What do they have in common?

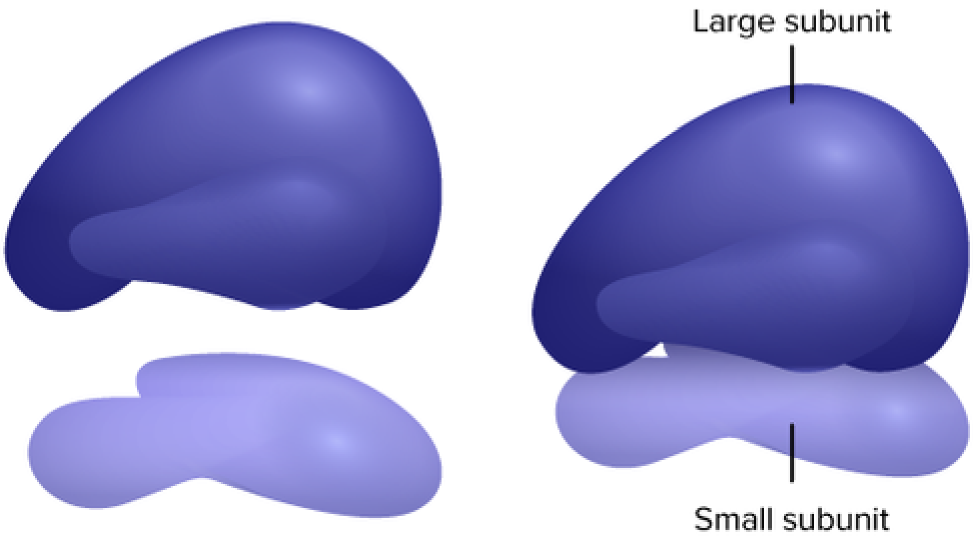
They have lots of mitochondria. Mitochondria are called the power plants of the cell, as these organelle are where most of the cell's energy is produced. Cells that need lots of energy have lots of mitochondria.

Ribosomes and Mitochondria

In addition to the nucleus, eukaryotic cell have many other cellular structures and organelles, including ribosomes and mitochondria. Ribosomes are cellular structures present in all cells.

Ribosomes

Ribosomes are small cellular structures that are the sites of protein synthesis (or assembly). They are made of ribosomal protein and ribosomal RNA, and are found in both eukaryotic and prokaryotic cell. Unlike organelles, ribosomes are not surrounded by a membrane. Each ribosome has two parts, a large and a small subunit, as shown in the **Figure** below. The subunits are attached to one another. Ribosomes can be found alone or in groups within the cytoplasm. Some ribosomes are attached to the endoplasmic reticulum (ER), and others are attached to the nuclear envelope.



[Figure 2]

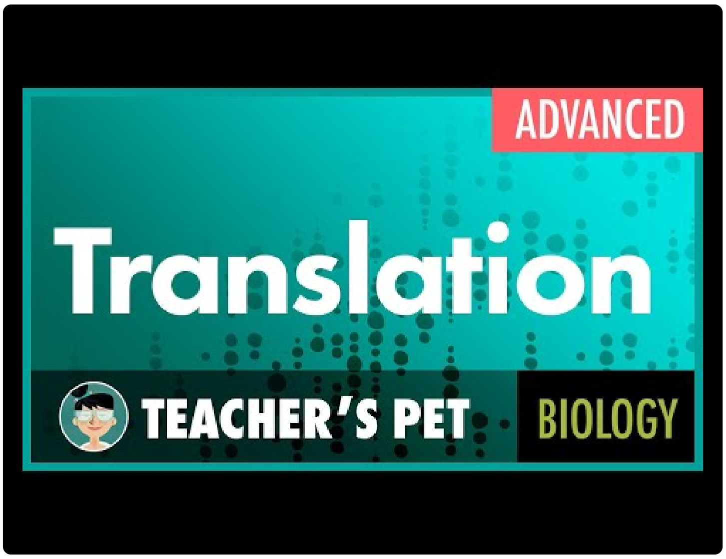
The two subunits that make up a ribosome, small organelles that are intercellular protein factories.

ribozyme are RNA molecules that catalyze chemical reaction, such as translation. **Translation** is the process of ordering the amino acid in the assembly of a protein, and translation will be discussed more in another concept. Briefly, the ribosomes interact with other RNA molecules to make chains of amino acids called polypeptide chains, due to the peptide bond that forms between individual amino acids. Polypeptide chains are built from the genetic instructions held within a messenger RNA (mRNA) molecule. Polypeptide chains that are made on the rough ER are inserted directly into the ER and then are transported to their various cellular destinations. Ribosomes on the rough ER usually produce proteins that are destined for the cell membrane.

DID YOU KNOW?

Although ribosomes are generally described as organelles, it is important to note that ribosomes are not organelles, they are not bound by a membrane, and are much smaller than other organelles.

Ribosomes are found in both eukaryotic and prokaryotic cells. Ribosomes are not surrounded by a membrane. The other organelles found in eukaryotic cells are surrounded by a membrane.



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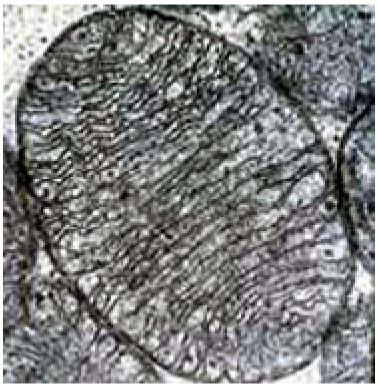
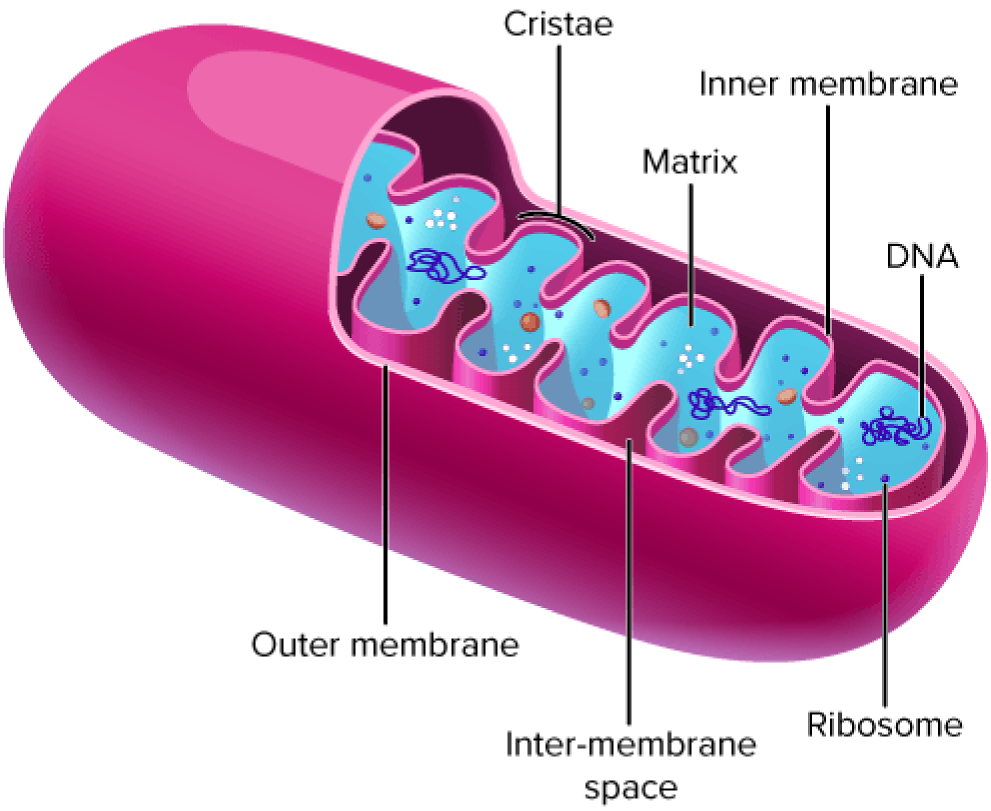
Mitochondria

A mitochondrion (**mitochondria**, plural), is a membrane-enclosed organelle that is found in most eukaryotic cells. Mitochondria are called the "power plants" of the cell because they are the sites of cellular respiration, where they use energy from organic compound to make **ATP** (adenosine triphosphate). **ATP** is the cell's energy source that is used for such things such as movement and cell division. Some ATP is made in the cytosol of the cell, but most of it is made inside mitochondria. The number of mitochondria in a cell depends on the cell's energy needs. For example, active human muscle cells may have thousands of mitochondria, while less active red blood cell do not have any.



[Figure 3]



[Figure 4]

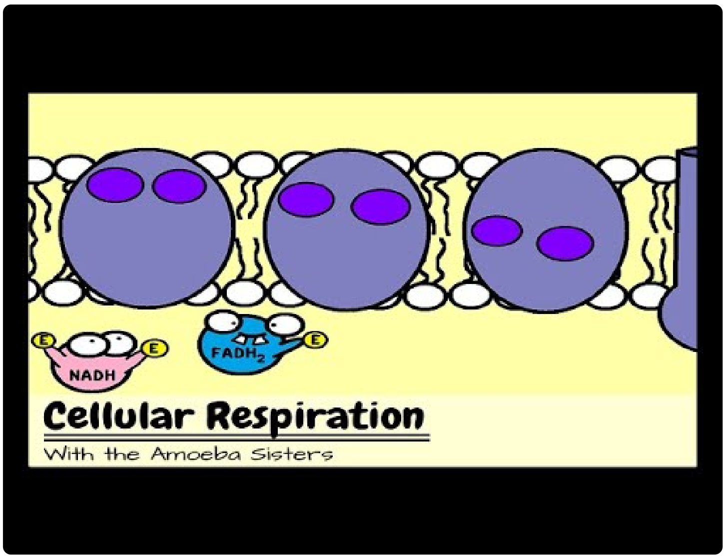
(first) Electron micrograph of a single mitochondrion, within which you can see many cristae. Mitochondria range from 1 to 10 μm in size. (second) This model of a mitochondrion shows the organized arrangement of the inner and outer membranes, the protein matrix, and the folded inner mitochondrial membranes.

As the **Figure** above shows, a mitochondrion has two phospholipid membranes. The smooth outer membrane separates the mitochondrion from the cytosol. The inner membrane has many folds, called **crista**. The fluid-filled inside of the mitochondrion, called the **matrix**, is where most of the cell's ATP is made.

DID YOU KNOW?

prokaryote lack mitochondria and instead produce ATP on their cell membrane.

Although most of a cell's DNA is contained in the cell nucleus, mitochondria have their own DNA. Mitochondria are able to reproduce asexually, and scientists think that they are descended from prokaryotes. According to the endosymbiotic theory, mitochondria were once free-living prokaryotes that infected or were engulfed by ancient eukaryotic cells. The invading prokaryotes were protected inside the eukaryotic host cell, and in turn the prokaryote supplied extra ATP to its host.



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Summary

- Ribosomes are small cellular structures and are the site of protein synthesis. Ribosomes are found in all cells.
- Mitochondria are where energy from organic compounds is used to make ATP.

Review

1. What is the function of a ribosome?
2. What is a significant difference between the structure of a ribosome and other organelles?
3. Identify the reason why mitochondria are called "power plants" of the cell.
4. Describe the structure of a mitochondrion.

Report Content Errors

2.8 Cell Structure

FlexBooks 2.0 > Biology For High School Diploma > Cell Structure

Last Modified: Sep 30, 2021

What you will learn

- organelle present in a eukaryotic cell
- Organelles involved in protein synthesis and transport

[Figure 1]

Does a cell have its own ER?

Yes, but in this case, the ER is not just for emergencies. True, there might be times when the cell responds to emergency conditions and the functions of the ER may be needed, but usually the cell's ER is involved in normal functions. protein are also made on the outside of the ER, and this starts a whole process of protein transport, both around the inside of the cell and to the cell membrane and out.

Organelles

In addition to the nucleus, eukaryotic cells have many other organelles, including the **endoplasmic reticulum**, **Golgi apparatus**, **vesicle**, **vacuole**, and **centriole**.

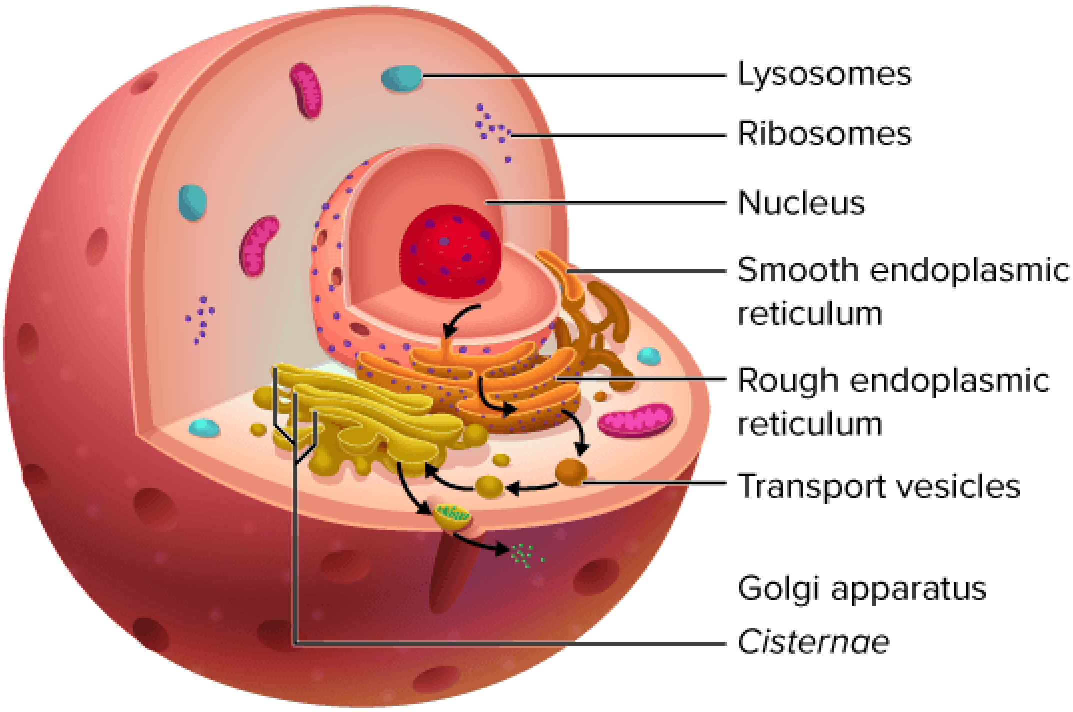
Endoplasmic Reticulum

The **endoplasmic reticulum (ER)** (plural, reticuli) is a network of phospholipid membranes that form hollow tubes, flattened sheets, and round sacs. These flattened, hollow folds and sacs are called cisternae. The ER has two major functions:

- Transport: Molecules, such as proteins, can move from place to place inside the ER, much like on an intracellular highway.
- Synthesis: ribosome that are attached to ER, similar to unattached ribosomes, make proteins. lipid are also produced in the ER.

There are two types of endoplasmic reticulum, **rough endoplasmic reticulum** (RER) and **smooth endoplasmic reticulum** (SER).

- **Rough endoplasmic reticulum** is studded with ribosomes, which gives it a "rough" appearance. These ribosomes make proteins that are then transported from the ER in small sacs called **transport vesicle**. The transport vesicles pinch off the ends of the ER. The rough endoplasmic reticulum works with the Golgi apparatus to move new proteins to their proper destinations in the cell. The membrane of the RER is continuous with the outer layer of the nuclear envelope.
- **Smooth endoplasmic reticulum** does not have any ribosomes attached to it, and so it has a smooth appearance. SER has many different functions, some of which include lipid synthesis, calcium ion storage, and drug detoxification. Smooth endoplasmic reticulum is found in both animal and plant cells and it serves different functions in each. The SER is made up of tubules and vesicles that branch out to form a network. In some cells there are dilated areas like the sacs of RER. Smooth endoplasmic reticulum and RER form an interconnected network.

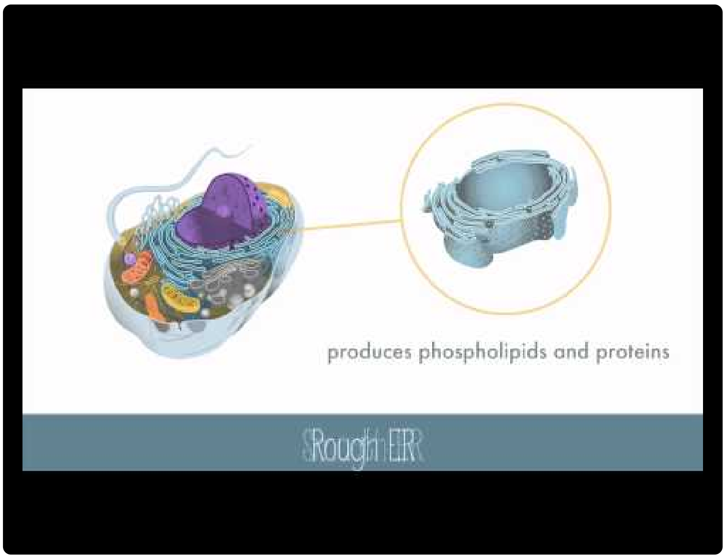


[Figure 2]

Image of nucleus, endoplasmic reticulum and Golgi apparatus, and how they work together. The process of secretion from endoplasmic reticuli to Golgi apparatus is shown.

Golgi Apparatus

The **Golgi apparatus** is a large organelle that is usually made up of five to eight cup-shaped, membrane-covered discs called cisternae, as shown in the **Figure** above. The cisternae look a bit like a stack of deflated balloons. The Golgi apparatus modifies, sorts, and packages different substances for secretion out of the cell, or for use within the cell. The Golgi apparatus is found close to the nucleus of the cell, where it modifies proteins that have been delivered in transport vesicles from the RER. It is also involved in the transport of lipids around the cell. Pieces of the Golgi membrane pinch off to form vesicles that transport molecules around the cell. The Golgi apparatus can be thought of as similar to a post office; it packages and labels "items" and then sends them to different parts of the cell. Both plant and animal cells have a Golgi apparatus. Plant cells can have up to several hundred Golgi stacks scattered throughout the cytoplasm. In plants, the Golgi apparatus contains enzyme that synthesize some of the cell wall polysaccharide.



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Vesicles

A **vesicle** is a small, spherical compartment that is separated from the cytosol by at least one lipid bilayer. Many vesicles are made in the Golgi apparatus and the endoplasmic reticulum, or are made from parts of the cell membrane. Vesicles from the Golgi apparatus can be seen in the **Figure** above. Because it is separated from the cytosol, the space inside the vesicle can be made to be chemically different from the cytosol. Vesicles are basic tools of the cell for organizing metabolism, transport, and storage of molecules. Vesicles are also used as chemical reaction chambers. They can be classified by their contents and function.

- **Transport vesicles** are able to move molecules between locations inside the cell. For example, transport vesicles move proteins from the rough endoplasmic reticulum to the Golgi apparatus.
- **lysosome** are vesicles that are formed by the Golgi apparatus. They contain powerful enzymes that could break down (digest) the cell. Lysosomes break down harmful cell products, waste materials, and cellular debris and then force them out of the cell. They also digest invading organism such as bacterium. Lysosomes also break down cells that are ready to die, a process called autolysis.
- **peroxisome** are vesicles that use oxygen to break down toxic substances in the cell. Unlike lysosomes, which are formed by the Golgi apparatus, peroxisomes self-replicate by growing bigger and then dividing. They are common in liver and kidney cells that break down harmful substances. Peroxisomes are named for the hydrogen peroxide (H_2O_2) that is produced when they break down organic compound. Hydrogen peroxide is toxic, and in turn is broken down into water (H_2O) and oxygen (O_2) molecules.

Vacuoles

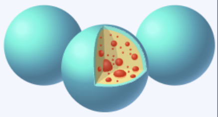
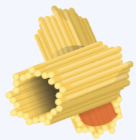
Vacuoles are membrane-bound organelles that can have secretory, excretory, and storage functions. Many organisms will use vacuoles as storage areas and some plant cells have very large vacuoles. Vesicles are much smaller than vacuoles and function in transporting materials both within and to the outside of the cell.

Centrioles

Centrioles are rod-like structures made of short microtubule. Nine groups of three microtubules make up each centriole. Two perpendicular centrioles make up the **centrosome**. Centrioles are very important in cellular division, where they arrange the mitotic spindle that pull the chromosome apart during mitosis.

CAN YOU MATCH?

Try matching the organelles with their functions.

	Organelles	Major Functions	
1	 Lysosomes	Use enzymes to break down molecules and recycle cell components.	A
2	 Centrioles	Helps to make proteins and lipids, and transports protein in the cell.	B
3	 Golgi Apparatus	Modifies, sorts, and packages proteins for secretion out of the cell, or for use within the cell.	C
4	 ER	Arrange the mitotic spindles that pull the chromosome apart during mitosis.	D

Answers: 1-A, 2-D, 3-C, 4-B

DID YOU KNOW?

Golgi apparatus is named after Camillo Golgi, an Italian scientist who discovered this organelle in 1897. Using a light microscope, he demonstrated the presence of the Golgi apparatus in a variety of cells.

Summary

- The endoplasmic reticulum (ER) is involved in the synthesis of lipids and synthesis and transport of proteins.
- The Golgi apparatus modifies, sorts, and packages different substances for secretion out of the cell, or for use within the cell.
- Vesicles are also used as chemical reaction chambers. Transport vesicles, lysosomes, and peroxisomes are types of vesicles.
- Vacuoles have secretory, excretory, and storage functions.
- Centrioles are made of short microtubules and are very important in cell division.

Review

1. List five organelles eukaryotes have that prokaryotes do not have.
2. Explain how the following organelles ensure that a cell has the proteins it needs: nucleus, rough ER, vesicles, and Golgi apparatus.
3. What is the main difference between rough endoplasmic reticulum and smooth endoplasmic reticulum?
4. Describe the three types of vesicles.

Report Content Errors

2.9 Plant Cell Structure

FlexBooks 2.0 > Biology For High School Diploma > Plant Cell Structure

Last Modified: Nov 23, 2021

What you will learn

- Special structures in plant cell and their role
- Structure and function of **chloroplast**

[Figure 1]

What do plants have to do that animals don't?

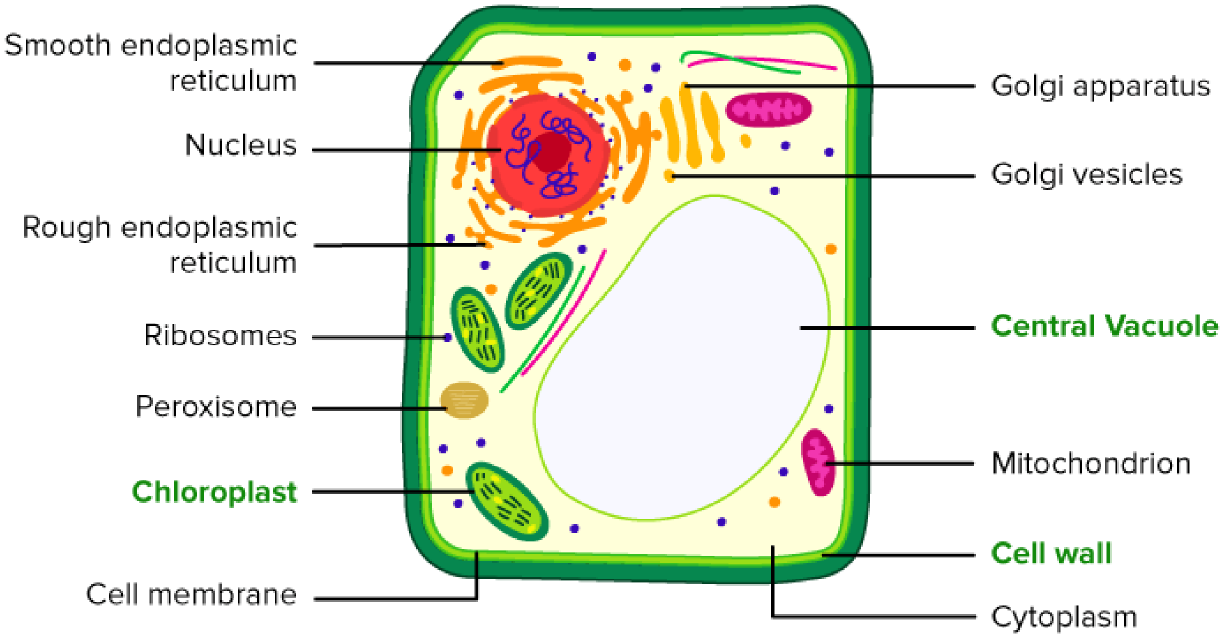
Many plant cells are green. Why? Plant cells also usually have a distinct shape. The rigid exterior around the cells is necessary to allow the plants to grow upright. animal cells do not have these rigid exteriors. There are other distinct differences between plant and animal cells. These will be the focus of this concept.

Plant Cells

Special Structures in Plant Cells

Most organelle are common to both animal and plant cells. However, plant cells also have features that animal cells do not have: a **cell wall**, a large **central vacuole**, and **plastid** such as chloroplasts.

Plants have very different lifestyles from animals, and these differences are apparent when you examine the structure of the plant cell. Plants make their own food in a process called **photosynthesis**. They take in carbon dioxide (CO_2) and water (H_2O) and convert them into sugars. The features unique to plant cells can be seen in the **Figure** below.



[Figure 2]

In addition to containing most of the organelles found in animal cells, plant cells also have a cell wall, a large central vacuole, and plastids. These three features are not found in animal cells.

The Cell Wall

A **cell wall** is a rigid layer that is found outside the cell membrane and surrounds the cell. The cell wall contains not only cellulose and protein, but other polysaccharide as well. The cell wall provides structural support and protection. Pores in the cell wall allow water and nutrient to move into and out of the cell. The cell wall also prevents the plant cell from bursting when water enters the cell.

microtubule guide the formation of the plant cell wall. Cellulose is laid down by enzyme to form the primary cell wall. Some plants also have a secondary cell wall. The secondary wall contains a lignin, a secondary cell component in plant cells that have completed cell growth/expansion.

The Central Vacuole

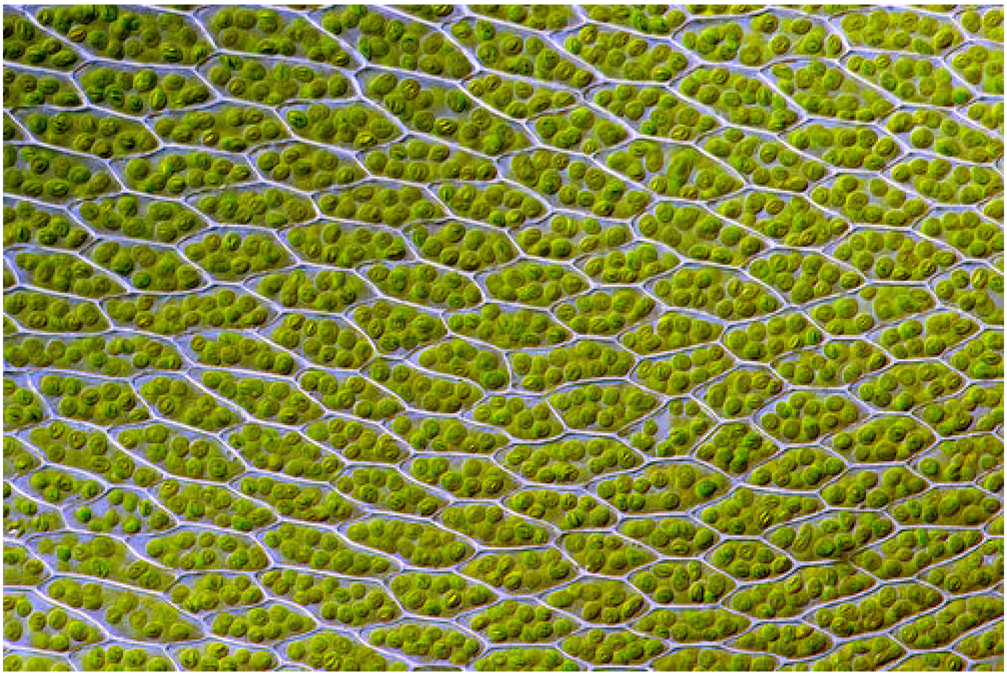
Most mature plant cells have a **central vacuole** that occupies more than 30% of the cell's volume. The central vacuole can occupy as much as 90% of the volume of certain cells. The central vacuole is surrounded by a membrane called the **tonoplast**. The central vacuole has many functions. Aside from storage, the main role of the vacuole is to maintain turgor pressure against the cell wall. Proteins found in the tonoplast control the flow of water into and out of the vacuole. The central vacuole also stores the pigments that color flower.

The central vacuole contains large amounts of a liquid called cell sap, which differs in composition to the cell cytosol. Cell sap is a mixture of water, enzymes, ion, salts, and other substances. Cell sap may also contain toxic byproducts that have been removed from the cytosol. Toxins in the vacuole may help to protect some plants from being eaten.

Plastids

Plant **plastids** are a group of closely related membrane-bound organelles that carry out many functions. They are responsible for photosynthesis, for storage of products such as starch, and for the synthesis of many types of molecules that are needed as cellular building blocks. Plastids have the ability to change their function between these and other forms. Plastids contain their own DNA and some ribosome, and scientists think that plastids are descended from photosynthetic bacterium that allowed the first eukaryote to make oxygen. The main types of plastids and their functions are:

- **Chloroplasts** are the organelle of photosynthesis. They capture light energy from the sun and use it with water and carbon dioxide to make food (sugar) for the plant. The arrangement of chloroplasts in a plant's cells can be seen in the **Figure** below.
- **chromoplast** make and store pigments that give petal and fruit their orange and yellow colors.
- **leucoplast** do not contain pigments and are located in roots and non-photosynthetic tissue of plants. They may become specialized for bulk storage of starch, lipid, or protein. However, in many cells, leucoplasts do not have a major storage function. Instead, they make molecules such as fatty acid and many amino acid.



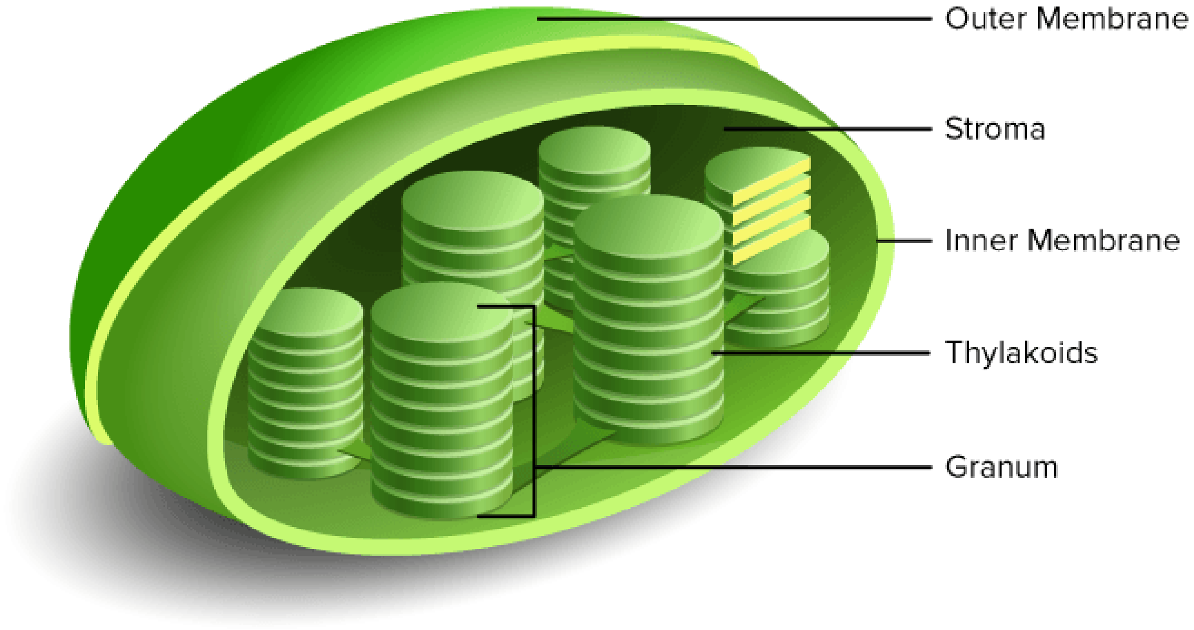
[Figure 3]

Plant cells with visible chloroplasts.

Chloroplasts

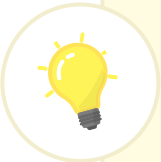
Chloroplasts capture light energy from the sun and use it with water and carbon dioxide to produce sugars for food. Chloroplasts look like flat discs and are usually 2 to 10 micrometers in diameter and 1 micrometer thick. A model of a chloroplast is shown in the **Figure** below. The chloroplast is enclosed by an inner and an outer phospholipid membrane. Between these two layers is the intermembrane space. The fluid within the chloroplast is called the **stroma**, and it contains one or more molecules of small, circular DNA. The stroma also has ribosomes. Within the stroma are stacks of **thylakoid**. The thylakoids are arranged in stacks called **granum** (singular: granum). A thylakoid has a flattened disk shape. Inside it is an empty area called the thylakoid space or lumen.

Within the thylakoid membrane is the complex of proteins and light-absorbing pigments, such as chlorophyll and carotenoids. This complex allows capture of light energy from many wavelengths because chlorophyll and carotenoids both absorb different wavelengths of light.



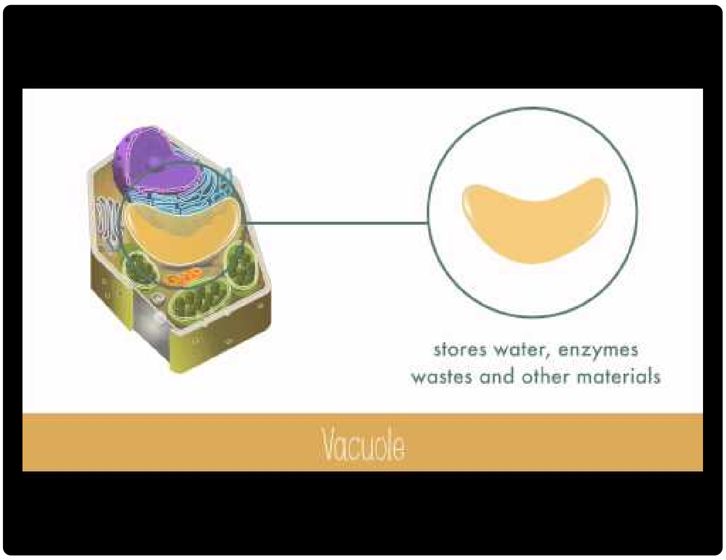
[Figure 4]

The internal structure of a chloroplast.



DID YOU KNOW?

Euglenoids are a unique group of unicellular protist with characteristics of both plant and animal cells. They have chloroplasts which help them make their own food in the presence of light. However, they can also live on nutrients in their sorroundings in the absence of light.



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Summary

- Plant cells have a cell wall, a large central vacuole, and plastids such as chloroplasts.
- The cell wall is a rigid layer that is found outside the cell membrane and surrounds the cell, providing structural support and protection.
- The central vacuole maintains turgor pressure against the cell wall.
- Chloroplasts capture light energy from the sun and use it with water and carbon dioxide to produce sugars for food during photosynthesis.

Review

1. List three structures that are found in plant cells but not in animal cells.
2. Identify two functions of plastids in plant cells.
3. What are the roles of the cell wall and the central vacuole?
4. Describe the chloroplast structure.

Report Content Errors

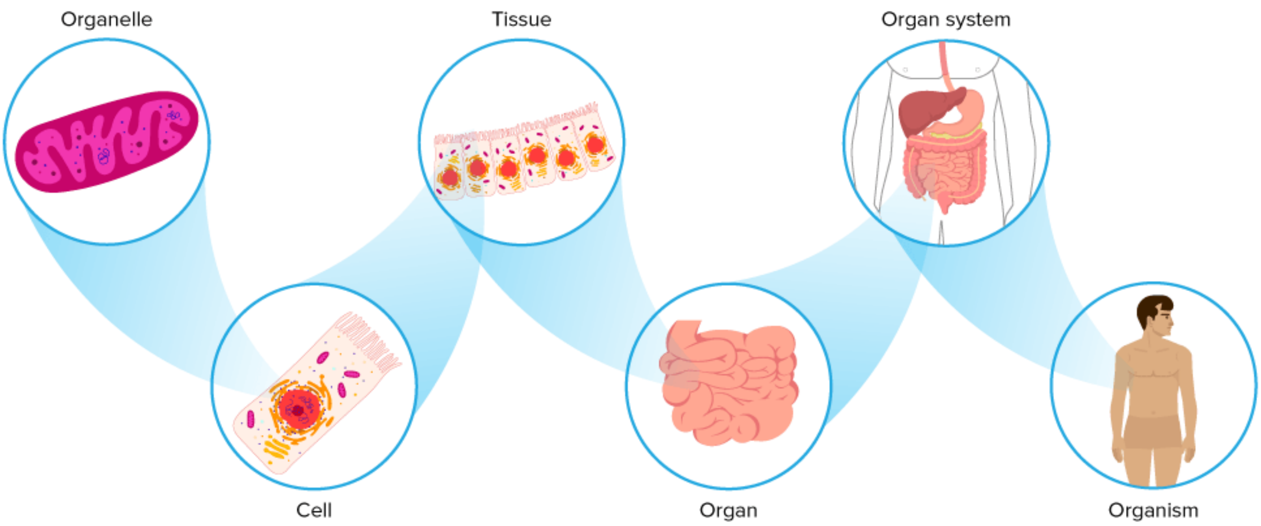
2.10 Cell Organization

FlexBooks 2.0 > Biology For High School Diploma > Cell Organization

Last Modified: Jan 18, 2022

What you will learn

- The biological levels of organization in an organism
- The origin of multicellular organisms



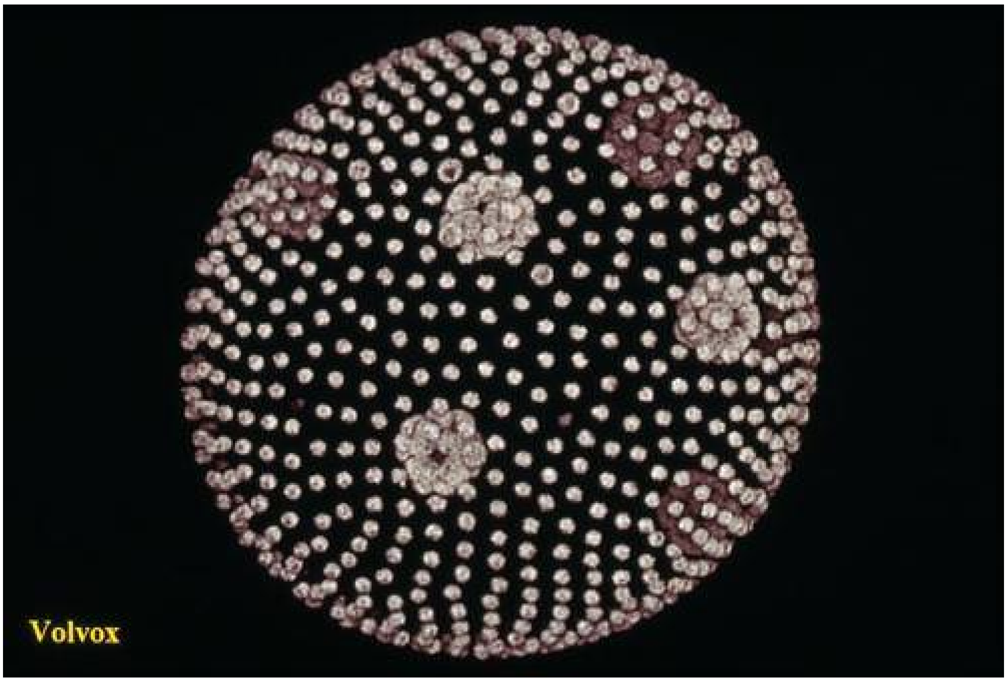
[Figure 1]

Why be organized?

It can be said organization leads to efficiency. And in you, cell are organized into **tissue**, which are organized into **organ**, which are organized into **organ system**, which form you. And it can be said that the human body is a very organized and efficient system.

Organization of Cells

Biological organization exists at all levels in organisms. It can be seen at the smallest level, in the molecules that made up such things as DNA and protein, to the largest level, in an organism such as a blue whale, the largest mammal on Earth. Similarly, single-celled prokaryote and eukaryote show the order in the way their cells are arranged. Single-celled organisms such as an amoeba are free-floating and independent-living. Their single-celled "bodies" are able to carry out all the processes of life, such as metabolism and respiration, without help from other cells. Some single-celled organisms, such as bacterium, can group together and form a **biofilm**. A **biofilm** is a large grouping of many bacteria that sticks to a surface and makes a protective coating over itself. Biofilms can show similarities to **multicellular organism**. Division of labor is the process in which one group of cells does one job (such as making the "glue" that sticks the biofilm to the surface), while another group of cells does another job (such as taking in nutrients). Multicellular organisms carry out their life processes through division of labor. They have specialized cells that do specific jobs. However, biofilms are not considered multicellular organisms and are instead called colonial organism. The difference between a multicellular organism and a colonial organism is that individual organisms from a colony or biofilm can, if separated, survive on their own, while cells from a multicellular organism (e.g., liver cells) cannot.



[Figure 2]

Colonial algae of the genus Volvox.

Colonial Organisms

Colonial organisms were probably one of the first evolutionary steps towards multicellular organisms. alga of the genus *Volvox* are an example of the border between colonial organisms and multicellular organisms.

Each *Volvox*, shown in the **Figure** above, is a colonial organism. It is made up of between 1,000 to 3,000 photosynthetic algae that are grouped together into a hollow sphere. The sphere has a distinct front and back end. The cells have eyespots, which are more developed in the cells near the front. This enables the colony to swim towards light.

Origin of Multicellularity

The oldest known multicellular organism is a red algae *Bangiomorpha pubescens*, fossil of which were found in 1.2 billion-year-old rock. As the first organisms were single-celled, these organisms had to evolve into multicellular organisms.

Scientists think that multicellularity arose from cooperation between many organisms of the same species. The **Colonial Theory** proposes that this cooperation led to the development of a multicellular organism. Many examples of cooperation between organisms in nature have been observed. For example, a certain species of amoeba (a single-celled protist) groups together during times of food shortage and forms a colony that moves as one to a new location. Some of these amoebas then become slightly differentiated from each other. *Volvox*, shown in the **Figure** above, is another example of a colonial organism. Most scientists accept that the Colonial Theory explains how multicellular organisms evolved.

Multicellular organisms are organisms that are made up of more than one type of cell and have specialized cells that are grouped together to carry out specialized functions. Most life that you can see without a microscope is multicellular. As discussed earlier, the cells of a multicellular organism would not survive as independent cells. The body of a multicellular organism, such as a tree or a cat, exhibits organization at several levels: tissues, organs, and organ systems. Similar cells are grouped into tissues, groups of tissues make up organs, and organs with a similar function are grouped into an organ system.

Levels of Organization in Multicellular Organisms

The simplest living multicellular organisms, sponges, are made of many specialized types of cells that work together for a common goal. Such cell types include digestive cells, tubular pore cells, and epidermal cells. Though the different cell types create a large, organized, multicellular structure — the visible sponge — they are not organized into true interconnected tissues. If a sponge is broken up by passing it through a sieve, the sponge will reform on the other side. However, if the sponge's cells are separated from each other, the individual cell types cannot survive alone. Simpler colonial organisms, such as members of the genus *Volvox*, as shown in the **Figure** above, differ in that their individual cells are free-living and can survive on their own if separated from the colony.

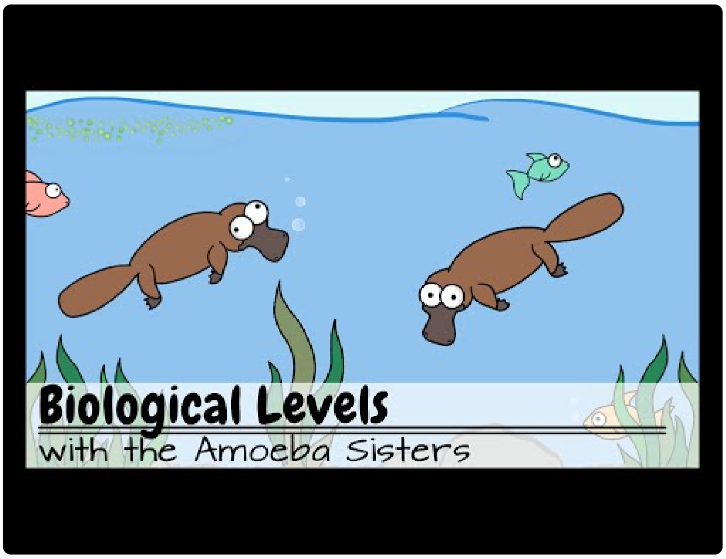
A **tissue** is a group of connected cells that have a similar function within an organism. More complex organisms such as jellyfish, coral, and sea anemones have a tissue level of organization. For example, jellyfish have tissues that have separate protective, digestive, and sensory functions.

An **organ** is a group of tissues that has a specific function or group of functions. Organs can be as primitive as the brain of a flatworm (a group of nerve cells), as large as the stem of a sequoia (up to 90 meters, or 300 feet, in height), or as complex as a human liver.

The most complex organisms (such as mammals, trees, and flowers) have organ systems. An **organ system** is a group of organs that act together to carry out complex related functions, with each organ focusing on a part of the task. An example is the human digestive system, in which the mouth ingests food, the stomach crushes and liquefies it, the pancreas and gall bladder make and release digestive enzyme, and the intestines absorb nutrient into the blood.

DID YOU KNOW?

There are only a few multicellular organisms that have an organ system with a fixed number of somatic cells at maturity. They are called Eutelic organisms. *Caenorhabditis elegans* is a nematode organism whose male individuals have 1033 somatic cells at maturity.



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Summary

- Single-celled organisms are able to carry out all the processes of life without help from other cells.
- Multicellular organisms carry out their life processes through division of labor. They have specialized cells that do specific jobs.
- The Colonial Theory proposes that cooperation among cells of the same species led to the development of a multicellular organism.

- Multicellular organisms, depending on their complexity, may be organized from cells to tissues, organs, and organ systems.

Review

1. What is a multicellular organism?
2. What is a cell feature that distinguishes a colonial organism from a multicellular organism?
3. What is the difference between a cell and a tissue?
4. Describe the top two levels of organization of an organism.

Report Content Errors

2.11 Diffusion

FlexBooks 2.0 > Biology For High School Diploma > Diffusion

Last Modified: Jan 25, 2022

What you will learn

- movement of molecules across the cell membrane
- Diffusion and **facilitated diffusion** processes

[Figure 1]

Can you help me move?

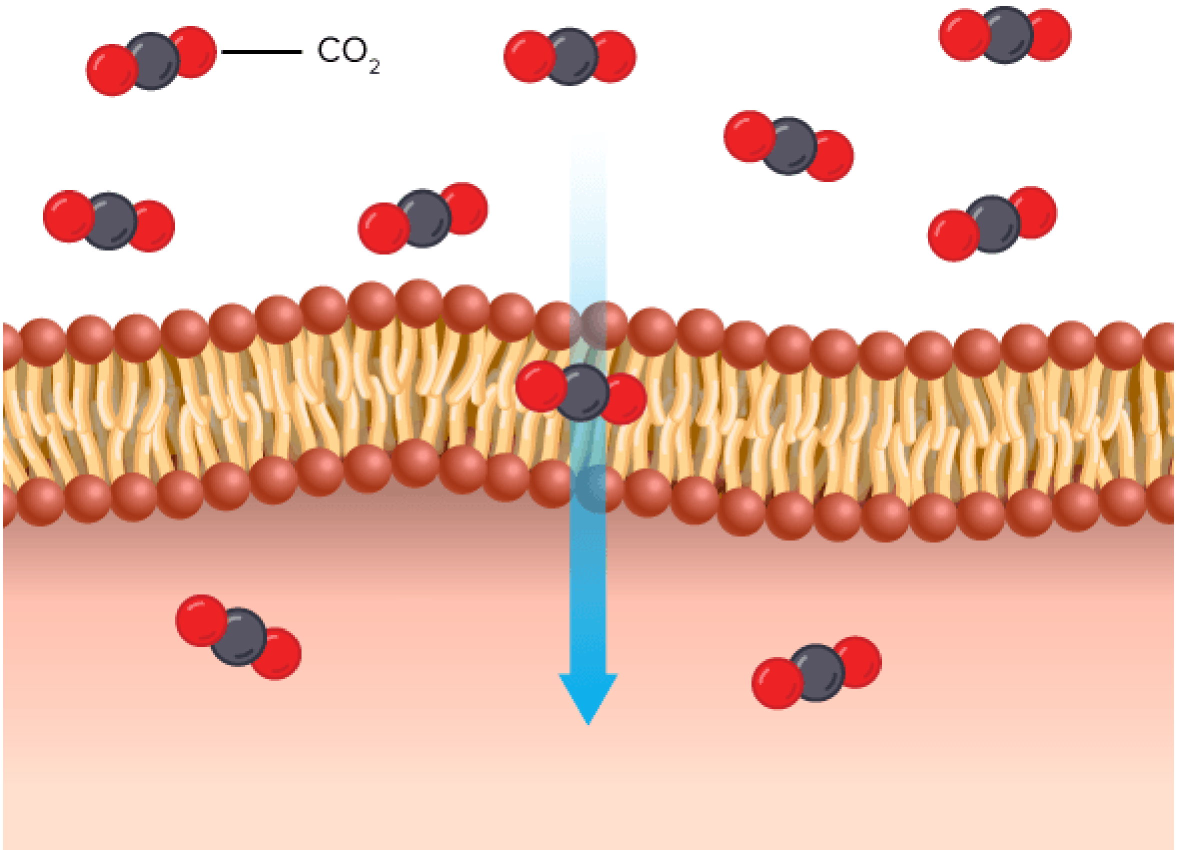
Often a large truck might be needed if you are moving large boxes and furniture. Just as a truck is needed to help move these items from one location to another, a cell needs help moving things as well, or facilitating the diffusion process. This would be the job of a special type of protein.

Diffusion and Facilitated Diffusion

Diffusion

Diffusion is the movement of molecules from an area of high concentration of the molecules to an area with a lower concentration. The difference in the concentrations of the molecules in the two areas is called the **concentration gradient**. Diffusion will continue until this gradient has been eliminated. Since diffusion moves materials from an area of higher concentration to the lower, it is described as moving solutes "down the concentration gradient." The end result of diffusion is an equal concentration, or **equilibrium**, of molecules on both sides of the membrane.

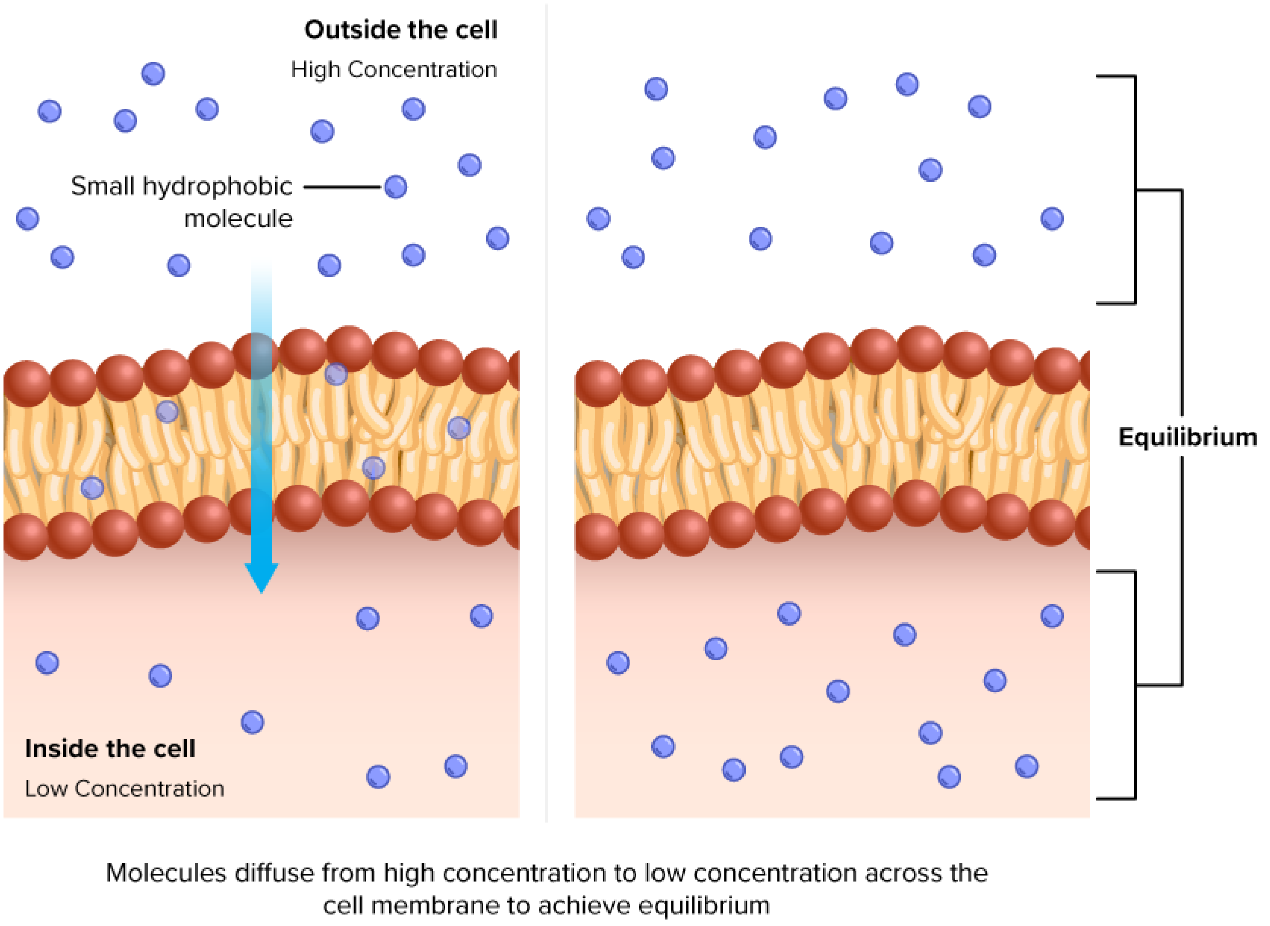
If a molecule can pass freely through a cell membrane, it will cross the membrane by diffusion (see the **Figure** below).



[Figure 2]

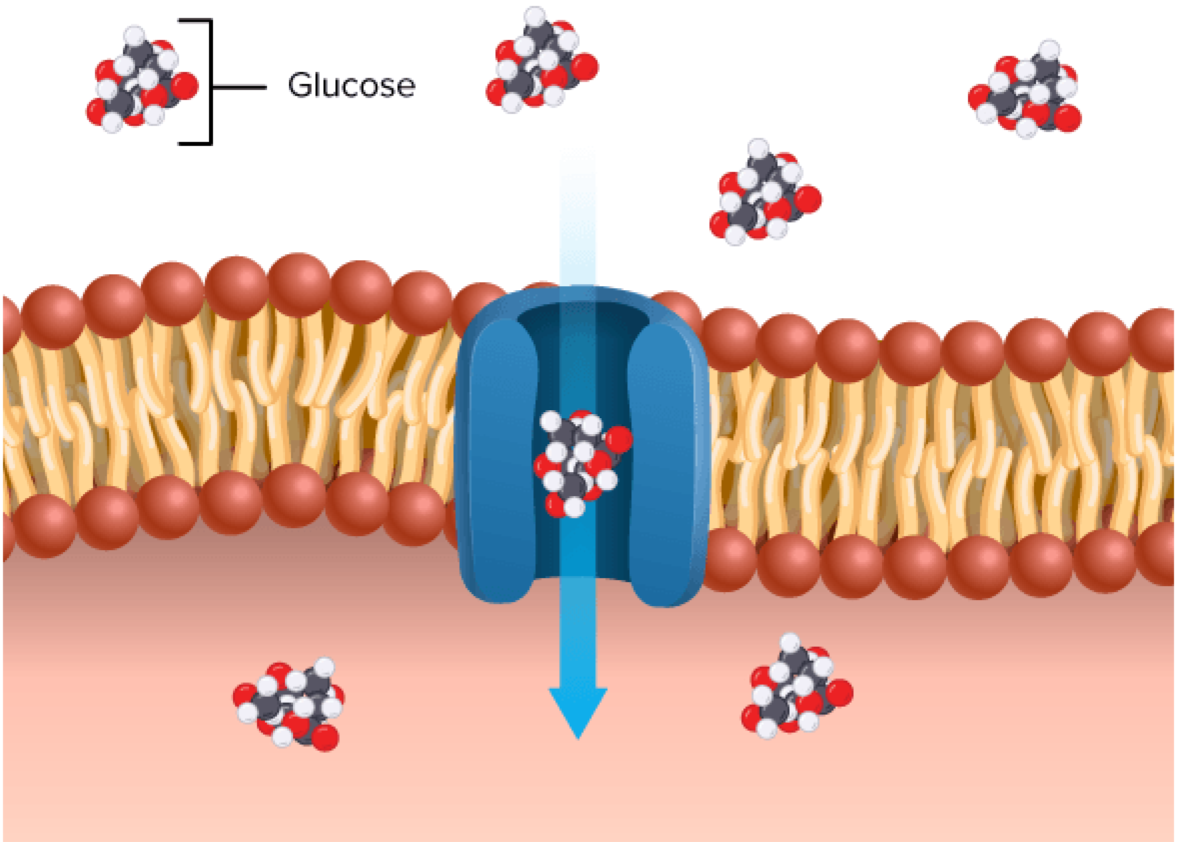
Molecules move from an area of high concentration to an area of lower concentration until an equilibrium is met. The molecules continue to cross the membrane at equilibrium, but at equal rates in both directions.

Change the concentration of the molecules across the cell to visualize equilibrium in the diffusion process.



Facilitated Diffusion

What happens if a substance needs assistance to move across or through the cell membrane? **Facilitated diffusion** is the diffusion of solutes through transport protein in the cell membrane. Facilitated diffusion is a type of **passive transport**. Even though facilitated diffusion involves transport proteins, it is still passive transport because the solute is moving down the concentration gradient (see the **Figure** below).



[Figure 3]

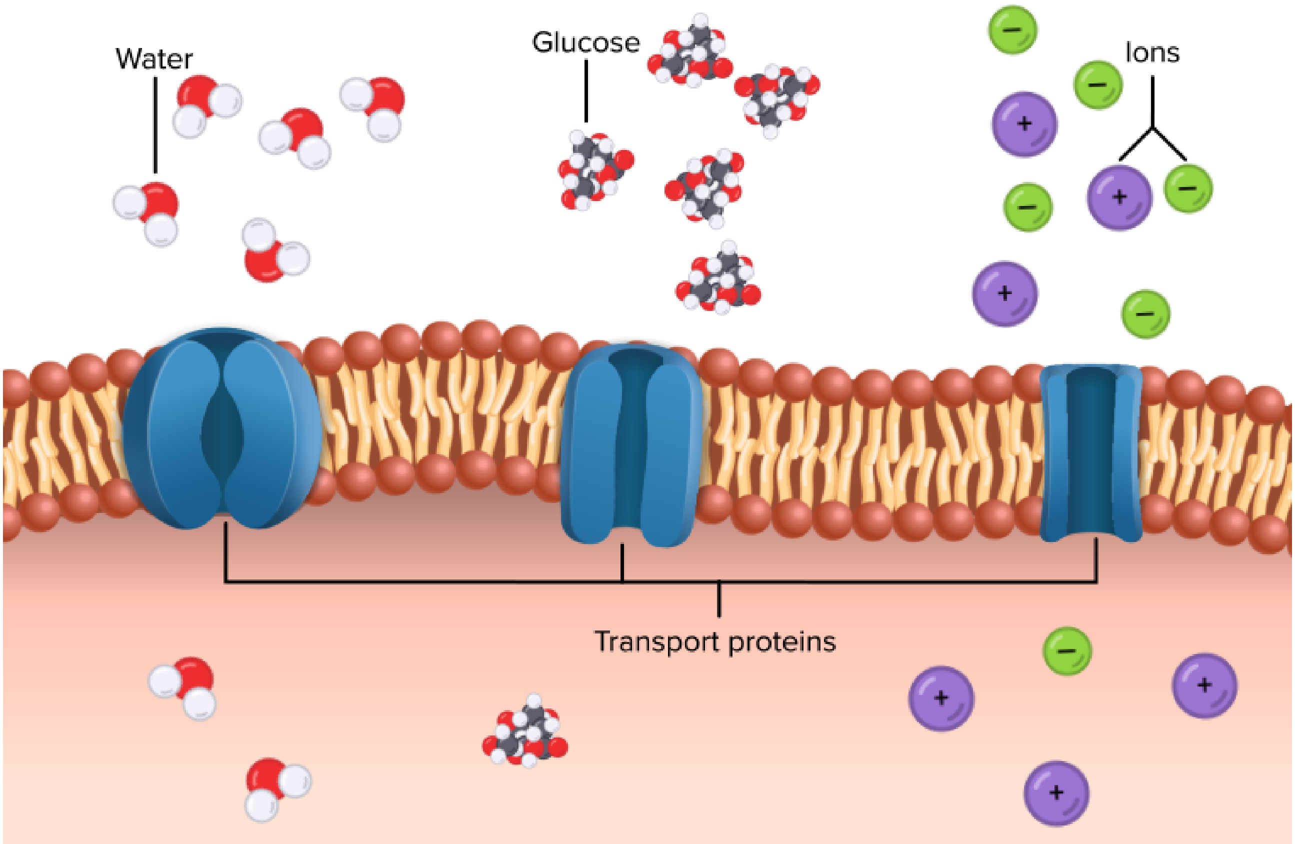
Facilitated Diffusion

Small nonpolar molecules can easily diffuse across the cell membrane. However, due to the hydrophobic nature of the lipid that make up cell membranes, polar molecules (such as water) and ion cannot do so. Instead, they diffuse across the membrane through transport proteins. A **transport protein** completely spans the membrane, and allows certain molecules or ions to diffuse across the membrane. channel protein, gated channel protein, and carrier protein are three types of transport proteins that are involved in facilitated diffusion.

A *channel protein*, a type of transport protein, acts like a pore in the membrane that lets water molecules or small ions through quickly. Water channel proteins (aquaporins) allow water to diffuse across the membrane at a very fast rate. ion channel proteins allow ions to diffuse across the membrane.

A *gated channel protein* is a transport protein that opens a "gate," allowing a molecule to pass through the membrane. Gated channels have a binding site that is specific for a given molecule or ion. A stimulus causes the "gate" to open or shut. The stimulus may be chemical or electrical signals, temperature, or mechanical force, depending on the type of gated channel. For example, the sodium gated channels of a nerve cell are stimulated by a chemical signal which causes them to open and allow sodium ions into the cell.

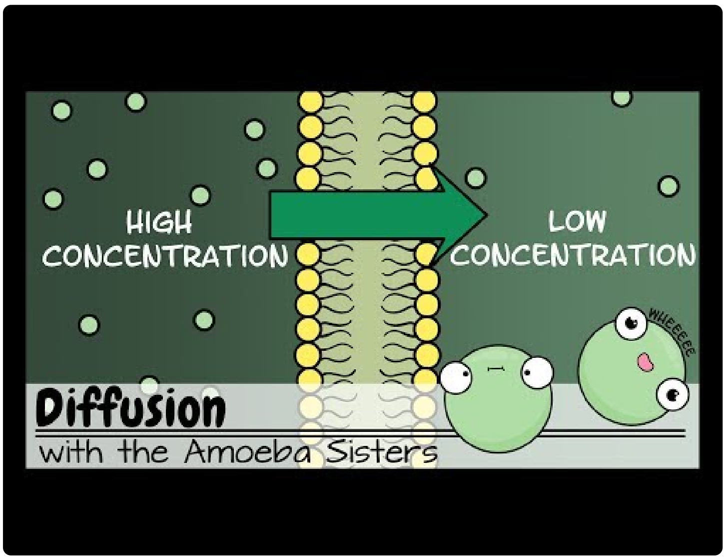
A *carrier protein* is a transport protein that is specific for an ion, molecule, or group of substances. Carrier proteins "carry" the ion or molecule across the membrane by changing shape after the binding of the ion or molecule. Carrier proteins are involved in passive and **active transport**. glucose molecules are too big to diffuse through the cell membrane easily, so they are moved across the membrane through carrier proteins. In this way glucose diffuses very quickly across a cell membrane, which is important because many cells depend on glucose for energy.



Facilitated diffusion through the cell membrane. Channel proteins and carrier proteins are shown. Water molecules and ions move through channel proteins. Glucose molecules are carried across the cell membrane by carrier proteins.

Ion Channels

Ions such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and chloride (Cl^-), are important for many cell functions. Because they are charged (polar), these ions do not diffuse through the membrane. Instead they move through ion channel proteins where they are protected from the hydrophobic interior of the membrane. *Ion channels* allow the formation of a concentration gradient between the extracellular fluid and the cytosol. Ion channels are very specific, as they allow only certain ions through the cell membrane. Some ion channels are always open, others are "gated" and can be opened or closed. Gated ion channels can open or close in response to different types of stimuli, such as electrical or chemical signals.



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DID YOU KNOW?

Voltage-gated ion channels located in neuron are good examples of transport proteins. These ion channels open in response to changes in the cell membrane's electrochemical potential and allow neurons to fire a nerve impulse.

Check your understanding!

PROGRESS 0 / 4

1. Which of the statement(s) is true about passive transport?

SELECT ALL THAT APPLY

a. It involves the movement of molecules along the concentration gradient.

b. This process does not require energy.

c. The molecules move from low concentration to high concentration.

d. Facilitated diffusion is a type of passive transport.

Check It

Hint

https://www.ck12.org/assessment/ui/embed.html?test/view/61289741500672dc326264b2&

Summary

- Diffusion is the movement of molecules from an area of high concentration of the molecules to an area with a lower concentration. The difference in the concentrations of the molecules in the two areas is called the concentration gradient.
- Facilitated diffusion is the diffusion of solutes through transport proteins in the cell membrane. Channel proteins, gated channel proteins, and carrier proteins are three types of transport proteins that are involved in facilitated diffusion.

Review

1. Explain how diffusion and facilitated diffusion differ.
2. What is facilitated diffusion?
3. What is a transport protein? Give three examples.
4. Assume a molecule must cross the cell membrane into a cell. The molecule is very large. How will it be transported into the cell?
5. Explain how carrier proteins function?
6. Explain the role of ion channels. Why are ion channels necessary?

Report Content Errors

2.12 Osmosis

FlexBooks 2.0 > Biology For High School Diploma > Osmosis

Last Modified: Nov 23, 2021

What will you learn

- The process of osmosis
- **osmotic pressure** and its role in water balance in organism
- How organisms control osmosis

[Figure 1]

Saltwater Fish vs. Freshwater Fish?

fish cell, like all cells, have semi-permeable membranes. Eventually, the concentration of "stuff" on either side of them will even out. A fish that lives in salt water will have somewhat salty water inside itself. Put it in the freshwater, and the freshwater will, through osmosis, enter the fish, causing its cells to swell, and the fish will die. What will happen to a freshwater fish in the ocean?

Osmosis

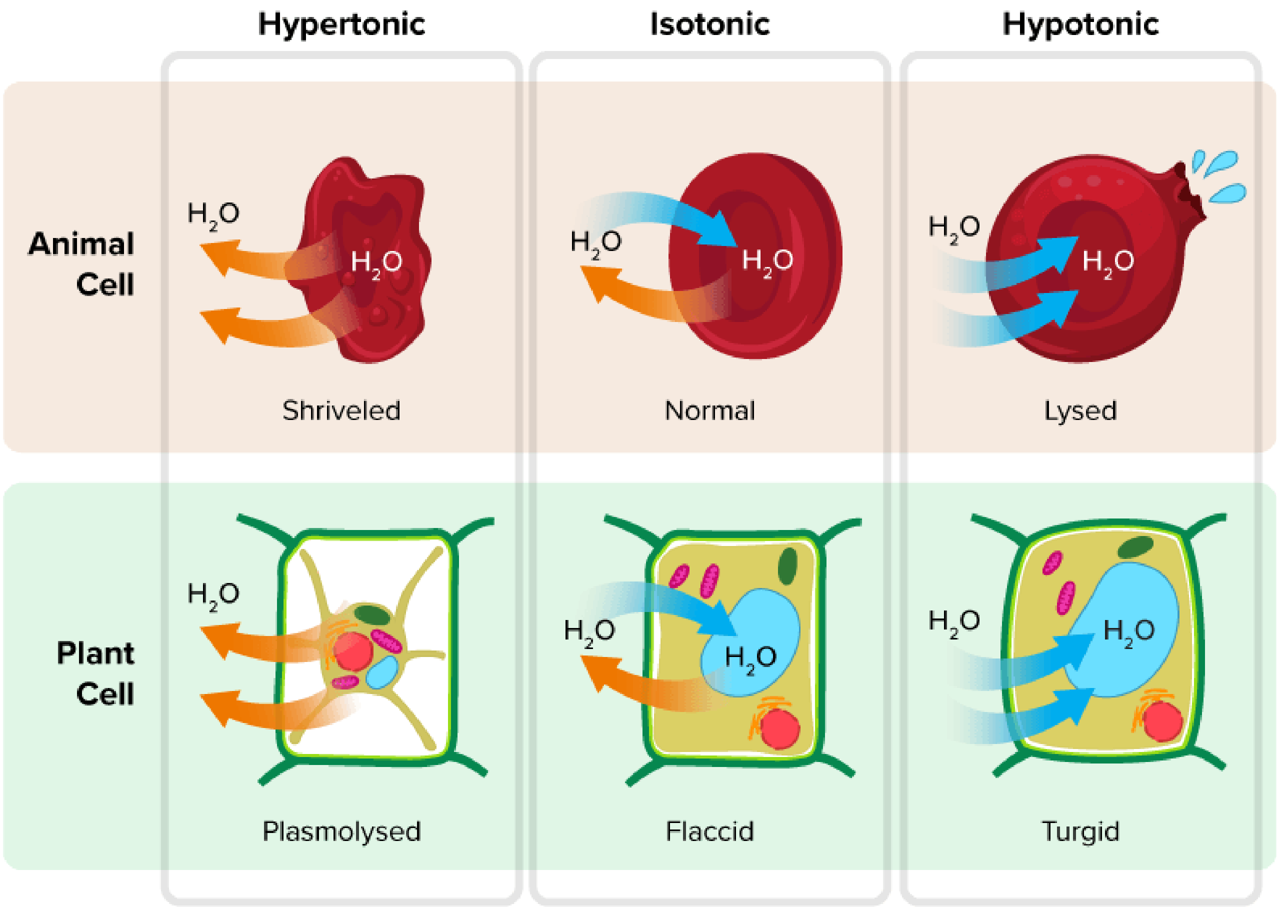
Imagine you have a cup that has 100ml water, and you add 15g of table sugar to the water. The sugar dissolves and the mixture that is now in the cup is made up of a **solute** (the sugar) that is dissolved in the **solvent** (the water). The mixture of a solute in a solvent is called a **solution**.

Imagine now that you have a second cup with 100ml of water, and you add 45 grams of table sugar to the water. Just like the first cup, the sugar is the solute, and the water is the solvent. But now you have two mixtures of different solute concentrations. In comparing two solutions of unequal solute concentration, the solution with the higher solute concentration is **hypertonic**, and the solution with the lower solute concentration is **hypotonic**. Solutions of equal solute concentration are **isotonic**. The first sugar solution is hypotonic to the second solution. The second sugar solution is hypertonic to the first.

You now add the two solutions to a beaker that has been divided by a **selectively permeable** membrane, with pores that are too small for the sugar molecules to pass through, but are big enough for the water molecules to pass through. The hypertonic solution is on one side of the membrane and the hypotonic solution on the other. The hypertonic solution has a lower water concentration than the hypotonic solution, so a concentration gradient of water now exists across the membrane. Water molecules will move from the side of higher water concentration to the side of lower concentration until both solutions are isotonic. At this point, **equilibrium** is reached.

Osmosis is the diffusion of water molecules across a selectively permeable membrane from an area of higher concentration to an area of lower concentration. Water moves into and out of cells by osmosis. If a cell is in a hypertonic solution, the solution has a lower water concentration than the cell cytosol, and water moves out of the cell until both solutions are isotonic. Cells placed in a hypotonic solution will take in water across their membrane until both the external solution and the cytosol are isotonic.

A cell that does not have a rigid cell wall, such as a red blood cell, will swell and lyse (burst) when placed in a hypotonic solution. Cells with a cell wall will swell when placed in a hypotonic solution, but once the cell is turgid (firm), the tough cell wall prevents any more water from entering the cell. When placed in a hypertonic solution, a cell without a cell wall will lose water to the environment, shrivel, and probably die. In a hypertonic solution, a cell with a cell wall will lose water too. The plasma membrane pulls away from the cell wall as it shrivels, a process called **plasmolysis**. animal cells tend to do best in an isotonic environment, plant cells tend to do best in a hypotonic environment, as shown in the **Figure** below.

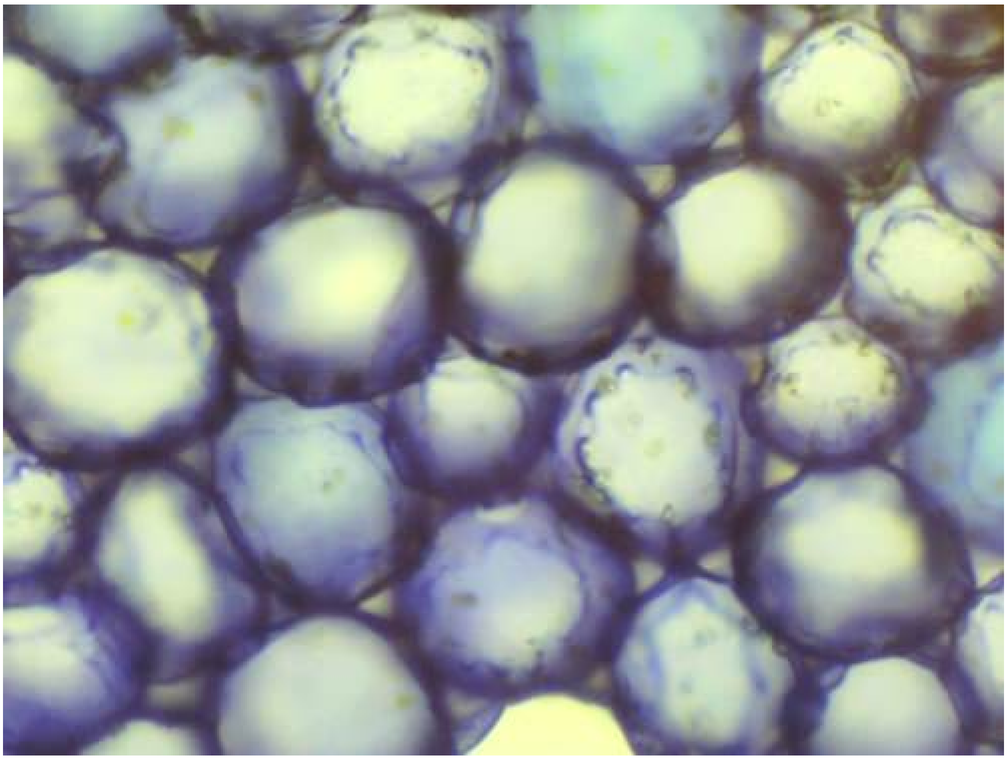


[Figure 2]

Unless an animal cell (such as the red blood cell in the top panel) has an adaptation that allows it to alter the osmotic uptake of water, it will lose too much water and shrivel up in a hypertonic environment. If placed in a hypotonic solution, water molecules will enter the cell, causing it to swell and burst. Plant cells (bottom panel) become plasmolyzed in a hypertonic solution, but tend to do best in a hypotonic environment. Water is stored in the central vacuole of the plant cell.

Osmotic Pressure

When water moves into a cell by osmosis, osmotic pressure may build up inside the cell. If a cell has a cell wall, the wall helps maintain the cell's water balance. **Osmotic pressure** is the main cause of support in many plants. When a plant cell is in a hypotonic environment, the osmotic entry of water raises the turgor pressure exerted against the cell wall until the pressure prevents more water from coming into the cell. At this point the plant cell is turgid (see the **Figure** below).



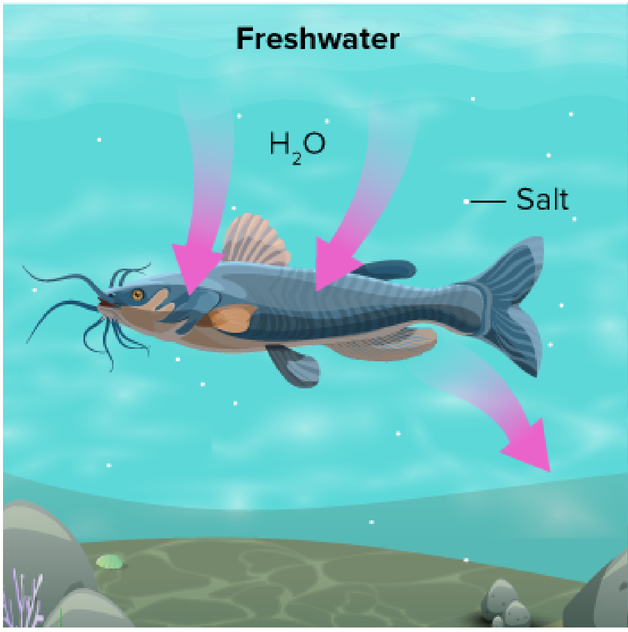
[Figure 3]

The central vacuoles of the plant cells in this image are full of water, so the cells are turgid.

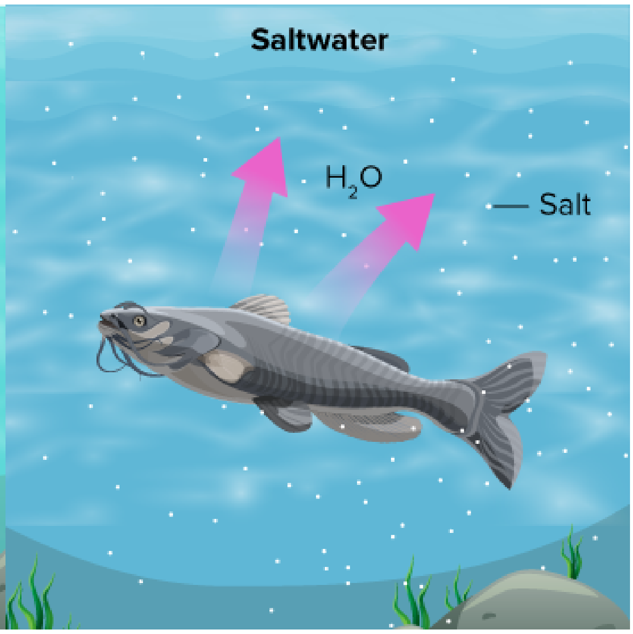
The action of osmosis can be very harmful to organisms, especially ones without cell walls. For example, if a saltwater fish (whose cells are isotonic with seawater), is placed in freshwater, its cells will take on excess water, lyse, and the fish will die. Another example of a harmful osmotic effect is the use of table salt to kill slugs and snails.

Controlling Osmosis

Organisms that live in a hypotonic environment such as freshwater, need a way to prevent their cells from taking in too much water by osmosis. Freshwater and saltwater fish have the ability to adjust to the osmotic pressure in the water around them. The **Figure** below explains what happens to a freshwater fish that is put in saltwater versus freshwater.



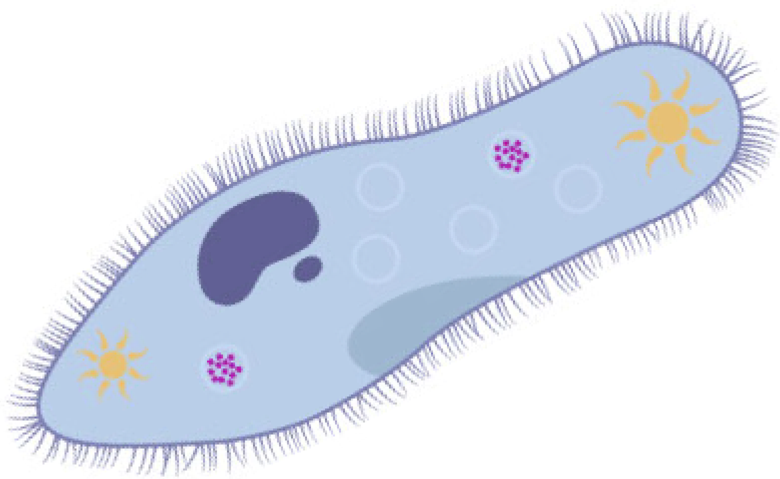
[Figure 4]



[Figure 5]

Freshwater fish regulate the amount of water going in and out of their bodies through several mechanisms like drinking less water and producing dilute urine. If freshwater fish are put in saltwater, they lose water from their bodies due to the hypertonic environment. Their cells shrivel and die.

A **contractile vacuole** is a type of vacuole that removes excess water from a cell. Freshwater protist, such as the paramecium shown in the **Figure** below, have a contractile vacuole. The vacuole is surrounded by several canals, which absorb water by osmosis from the cytoplasm. After the canals fill with water, the water is pumped into the vacuole. When the vacuole is full, it pushes the water out of the cell through a pore.

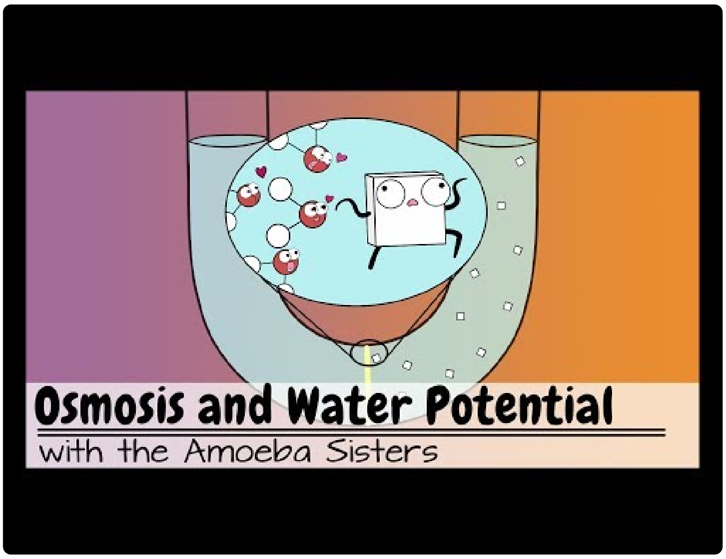


[Figure 6]

The contractile vacuole is the star-like structure within the paramecia.

DID YOU KNOW?

Triathletes and endurance runners never drink plain water when they get thirsty. They drink sports drinks or juices with added salts. This replaces the salts they lose by sweating. Drinking plain water can quickly lead to salt imbalance in their bodies.



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Summary

- Osmosis is the diffusion of water.
- In comparing two solutions of unequal solute concentration, the solution with the higher solute concentration is hypertonic, and the solution with the lower concentration is hypotonic. Solutions of equal solute concentration are isotonic.
- A contractile vacuole is a type of vacuole that removes excess water from a cell.

Review

1. What is osmosis? What type of transport is it?
2. How does osmosis differ from diffusion?
3. What happens to red blood cells when placed in a hypotonic solution?
4. What will happen to a salt water fish if placed in freshwater?

Report Content Errors

2.13 Passive Transport

FlexBooks 2.0 > Biology For High School Diploma > Passive Transport

Last Modified: Jan 18, 2022

What you will learn

- How molecules can pass through a cell membrane in passive transport, active transport, and vesicle transport
- What happens in **diffusion**, osmosis, and **facilitated diffusion**

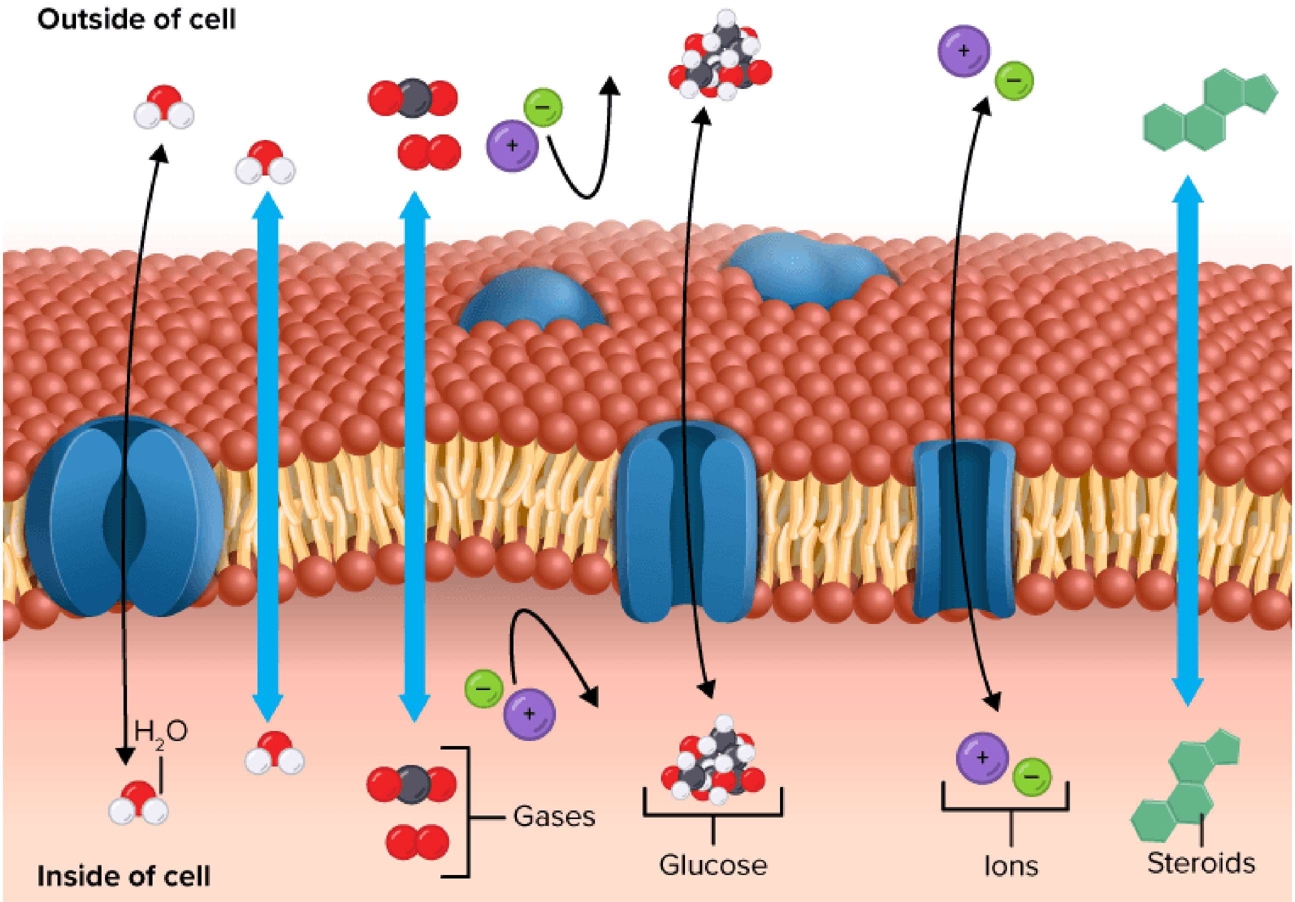
[Figure 1]

What will eventually happen to these dyes?

They will all blend together. The dyes will move through the water until an even distribution is achieved. The process of moving from areas of high amounts to areas of low amounts is called diffusion a type of passive transport.

Passive Transport

Probably the most important feature of a cell's phospholipid membranes is that they are **selectively permeable** or **semipermeable**. A membrane that is selectively permeable has control over what molecules or ion can enter or leave the cell, as shown in the **Figure** below. The permeability of a membrane is dependent on the organization and characteristics of the membrane lipid and protein. In this way, cell membranes help maintain a state of homeostasis within cells (and tissue, organ, and organ systems) so that an organism can stay alive and healthy.



[Figure 2]

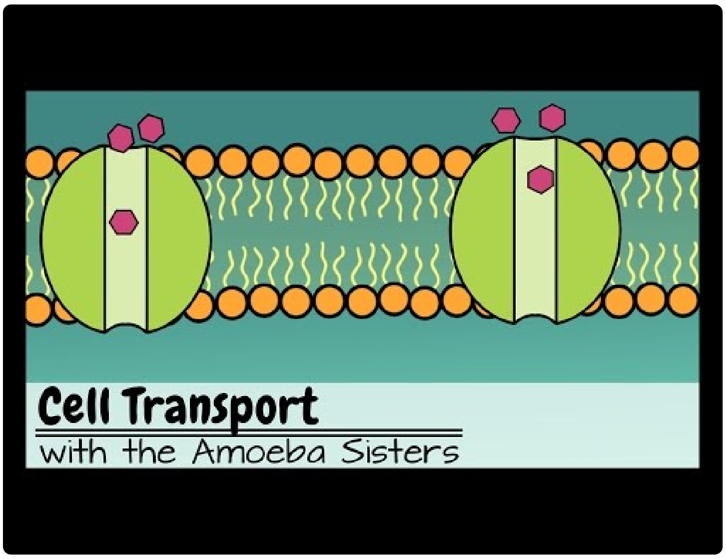
A selectively permeable membrane allows certain molecules through, but not others.

Transport Across Membranes

The molecular make-up of the phospholipid bilayer limits the types of molecules that can pass through it. For example, **hydrophobic** (water-hating) molecules, such as carbon dioxide (CO_2) and oxygen (O_2), can easily pass through the lipid bilayer, but ions such as calcium (Ca^{2+}) and polar molecules cannot. The hydrophobic interior of the phospholipid bilayer does not allow ions or polar molecules through because these molecules are **hydrophilic**, or water loving. In addition, large molecules such as sugars and proteins are too big to pass through the bilayer. **transport protein** within the membrane allow these molecules to pass through the membrane, and into or out of the cell. This way, polar molecules avoid contact with the nonpolar interior of the membrane, and large molecules are moved through large pores.

Every cell is contained within a membrane punctuated with transport proteins that act as channels or pumps to let in or force out certain molecules. The purpose of the transport proteins is to protect the cell's internal environment and to keep its balance of salts, nutrient, and proteins within a range that keeps the cell and the organism alive.

There are three main ways that molecules can pass through a phospholipid membrane. The first way requires no energy input by the cell and is called passive transport. The second way requires that the cell uses energy to pull in or pump out certain molecules and ions and is called **active transport**. The third way is through vesicle transport, in which large molecules are moved across the membrane in bubble-like sacks that are made from pieces of the membrane.



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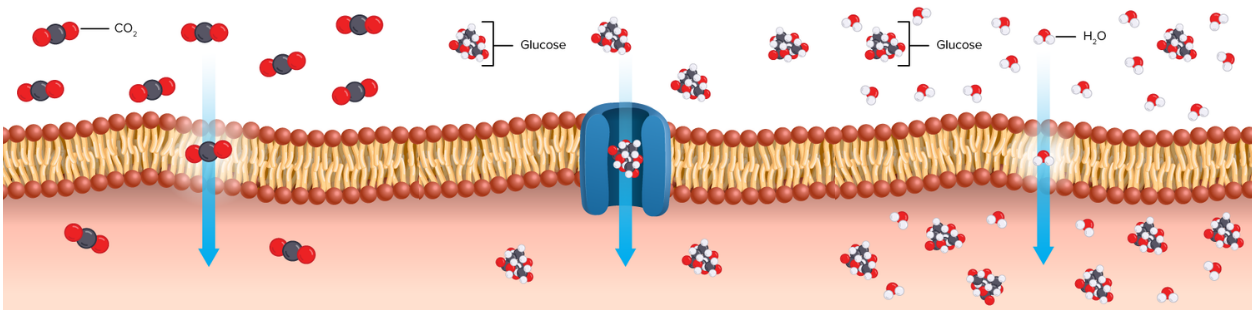


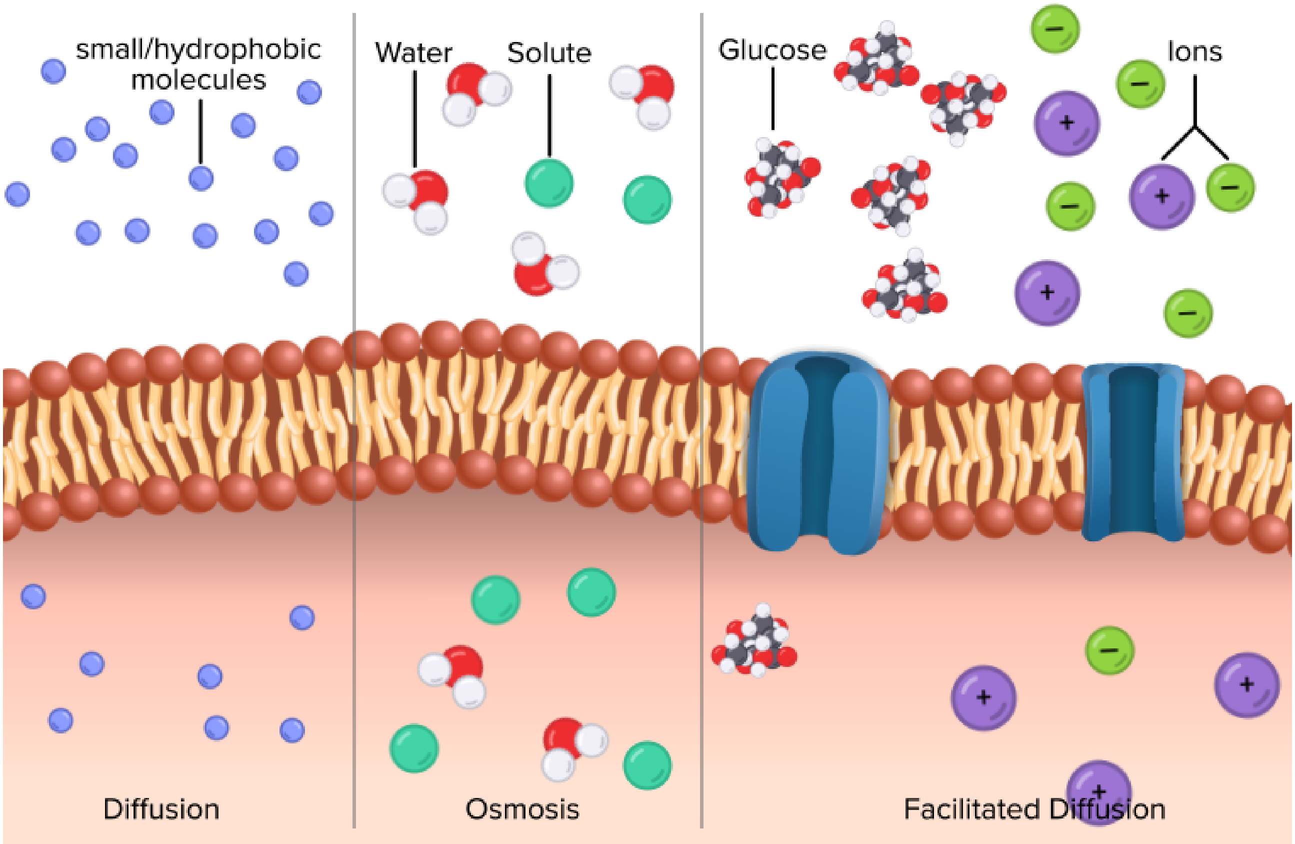
[Figure 3]	[Figure 4]	[Figure 5]
Diffusion	Facilitated diffusion	Osmosis

Passive transport is a way that small molecules or ions move across the cell membrane without input of energy by the cell. The three main kinds of passive transport are diffusion, osmosis, and facilitated diffusion (see the **Figure** above).

- **Diffusion** is the movement of molecules from an area of high concentration of molecules to an area with a lower concentration. The difference in the concentrations of the molecules in the two areas is called the concentration gradient. Since diffusion moves materials from an area of higher concentration to a lower concentration, it is described as moving solutes "down the concentration gradient."
- **Facilitated diffusion** is the diffusion of solutes through transport proteins in the cell membrane. Even though facilitated diffusion involves transport proteins, it is still passive transport because the solute is moving down the concentration gradient.
- **Osmosis** is the diffusion of water molecules across a selectively permeable membrane from an area of higher water concentration to an area of lower concentration.

DID YOU KNOW?

dialysis involves the diffusion of solutes from blood across a semipermeable membrane. Dialysis is a procedure to remove waste products and excess fluid from the blood when the kidney stop working properly. It often involves diverting blood to a machine to be cleaned.



Summary

- The cell membrane is selectively permeable, allowing only certain substances to pass through.
- Passive transport is a way that small molecules or ions move across the cell membrane without input of energy by the cell.
- The three main kinds of passive transport are diffusion, osmosis, and facilitated diffusion.

Review

1. Define semipermeable.
2. What is diffusion?
3. What is a concentration gradient?
4. What is meant by passive transport?

Report Content Errors

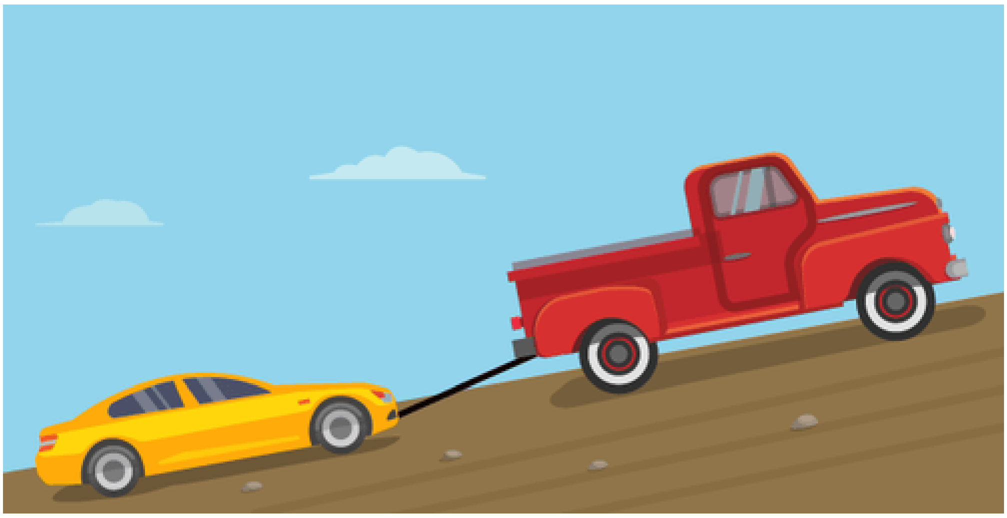
2.14 Active Transport

FlexBooks 2.0 > Biology For High School Diploma > Active Transport

Last Modified: Oct 08, 2021

What you will learn

- Types of active transport
- Role of ATP in active transport
- Difference between active and passive transport



[Figure 1]

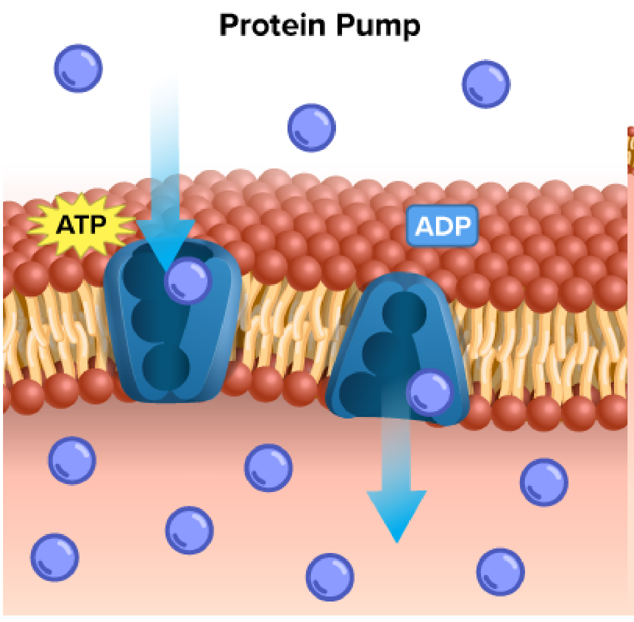
Need to move something really heavy?

If you did, it would take a lot of energy. Sometimes, moving things into or out of the cell also takes energy. How would the cell move something against a concentration gradient? It starts by using energy.

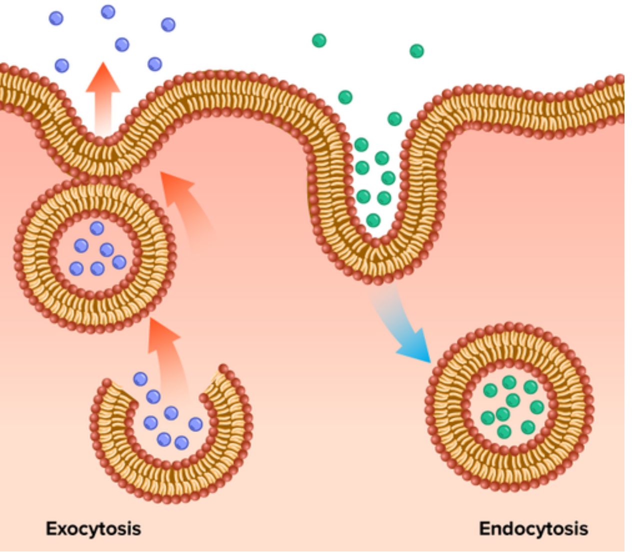
Active Transport

In contrast to passive transport, which does not require energy and carries molecules or ion down a concentration gradient, active transport pumps molecules and ions against a concentration gradient. Sometimes an organism needs to transport something against a concentration gradient. The only way this can be done is through active transport, which uses energy in the form of ATP (adenosine triphosphate) that is produced by cellular respiration. In active transport, the particles move across a cell membrane from a lower concentration to a higher concentration (see the **Figure** below). **Active transport** is the energy-requiring process of pumping molecules and ions across membranes "uphill" - against a concentration gradient.

- The active transport of small molecules or ions across a cell membrane is generally carried out by transport protein that are found in the membrane, also known as a protein pump.
- Larger molecules such as starch can also be actively transported across the cell membrane by vesicle transport processes called endocytosis (substances enter the cell) and exocytosis (substances exit the cell).



[Figure 2]



[Figure 3]

Types of Active Transport: Protein Pump, Exocytosis, Endocytosis

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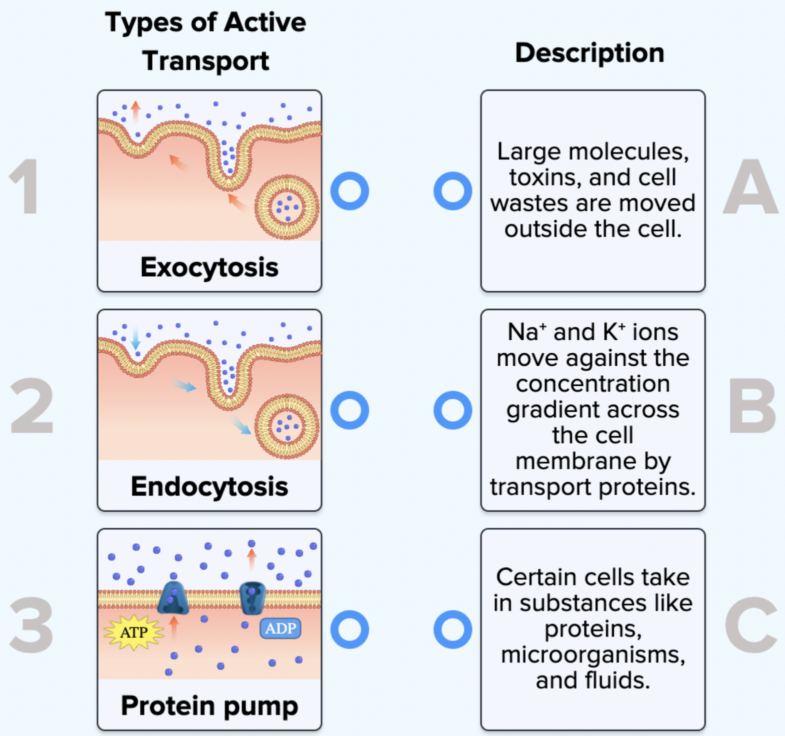
Homeostasis and Cell Function

homeostasis refers to the balance, or equilibrium, within the cell or a body. It is an organism's ability to keep a constant internal environment. Keeping a stable internal environment requires constant adjustments as conditions change inside and outside the cell. The adjusting of systems within a cell is called homeostatic regulation. Because the internal and external environments of a cell are constantly changing, adjustments must be made continuously to stay at or near the set point (the normal level or range). Homeostasis is a dynamic equilibrium rather than an unchanging state.

CAN YOU MATCH?

Try matching the type of active transport with their functions?



Answers: 1-A, 2-C, 3-B

DID YOU KNOW?

Plant cells use active transport to transport materials throughout the plant. Transport of ions and mineral from the soil to roots, transport of sugars from leaves to fruit, transport of nitrate and chloride from the cytosol to vacuole are some examples of active transport in plants.

Summary

- Active transport is the energy-requiring process of pumping molecules and ions across membranes against a concentration gradient.

- Active transport processes help maintain homeostasis.

Review

1. What is active transport?
2. Explain how cell transport helps an organism maintain homeostasis.

Report Content Errors

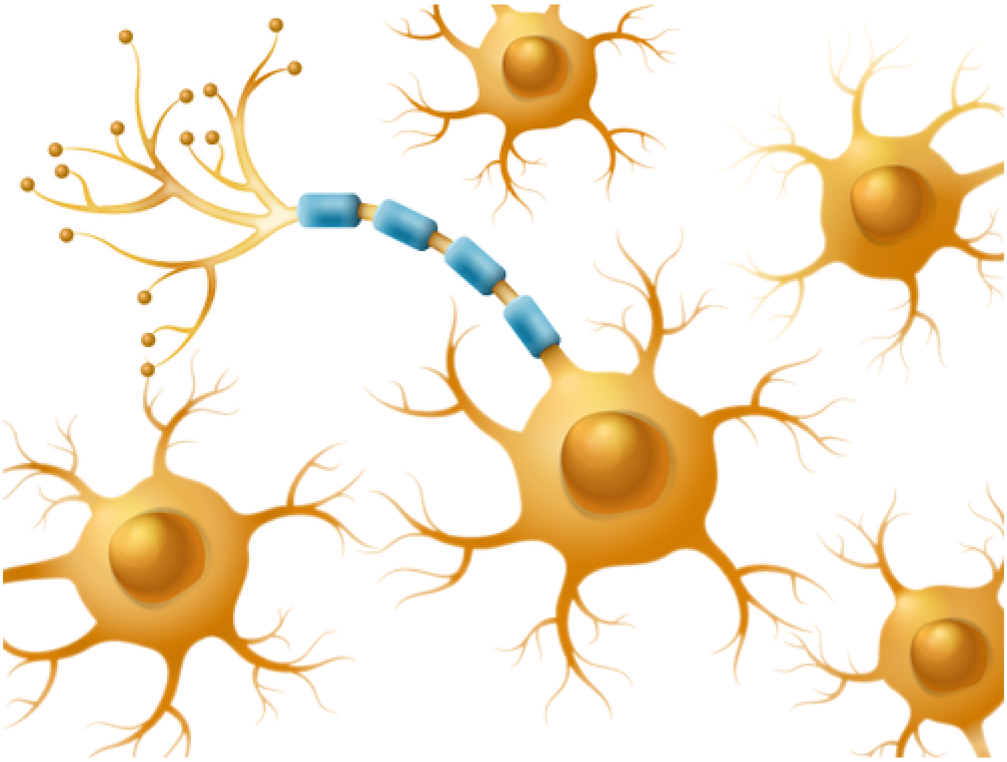
2.15 Sodium-Potassium Pump

FlexBooks 2.0 > Biology For High School Diploma > Sodium-Potassium Pump

Last Modified: Oct 08, 2021

What you will learn

- How the sodium-potassium pump works in **active transport**
- The role of the electrochemical gradient in the movement of ion across the cell membrane



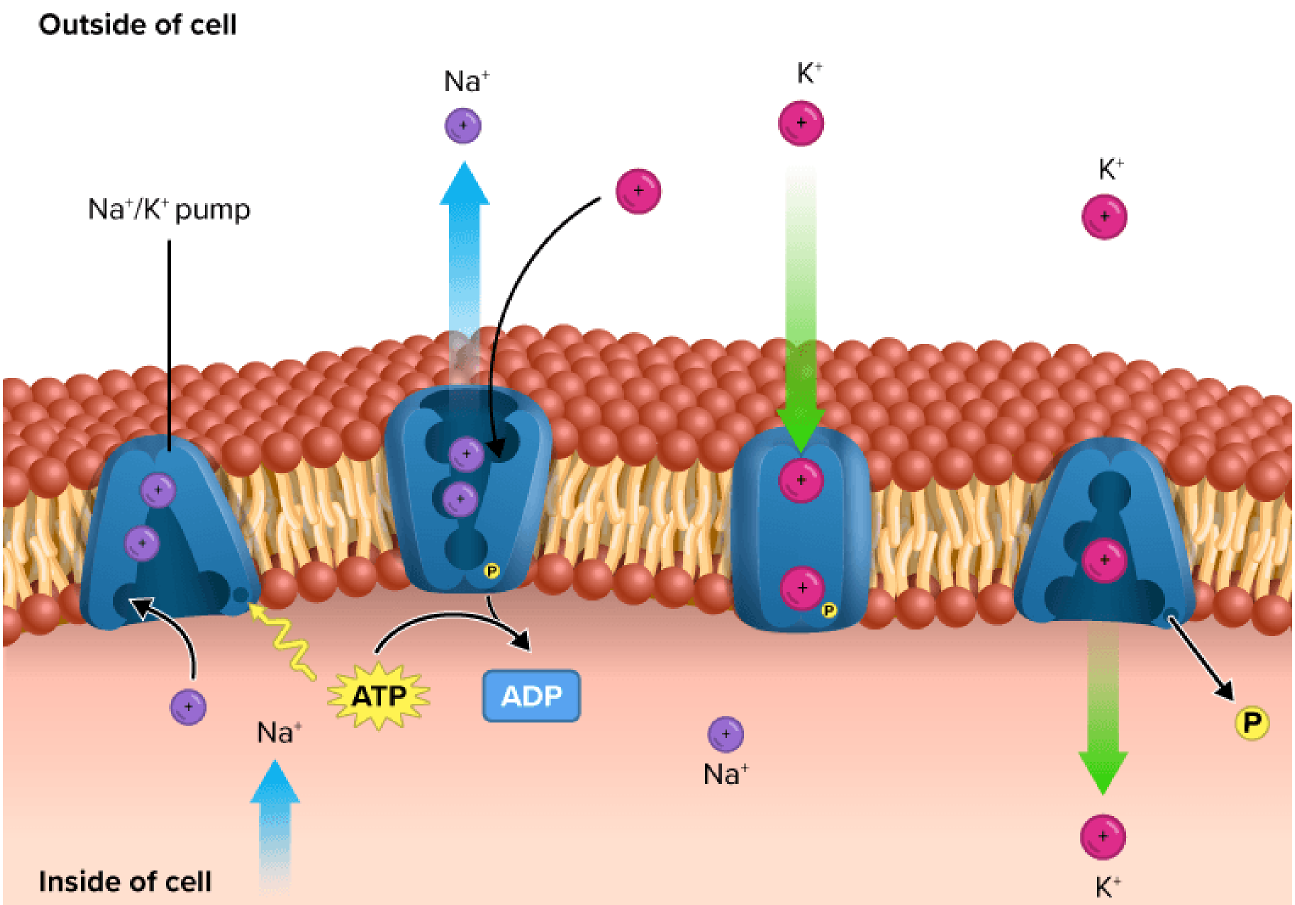
[Figure 1]

What is this incredible object?

Would it surprise you to learn that it is a human cell? The image represents an active human nerve cell. How nerve cells function will be the focus of another concept. However, active transport processes play a significant role in the function of these cells. Specifically, it is the sodium-potassium pump that is active in the axon of these nerve cells.

The Sodium-Potassium Pump

Active transport is the energy-requiring process of pumping molecules and ions across membranes "uphill" - against a concentration gradient. To move these molecules against their concentration gradient, a carrier protein is needed. Carrier proteins can work with a concentration gradient (during passive transport), but some carrier proteins can move solutes against the concentration gradient (from low concentration to high concentration), with an input of energy. In active transport, as carrier proteins are used to move materials against their concentration gradient, these protein are known as pumps. As in other types of cellular activities, ATP supplies the energy for most active transport. One way ATP powers active transport is by transferring a phosphate group directly to a carrier protein. This may cause the carrier protein to change its shape, which moves the molecule or ion to the other side of the membrane. An example of this type of active transport system, as shown in the **Figure** below, is the **sodium-potassium pump,** which exchanges sodium ions for potassium ions across the cell membrane of animal cells.



[Figure 2]

The sodium-potassium pump system moves sodium and potassium ions against large concentration gradients. It moves two potassium ions into the cell where potassium levels are high, and pumps three sodium ions out of the cell and into the extracellular fluid.

As is shown in the **Figure** above, three sodium ions bind with the protein pump inside the cell. The carrier protein then gets energy from ATP and changes shape. In doing so, it pumps the three sodium ions out of the cell. At that point, two potassium ions from outside the cell bind to the protein pump. The potassium ions are then transported into the cell, and the process repeats. The sodium-potassium pump is found in the cell membrane of almost every human cell and is common to all cellular life. It helps maintain cell potential and regulates cellular volume.

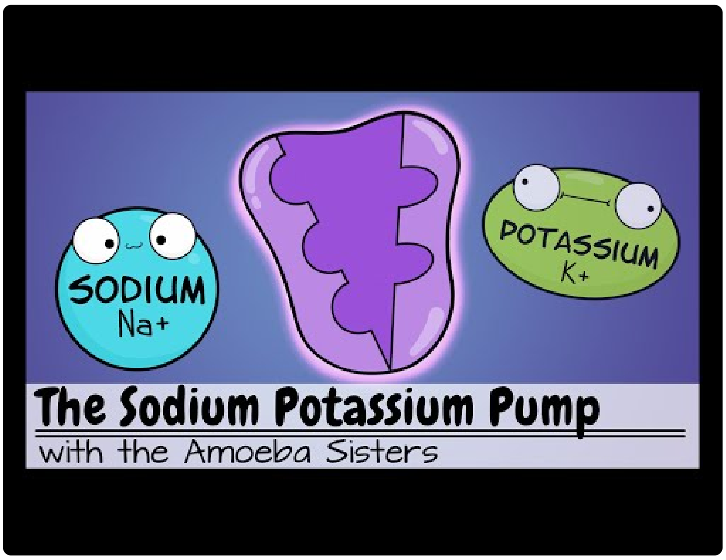
DID YOU KNOW?

The sodium–potassium pump was discovered in 1957 by the Danish scientist Jens Christian Skou, who was awarded a Nobel Prize for his work in 1997. Only after his discovery scientists understood how ions moved in and out of cells.

The Electrochemical Gradient

The active transport of ions across the membrane causes an electrical gradient to build up across the cell membrane. The number of positively charged ions outside the cell is greater than the number of positively charged ions in the cytosol. This results in a relatively negative charge on the inside of the membrane, and a positive charge on the outside. This difference in charges causes a voltage across the membrane. Voltage is electrical potential energy that is caused by a separation of opposite charges, in this case across the membrane. The voltage across a membrane is called **membrane potential**. Membrane potential is very important for the conduction of electrical impulses along nerve cells.

Because the inside of the cell is negative compared to outside the cell, the membrane potential favors the movement of positively charged ions (cations) into the cell, and the movement of negative ions (anions) out of the cell. So, there are two forces that drive the diffusion of ions across the cell membrane—a chemical force (the ions' concentration gradient), and an electrical force (the effect of the membrane potential on the ions' movement). These two forces working together are called an **electrochemical gradient**, and will be discussed in detail in "Nerve Cells" and "Nerve Impulses" concepts.



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Summary

- Active transport is the energy-requiring process of pumping molecules and ions across membranes against a concentration gradient.
- The sodium-potassium pump is an active transport pump that exchanges sodium ions for potassium ions.

Review

1. What is active transport?
2. What type of protein is involved in active transport?
3. Describe how the sodium-potassium pump functions.
4. What is the electrochemical gradient?

Report Content Errors

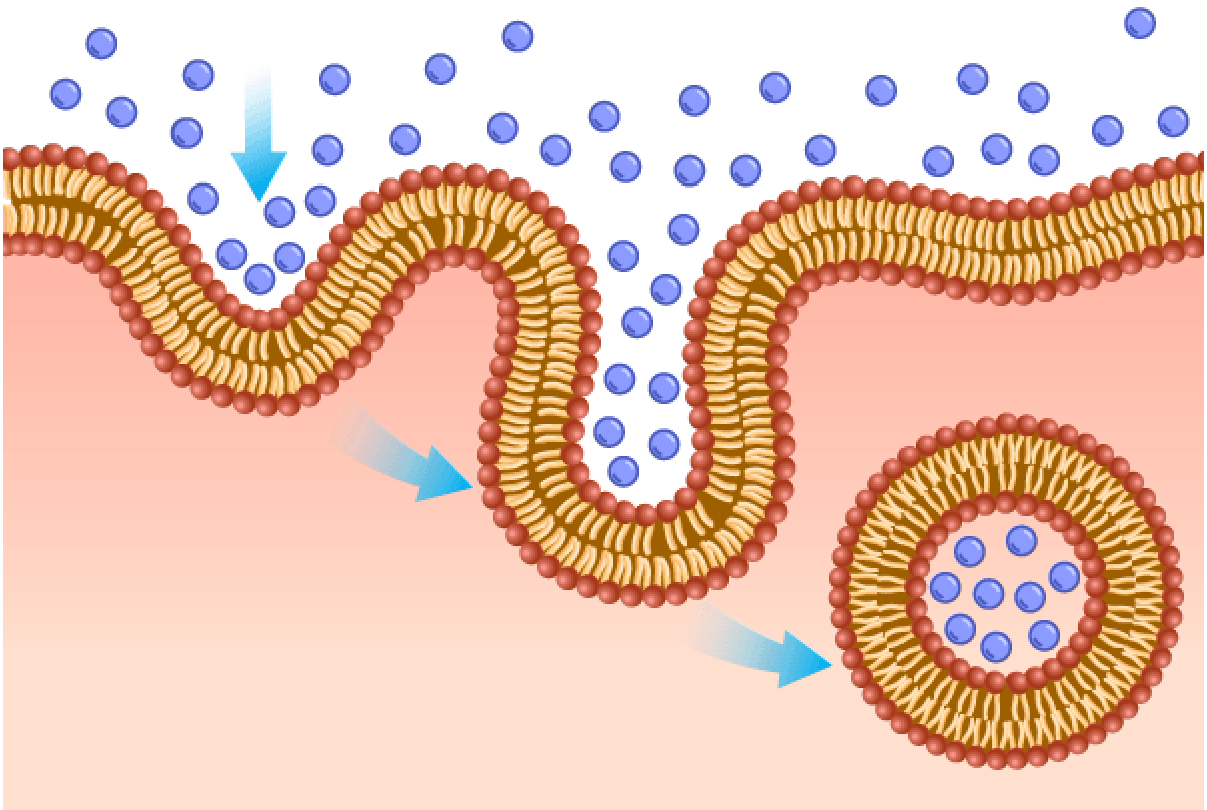
2.16 Exocytosis and Endocytosis

FlexBooks 2.0 > Biology For High School Diploma > Exocytosis and Endocytosis

Last Modified: Jan 18, 2022

What you will learn

- How vesicle in the cytoplasm move large particles across the cell membrane
- What happens in **endocytosis** and exocytosis



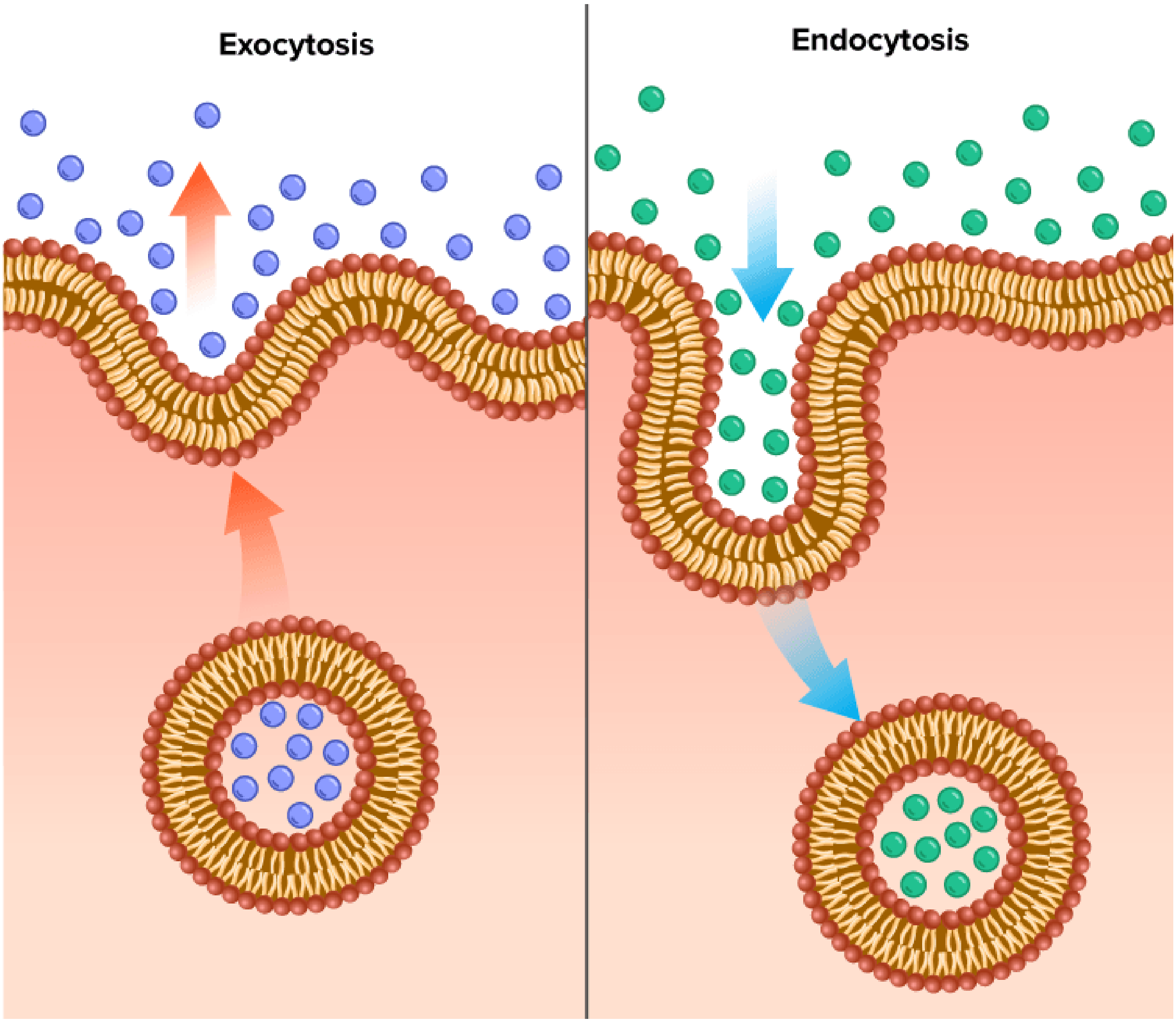
[Figure 1]

What does a cell "eat"?

Is it possible for objects larger than a small molecule to be engulfed by a cell? Of course, it is. For example, cells of the immune system consistently destroy pathogen by essentially "eating" them.

Vesicle Transport

Some molecules or particles are just too large to pass through the plasma membrane or to move through a transport protein. So cells use two other **active transport** processes to move these macromolecules (large molecules) into or out of the cell. Vesicles or other bodies in the cytoplasm move macromolecules or large particles across the plasma membrane. There are two types of vesicle transport, endocytosis and **exocytosis** (illustrated in the **Figure** below). Both processes are **active transport** processes, requiring energy.



[Figure 2]

Illustration of the two types of vesicle transport, exocytosis and endocytosis.

Endocytosis and Exocytosis

Endocytosis is the process of capturing a substance or particle from outside the cell by engulfing it with the cell membrane. The membrane folds over the substance and it becomes completely enclosed by the membrane. At this point a membrane-bound sac, or vesicle, pinches off and moves the substance into the cytosol. There are two main kinds of endocytosis:

- **phagocytosis**, or *cellular eating,* occurs when the dissolved materials enter the cell. The plasma membrane engulfs the solid material, forming a phagocytic vesicle.
- **pinocytosis**, or *cellular drinking,* occurs when the plasma membrane folds inward to form a channel allowing dissolved substances to enter the cell, as shown in the **Figure** below. When the channel is closed, the liquid is encircled within a pinocytic vesicle.

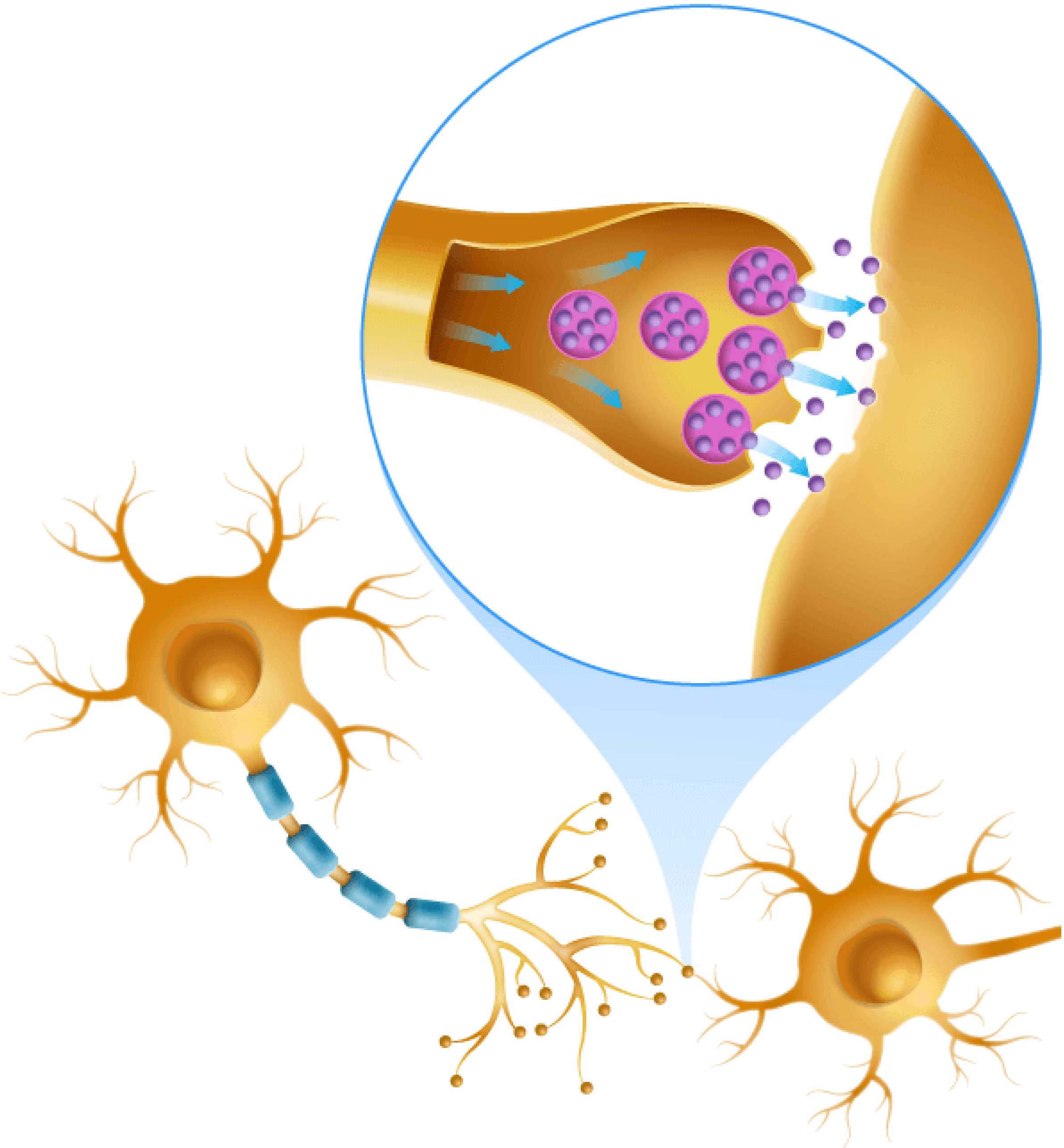
[Figure 3]

Transmission electron microscope image of brain tissue that shows pinocytotic vesicles. Pinocytosis is a type of endocytosis.

DID YOU KNOW?

Vesicles play an important role in capturing pathogens or other unknown substances that may endanger the organism. When pathogens are identified by the immune system, they are engulfed by immune cells to be destroyed.

Exocytosis describes the process of vesicles fusing with the plasma membrane and releasing their contents to the outside of the cell, as shown in the **Figure** below. Exocytosis occurs when a cell produces substances for export, such as a protein, or when the cell is getting rid of a waste product or a toxin. Newly made membrane protein and membrane lipid are moved on top of the plasma membrane by exocytosis.



[Figure 4]

Illustration of an axon releasing a neurotransmitter by exocytosis.

DID YOU KNOW?

Exocytosis is a primary process involved in the cell membrane repair. When transport vesicle fuse with the cell membrane during exocytosis, they replenish the cell membrane's phospholipid bilayer.

Click to view Interactive

Click to view Interactive

Summary

- Active transport is the energy-requiring process of pumping molecules and ions across membranes against a concentration gradient.
- Endocytosis is the process of capturing a substance or particle from outside the cell by engulfing it with the cell membrane and bringing it into the cell.
- Exocytosis describes the process of vesicles fusing with the plasma membrane and releasing their contents to the outside of the cell.
- Both endocytosis and exocytosis are active transport processes.

Review

1. What is the difference between endocytosis and exocytosis?
2. Why is pinocytosis a form of endocytosis?
3. Are vesicles involved in passive transport? Explain.

Report Content Errors

2.17 Autotrophs and Heterotrophs

FlexBooks 2.0 > Biology For High School Diploma > Autotrophs and Heterotrophs

Last Modified: Nov 23, 2021

What you will learn

- Differences between **autotroph** and **heterotroph**
- Comparison of **photosynthesis** and **cellular respiration**

[Figure 1]

Name one major difference between a plant and an animal.

There are many differences, but in terms of energy, it all starts with sunlight. Plants absorb the energy from the sun and turn it into ***food***. You can sit in the sun for hours and hours. You will feel warm, but you're not going to absorb any energy. You have to eat to obtain your energy.

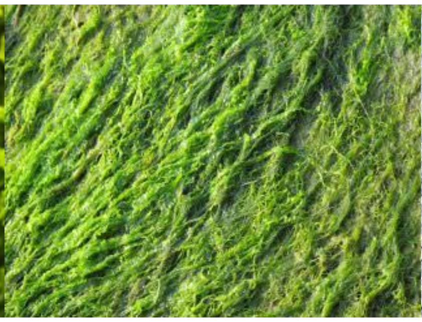
Autotrophs vs. Heterotrophs

Living organism obtain chemical energy in one of two ways.

Autotrophs, shown in the **Figure** below, store chemical energy in carbohydrate food molecules they build themselves. **Food** is chemical energy stored in organic molecule. Food provides both the energy to do work and the carbon to build bodies. Because most autotrophs transform sunlight to make food, we call the process they use **photosynthesis**. Only three groups of organisms - plants, alga, and some bacterium - are capable of this life-giving energy transformation. Autotrophs make food for their own use, but they make enough to support other life as well. Almost all other organisms depend absolutely on these three groups for the food they produce. The **producer**, as autotrophs are also known, begin **food chain** which feed all life.

Heterotrophs cannot make their own food, so they must eat or absorb it. For this reason, heterotrophs are also known as **consumers**. Consumers include all animal and fungus and many protist and bacteria. They may consume autotrophs or other heterotrophs or organic molecules from other organisms. Heterotrophs show great diversity and may appear far more fascinating than producers. But heterotrophs are limited by our utter dependence on those autotrophs that originally made our food. If plants, algae, and autotrophic bacteria vanished from earth, animals, fungi, and other heterotrophs would soon disappear as well. All life requires a constant input of energy. Only autotrophs can transform that ultimate, solar source into the chemical energy in food that powers life, as shown in the **Figure** below. A food chain shows how energy and matter flow from producers to consumers. Matter is recycled, but energy must keep flowing into the system. Where does this energy come from? Though the food chains "ends" with decomposer, do decomposers, in fact, digest matter from each level of the food chain?

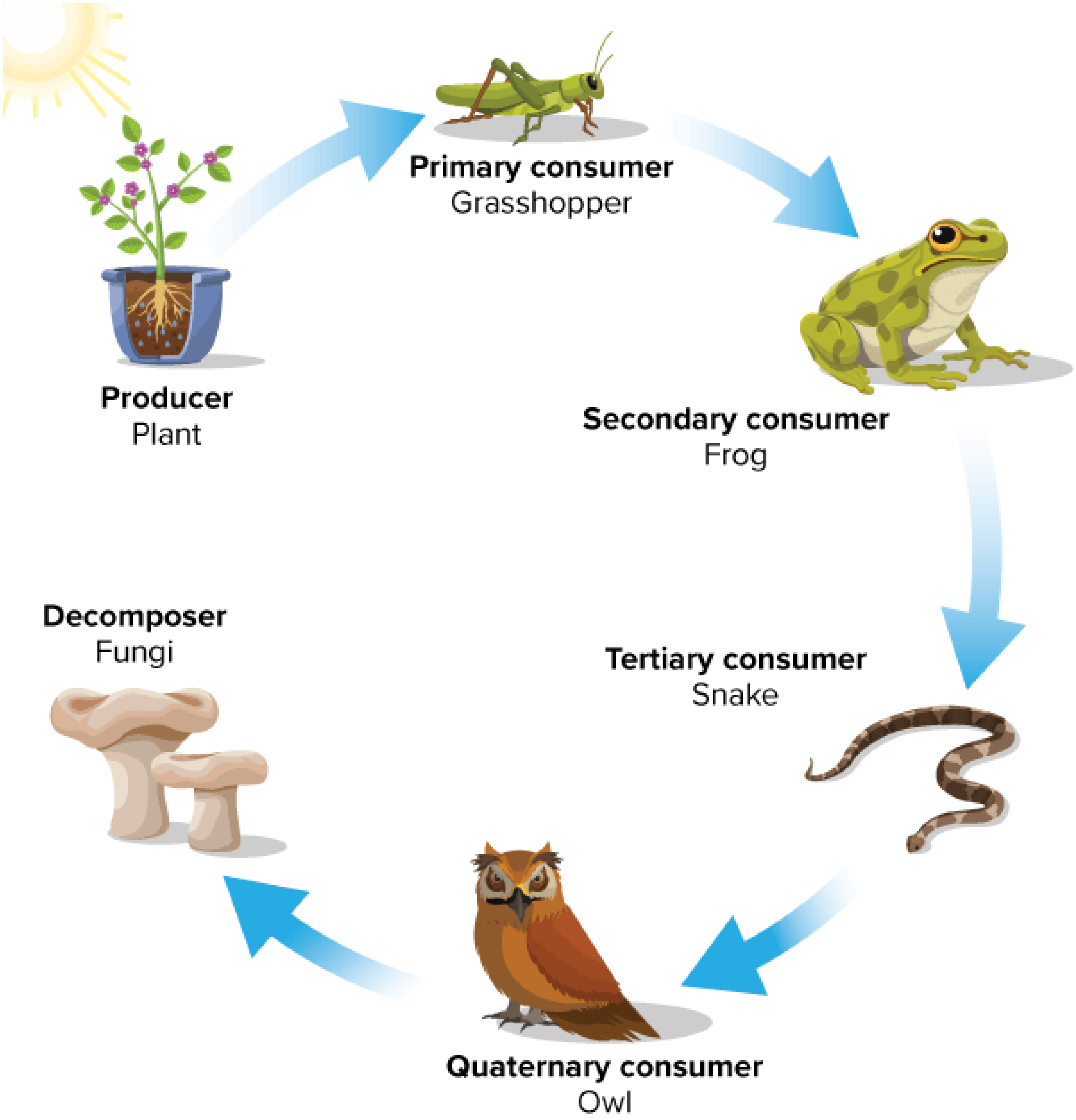
[Figure 2]



[Figure 3]

[Figure 4]

Photosynthetic autotrophs, which make food using the energy in sunlight, include *(first)* plants, *(second)* algae, and *(third)* certain bacteria.



[Figure 5]

Food chain

Photosynthesis provides over 99 percent of the energy for life on earth. A much smaller group of autotrophs - mostly bacteria in dark or low-oxygen environments - produce food using the chemical energy stored in inorganic molecules such as hydrogen sulfide, ammonia, or methane. While photosynthesis transforms light energy to chemical energy, this alternate method of making food transfers chemical energy from inorganic to organic molecules. It is therefore called **chemosynthesis**, and is characteristic of the tubeworms shown in the **Figure** below. Some of the most recently discovered chemosynthetic bacteria inhabit deep ocean hot water vents or "black smokers." There, they use the energy in gases from the Earth's interior to produce food for a variety of unique heterotrophs: giant tube worms, blind shrimp, giant white crabs, and armored snails. Some scientists think that chemosynthesis may support life below the surface of Mars, Jupiter's moon, Europa, and other planets as well. ecosystem based on chemosynthesis may seem rare and exotic, but they too illustrate the absolute dependence of heterotrophs on autotrophs for food.

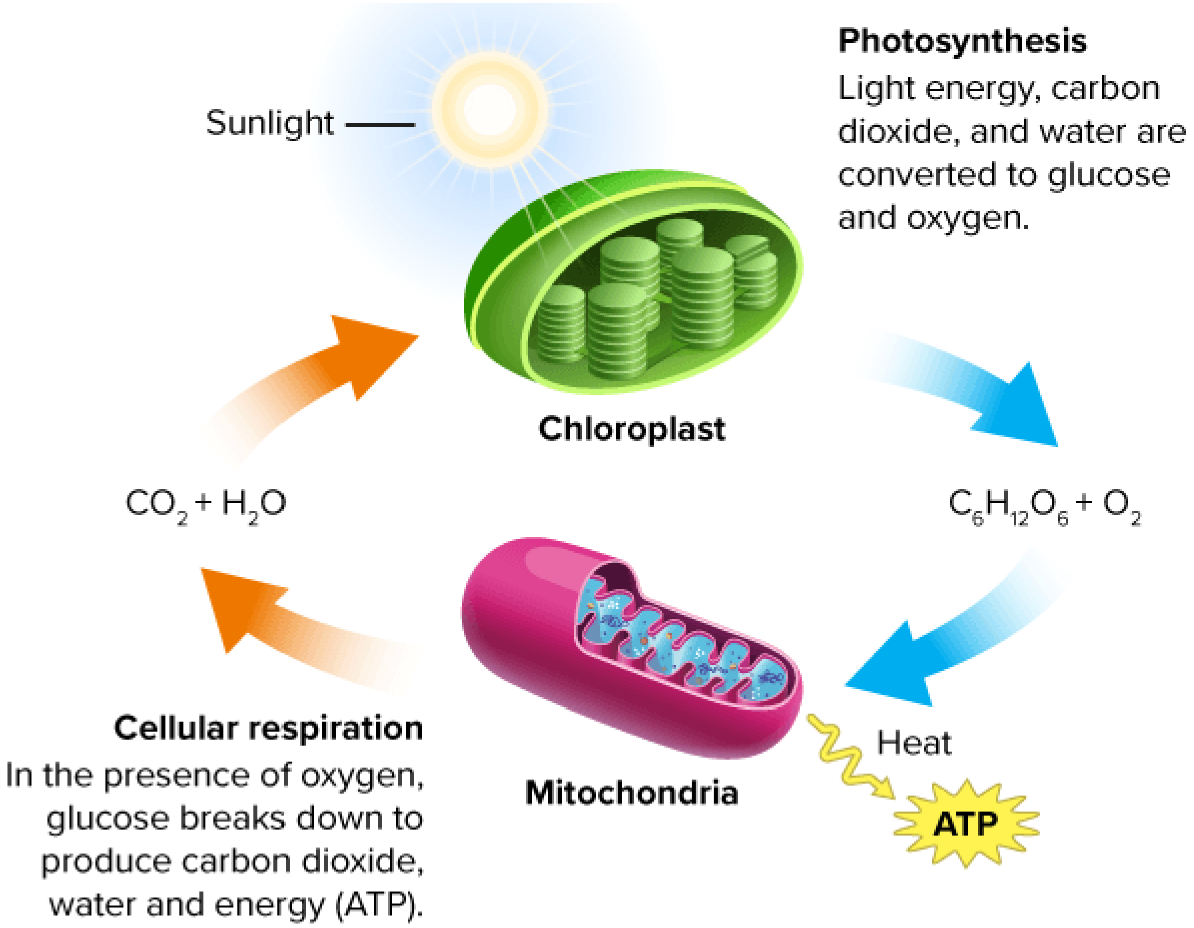
[Figure 6]

Tubeworms get their energy from chemosynthetic bacteria living within their tissues. No digestive systems needed!

Making and Using Food

The flow of energy through living organisms begins with photosynthesis. This process stores energy from sunlight in the chemical bond of glucose. By breaking the chemical bonds in glucose, cell release the stored energy and make the **ATP** (also known as adenosine triphosphate, an energy-carrying molecule) they need. The process in which glucose is broken down and ATP is made is called **cellular respiration**.

Photosynthesis and cellular respiration are like two sides of the same coin. This is apparent from the **Figure** below. The products of one process are the reactant of the other. Together, the two processes store and release energy in living organisms. The two processes also work together to recycle oxygen in Earth's atmosphere.



[Figure 7]

This diagram compares and contrasts photosynthesis and cellular respiration. It also shows how the two processes are related.

Photosynthesis

Photosynthesis is often considered to be the single most important life process on Earth. It changes light energy into chemical energy and also releases oxygen. Without photosynthesis, there would be no oxygen in the atmosphere. Photosynthesis involves many chemical reaction, but they can be summed up in a single chemical equation:

$$6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

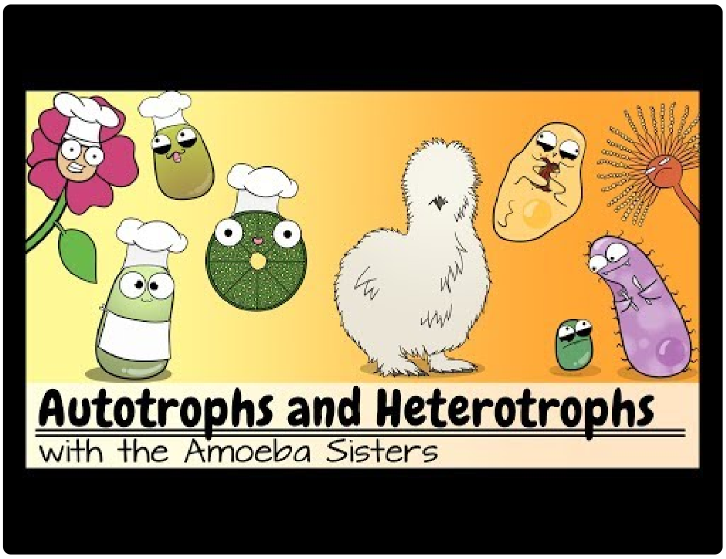
Photosynthetic autotrophs capture light energy from the sun and absorb carbon dioxide and water from their environment. Using the light energy, they combine the reactants to produce glucose and oxygen, which is a waste product. They store the glucose, usually as starch, and they release the oxygen into the atmosphere.

Cellular Respiration

Cellular respiration actually “burns” glucose for energy. However, it doesn’t produce light or intense heat as some other types of burning do. This is because it releases the energy in glucose slowly, in many small steps. It uses the energy that is released to form molecules of ATP. Cellular respiration involves many chemical reactions, which can be summed up with this chemical equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Chemical Energy (in ATP)}$$

Cellular respiration occurs in the cells of all living things. It takes place in the cells of both autotrophs and heterotrophs. All of them burn glucose to form ATP.



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DID YOU KNOW?

Plants carry out respiration during the day and night. During the day, both cellular respiration and light-dependent reactions of photosynthesis take place. During the night, only cellular respiration and light-independent reactions of photosynthesis occur.

Check your understanding!

PROGRESS 0 / 4

1. Which of the following are examples of autotrophs?

SELECT ALL THAT APPLY

a Plants

b Algae

c Cyanobacteria

d Tubeworms

Check It

Hint

https://www.ck12.org/assessment/ui/embed.html?test/view/614c36b32ce1b6f233840b67&

Summary

- Autotrophs store chemical energy in carbohydrate food molecules they build themselves. Most autotrophs make their "food" through photosynthesis using the energy of the sun.
- Heterotrophs cannot make their own food, so they must eat or absorb it.
- Chemosynthesis is used to produce food using the chemical energy stored in inorganic molecules.

Review

1. Compare autotrophs to heterotrophs, and describe the relationship between these two groups of organisms.
2. Name and describe the two types of food making processes found among autotrophs. Which is quantitatively more important to life on earth?
3. Describe the flow of energy through a typical food chain (describing "what eats what"), including the original source of that energy and its ultimate form after use.

Report Content Errors

2.18 Glucose and ATP

FlexBooks 2.0 > Biology For High School Diploma > Glucose and ATP

Last Modified: Nov 23, 2021

What you will learn

- The role of **glucose** and **ATP** as energy-carrying molecules
- How cell use glucose and ATP

[Figure 1]

Need lots of energy?

To run a marathon, probably. Where does this extra energy come from? carbohydrate loading is a strategy used by endurance athletes to maximize the storage of energy, in the form of glycogen, in the muscles. Glycogen forms an energy reserve that can be quickly mobilized to meet a sudden need for glucose, which is then turned into ATP through the process of cellular respiration.

Glucose and ATP

Energy-Carrying Molecules

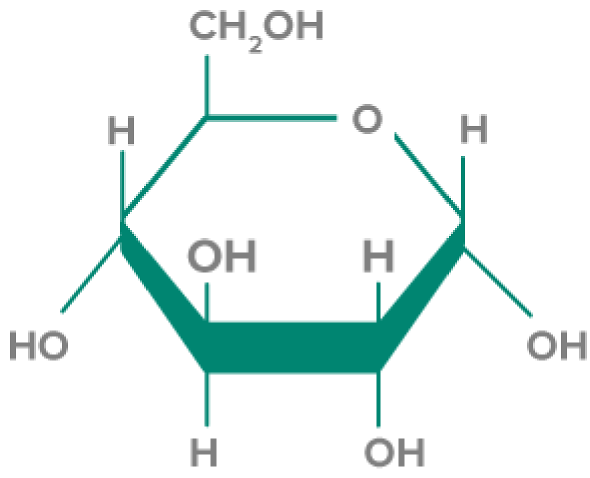
You know that the fish you had for lunch contained protein molecules. But do you know that the atoms in that protein could easily have formed the color in a dragonfly's eye, the heart of a water flea, and the whip-like tail of a *Euglena* before they hit your plate as sleek fish muscle? food consists of organic (carbon-containing) molecules that store energy in the chemical bond between their atoms. organism use the atoms of food molecules to build larger organic molecule including proteins, DNA, and fats (lipids), and use the energy in food to power life processes. By breaking the bonds in food molecules, cells release energy to build new compounds. Although some energy dissipates as heat at each energy transfer, much of it is stored in the newly made molecules. Chemical bonds in organic molecules are a reservoir of the energy used to make them. Fueled by the energy from food molecules, cells can combine and recombine the element of life to form thousands of different molecules. Both the energy (despite some loss) and the materials (despite being reorganized) pass from producer to consumer – perhaps from algal tails to water flea hearts, to dragonfly eye colors, to fish muscle, to you!

The process of photosynthesis, which usually begins the flow of energy through life, uses many different kinds of energy-carrying molecules to transform sunlight energy into chemical energy and build food. Some carrier molecules hold energy briefly, quickly shifting it like a hot potato to other molecules. This strategy allows energy to be released in small, controlled amounts. An example starts in **chlorophyll,** the green pigment present in most plants, which helps convert solar energy to chemical energy. When a chlorophyll molecule absorbs light energy, electrons are excited and "jump" to a higher energy level. The excited electrons then bounce to a series of carrier molecules, losing a little energy at each step. Most of the "lost" energy powers some small cellular task, such as moving ion across a membrane or building up another molecule. Another short-term energy carrier important to photosynthesis, **NADPH**, holds chemical energy a bit longer but soon "spends" it to help to build sugar.

Two of the most important energy-carrying molecules are **glucose** and adenosine triphosphate commonly referred to as **ATP**. These are nearly universal fuels throughout the living world and are both key players in photosynthesis, as shown below.

Glucose

A molecule of glucose, which has the chemical formula $C_6H_{12}O_6$, carries a packet of chemical energy just the right size for transport and uptake by cells. In your body, glucose is the "deliverable" form of energy, carried in your blood through capillaries to each of your 100 trillion cells. Glucose is also the carbohydrate produced by photosynthesis, and as such is the near-universal food for life.



[Figure 2]

Glucose is the energy-rich product of photosynthesis, a universal food for life. It is also the primary form in which your bloodstream delivers energy to every cell in your body.

DID YOU KNOW?

A hummingbird consumes half its body weight in food every day mostly in the form of sugary flower-nectar. It needs a high amount of energy for flapping its wing about 50 times per second!

ATP

ATP molecules store smaller quantities of energy, but each release just the right amount to actually do work within a cell. Muscle cell proteins, for example, pull each other with the energy released when bonds in ATP break open (discussed below). The process of photosynthesis also makes and uses ATP - for energy to build glucose! ATP, then, is the usable form of energy for your cells. ATP is commonly referred to as the "energy currency" of the cell.

Why do we need both glucose and ATP?

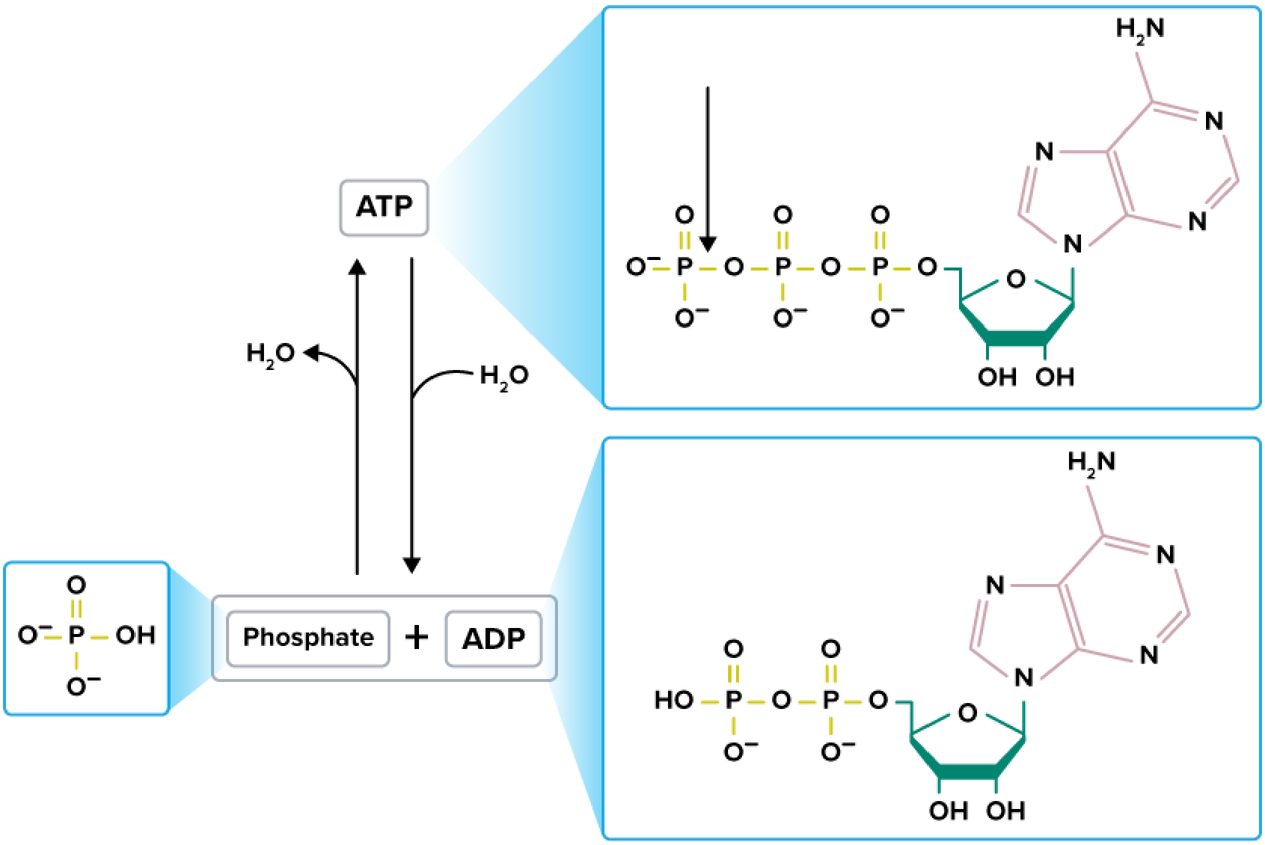
Why don't plants just make ATP and be done with it? If energy were money, ATP would be a quarter. Enough money to operate a parking meter or washing machine. Glucose would be a ten-dollar bill – much easier to carry around in your wallet, but too large to do the actual work of paying for parking or washing. Just as we find several denominations of money useful, organisms need several "denominations" of energy – a smaller quantity for work within cells, and a larger quantity for stable storage, transport, and delivery to cells.

(Actually, a glucose molecule would be about $9.50, as, under the proper conditions, up to 38 ATP are produced for each glucose molecule.)

Let's take a closer look at a molecule of ATP. Although it carries less energy than glucose, its structure is more complex. The "A" in ATP refers to the majority of the molecule, adenosine, a combination of a nitrogenous base and a five-carbon sugar. The "TP" indicates the three phosphates, linked by bonds that hold the energy actually used by cells. Usually, only the outermost bond breaks to release or spend energy for cellular work.

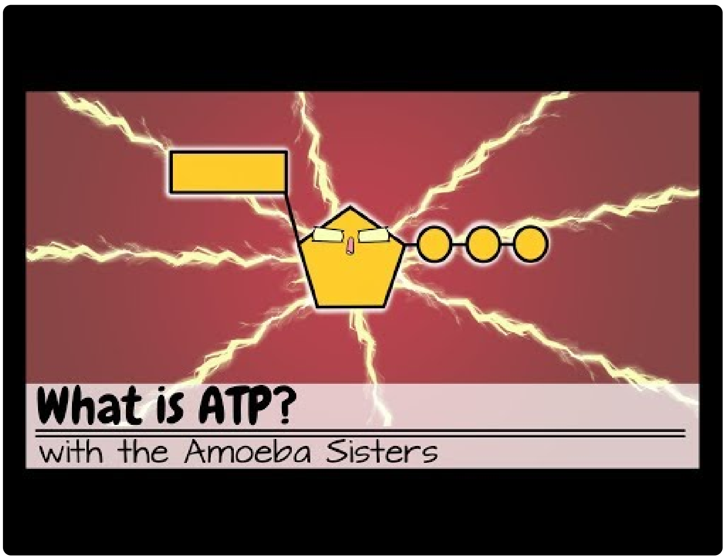
An ATP molecule, shown in the **Figure** below, is like a rechargeable battery: its energy can be used by the cell when it breaks apart into ADP (adenosine diphosphate) and phosphate, and then the "worn-out battery" ADP can be recharged using new energy to attach a new phosphate and rebuild ATP. The materials are recyclable, but recall that energy is not!

How much energy does it cost to do your body's work? A single cell uses about 10 million ATP molecules per second and recycles all of its ATP molecules about every 20-30 seconds.



[Figure 3]

An arrow shows the bond between two phosphate groups in an ATP molecule. When this bond breaks, its chemical energy can do cellular work. The resulting ADP molecule is recycled when new energy attaches another phosphate, rebuilding ATP.



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PROGRESS 0 / 4

1. What do your cells use carbohydrates for?

SELECT ALL THAT APPLY

a as a form of stored food in muscles

b as a source of glucose

c as a source of ATP

d as a source of amino acids

Check It

Hint

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Summary

- Glucose is the carbohydrate produced by photosynthesis. Energy-rich glucose is delivered through your blood to each of your cells.
- ATP is the usable form of energy for your cells.

Review

1. The fact that all organisms use similar energy-carrying molecules shows one aspect of the grand "Unity of Life." Name two universal energy-carrying molecules, and explain why most organisms need both carriers rather than just one.
2. A single cell uses about 10 million ATP molecules per second. Explain how cells use the energy and recycle the materials in ATP.
3. ATP and glucose are both molecules that organisms use for energy. They are like the tank of a tanker truck that delivers gas to a gas station and the gas tank that holds the fuel for a car. Which molecule is like the tank of the delivery truck, and which is like the gas tank of the car? Explain your answer.

2.19 Chloroplast

FlexBooks 2.0 > Biology For High School Diploma > Chloroplast

Last Modified: Nov 23, 2021

What you will learn

- Structure and function of chloroplast
- Parts of the chloroplast used in **photosynthesis**

[Figure 1]

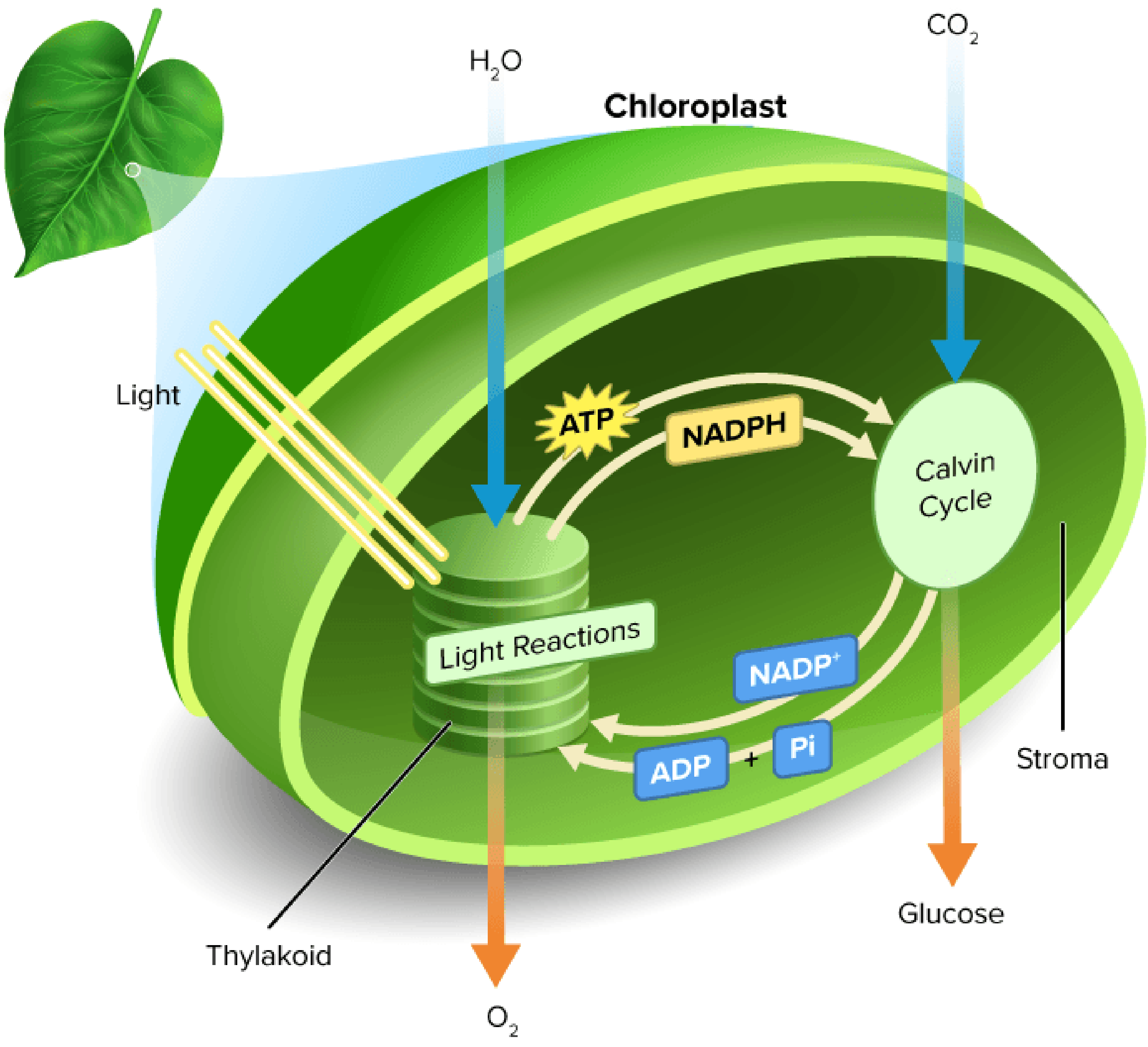
What do pancakes and chloroplasts have in common?

The chloroplast is the site of photosynthesis. Part of the photosynthesis reactions occurs in an internal membrane within the organelle. The chloroplast contains many of these internal membranes, making photosynthesis very efficient. These internal membranes stack on top of each other, just like a stack of pancakes.

Stages of Photosynthesis

Photosynthesis occurs in two stages, which are shown in the **Figure** below.

1. Stage I is called the **light reactions**. This stage uses water and changes light energy from the sun into chemical energy stored in ATP and **NADPH** (another energy-carrying molecule). This stage also releases oxygen as a waste product.
2. Stage II is called the **Calvin cycle**. This stage combines carbon from carbon dioxide in the air and uses the chemical energy in ATP and NADPH to make glucose.



[Figure 2]

The two stages of photosynthesis are the light reactions and the Calvin cycle. Do you see how the two stages are related?

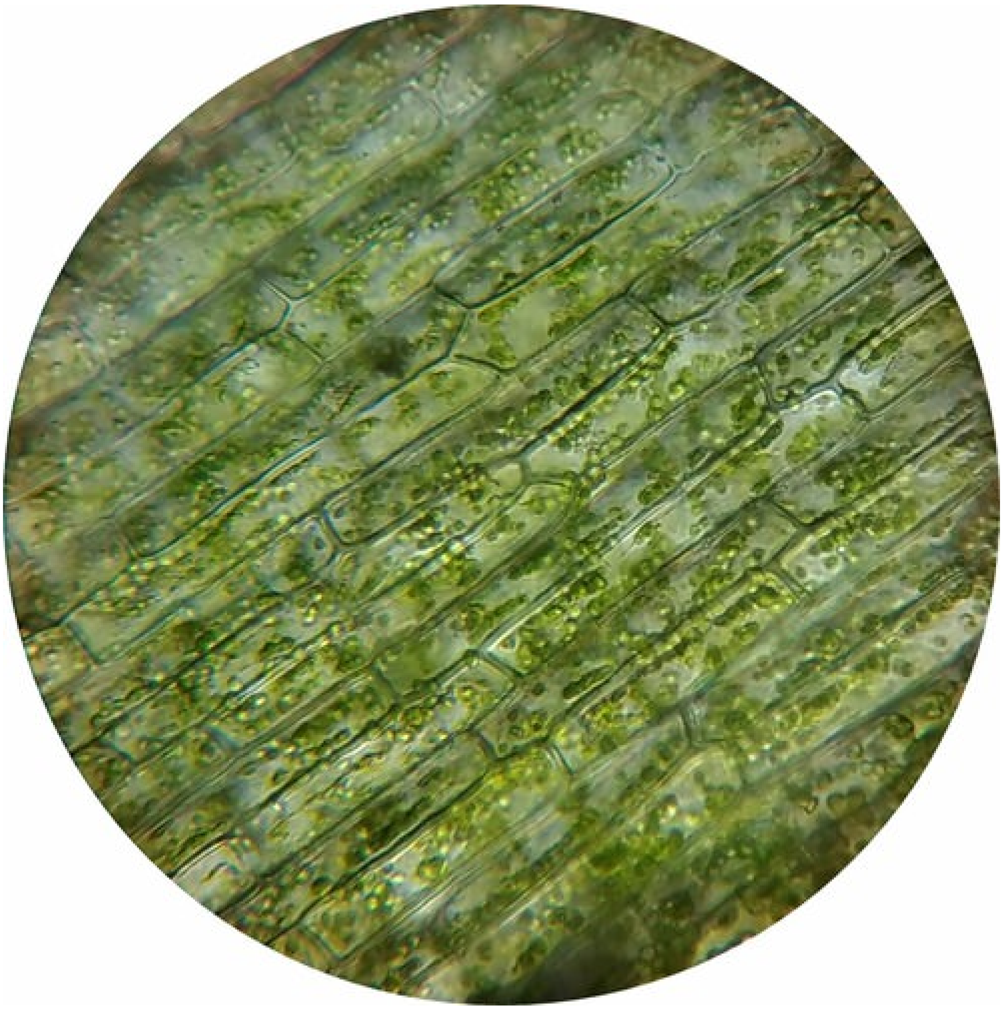
Before you read about these two stages of photosynthesis in greater detail, you need to know more about the chloroplast, where the two stages take place.

The Chloroplast

Chloroplasts: Theaters for Photosynthesis

Photosynthesis, the process of turning the energy of sunlight into “food,” is divided into two basic sets of reactions, known as the light reactions and the Calvin cycle, which uses carbon dioxide. As you study the details in other concepts, refer frequently to the chemical equation of photosynthesis: $6CO_2 + 6H_2O$ + Light Energy $\rightarrow C_6H_{12}O_6 + 6O_2$. Photosynthesis occurs in the chloroplast, an organelle specific to plant cell.

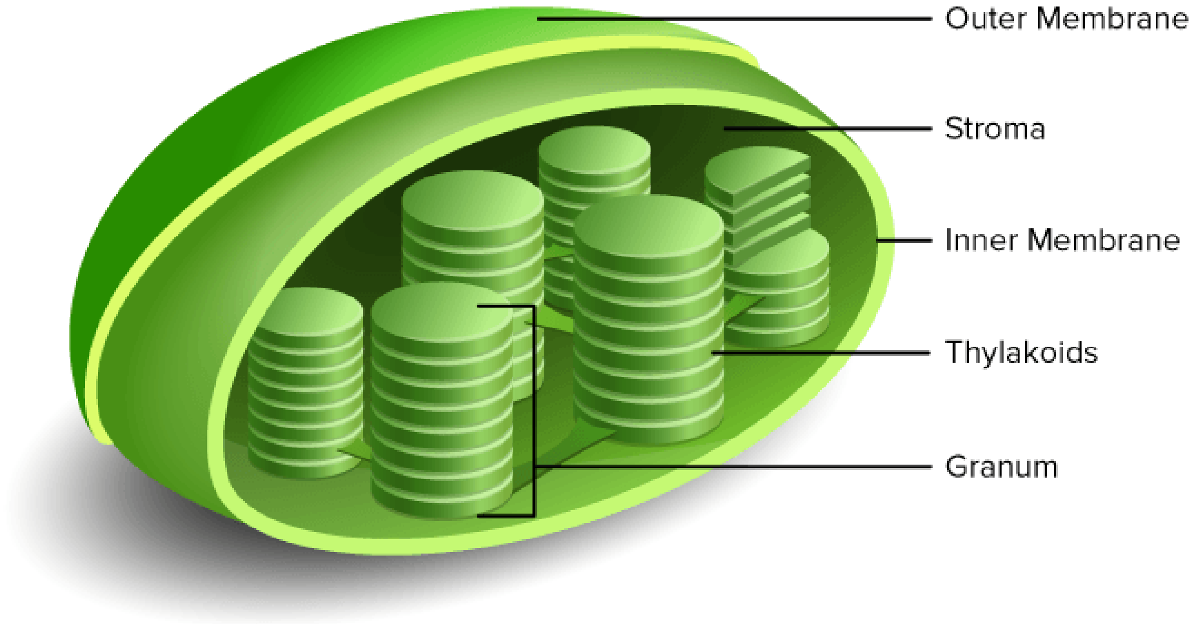
If you examine plant cells, shown in the **Figure** below, under a microscope, you will see within each cell dozens of small green ovals. These are **chloroplasts**, the organelles which conduct photosynthesis in plants and alga. Chloroplasts closely resemble some types of bacterium and even contain their own circular DNA and ribosome. In fact, the **endosymbiotic theory** holds that chloroplasts were once independently living bacteria (prokaryotes). So when we say that photosynthesis occurs within chloroplasts, we speak not only of the organelles within plants and algae but also of some bacteria – in other words, virtually all photosynthetic autotroph.



[Figure 3]

Plant cells under a microscope. Many green chloroplasts are visible.

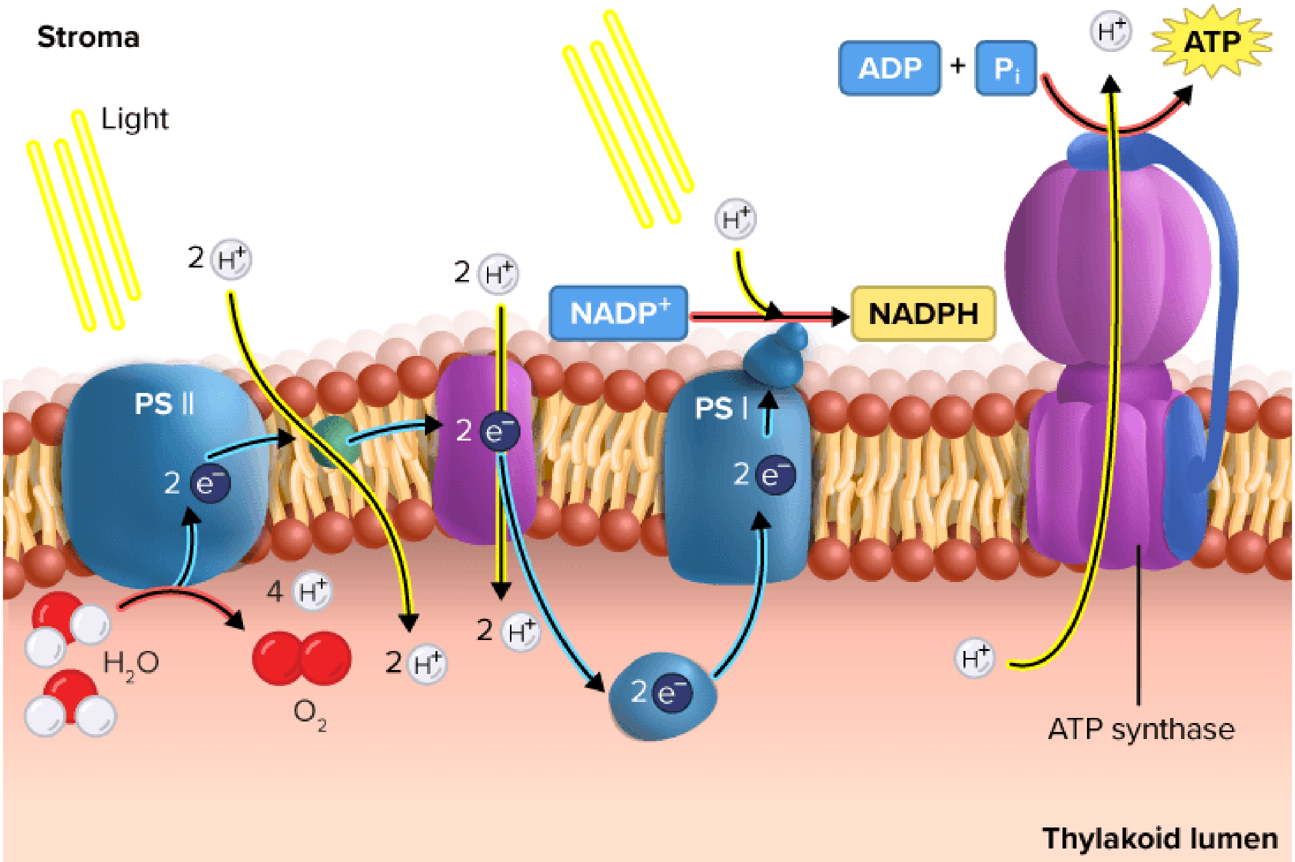
Each chloroplast contains neat stacks called **granum** (singular, granum). The grana consist of sac-like membranes, known as **thylakoid** membranes. These membranes contain **photosystem**, which are groups of molecules that include **chlorophyll**, a green pigment. The light reactions of photosynthesis occur in the thylakoid membranes. The **stroma** is the space outside the thylakoid membranes. This is where the reactions of the Calvin cycle take place. In addition to enzyme, two basic types of molecules - pigments and **electron carrier** – are key players in this process and are also found in the thylakoid membranes.



[Figure 4]

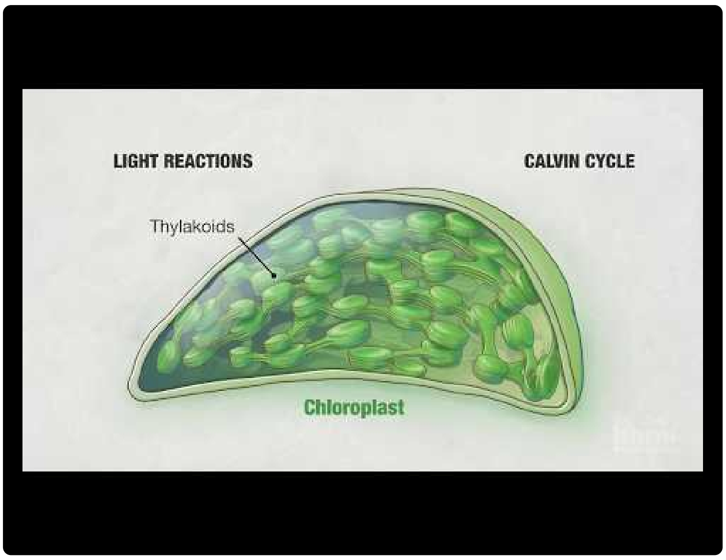
A chloroplast consists of thylakoid membranes surrounded by stroma. The thylakoid membranes contain molecules of the green pigment chlorophyll.

Electron carrier molecules are usually arranged in **electron transport chains** (ETCs). These accept and pass along energy-carrying electrons in small steps (**Figure** below). In this way, they produce ATP and NADPH, which temporarily store chemical energy. Electrons in transport chains behave much like a ball bouncing down a set of stairs – a little energy is lost with each bounce. However, the energy "lost" at each step in an **electron transport chain** accomplishes a little bit of work, which eventually results in the synthesis of ATP.



[Figure 5]

This figure shows the light reactions of photosynthesis. This stage of photosynthesis begins with photosystem II (PS II) (so named because it was discovered after photosystem I (PS I)). Find the two electrons (2 e-) in photosystem II, and then follow them through the electron transport chain (also called the electron transfer chain) to the formation of NADPH. Where do the hydrogen ions (H+) come from that help make ATP?



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Summary

- Photosynthesis occurs in two stages, the light reactions and the Calvin cycle.
- Photosynthesis occurs in the chloroplast, an organelle specific to plant cells.
- The light reactions of photosynthesis occur in the thylakoid membranes of the chloroplast.
- Electron carrier molecules are arranged in electron transport chains that produce ATP and NADPH, which temporarily store chemical energy.

Review

1. Describe the chloroplast's role in photosynthesis.
2. Explain how the structure of a chloroplast (its membranes and thylakoids) makes its function (the chemical reactions of photosynthesis) more efficient.
3. Describe electron carriers and the electron transport chain.

Report Content Errors

2.20 Leaves and Photosynthesis

FlexBooks 2.0 > Biology For High School Diploma > Leaves and Photosynthesis

Last Modified: Aug 24, 2020

[Figure 1]

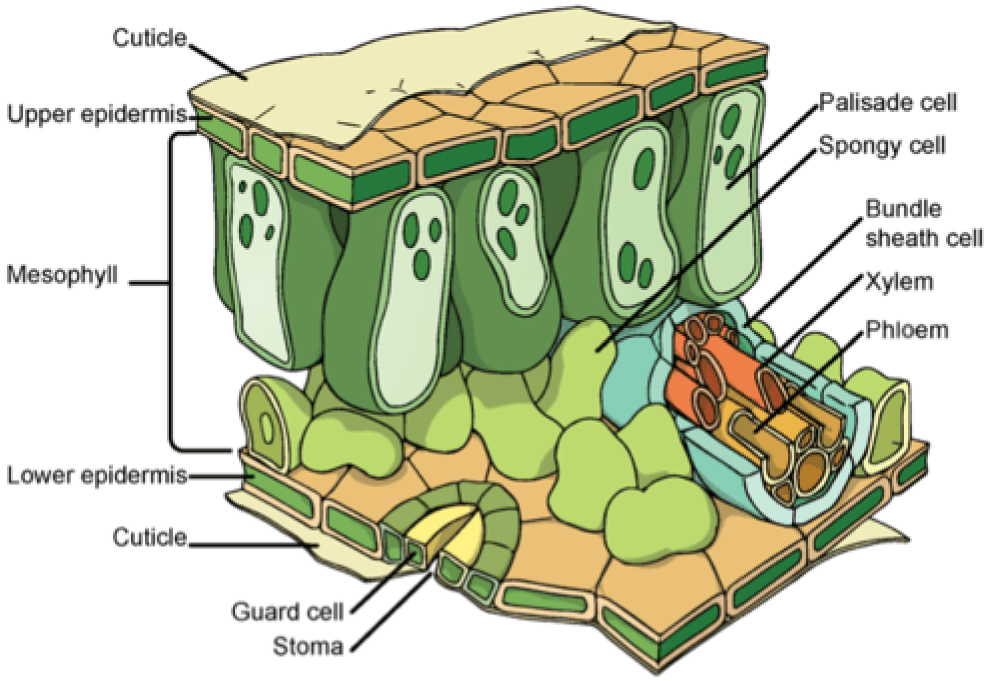
Oxygen — the oxygen that we breath — is just a waste product of what reaction?

Every split second that sunlight hits that leaf, **photosynthesis** is initiated, bringing energy into the ecosystem. It could be said that this is one of the most important - if not the absolutely most important - biochemical reaction. And it all starts with the leaf.

Factories for Photosynthesis

Photosynthesis is the process that uses energy from the sun, together with carbon dioxide and water, to make glucose and oxygen. The primary role of photosynthesis is to make the carbohydrate, suggesting that oxygen, which is released back into the atmosphere, is just a waste product.

You can think of a single leaf as a photosynthesis factory. A factory has specialized machines to produce a product. It's also connected to a transportation system that supplies it with raw materials and carries away the finished product. In all these ways, a leaf resembles a factory. The cross section of a leaf in **Figure** below lets you look inside a leaf "factory."

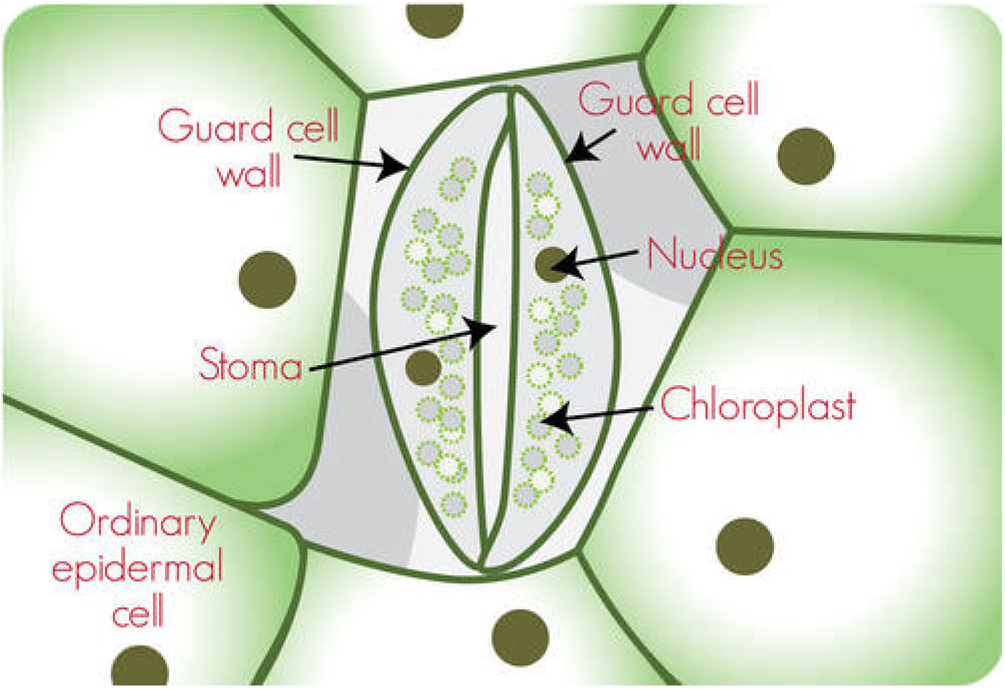


[Figure 2]

There's more to a leaf than meets the eye. Can you identify the functions of each of the labeled structures in the diagram?

A leaf consists of several different kinds of specialized tissue that work together to make food by photosynthesis. The major tissues are **mesophyll**, vein, and epidermis.

- **Mesophyll** makes up most of the leaf's interior. This is where photosynthesis occurs. Mesophyll consists mainly of parenchymal cell with chloroplast.
- **Veins** are made primarily of xylem and phloem. They transport water and mineral to the cells of leaves and carry away dissolved sugar.
- The **epidermis** of the leaf consists of a single layer of tightly-packed dermal cells. They secrete waxy cuticle to prevent evaporation of water from the leaf. The epidermis has tiny pores called **stoma** (singular, stoma) that control **transpiration** and gas exchange with the air. For photosynthesis, stomata must control the transpiration of water vapor and the exchange of carbon dioxide and oxygen. Stomata are flanked by **guard cell** that swell or shrink by taking in or losing water through **osmosis**. When they do, they open or close the stomata (see **Figure** below).



[Figure 3]

For photosynthesis, stomata must control the transpiration of water vapor and the exchange of carbon dioxide and oxygen. Stomata are flanked by guard cells that swell or shrink by taking in or losing water through osmosis. When they do, they open or close the stomata.

Click to view Interactive

Summary

- Specialized cells and tissues in leaves work together to perform photosynthesis.

Review

1. Explain how a leaf is like a factory.
2. Explain the role of stomata during photosynthesis.
3. What controls the opening of stomata?

Report Content Errors

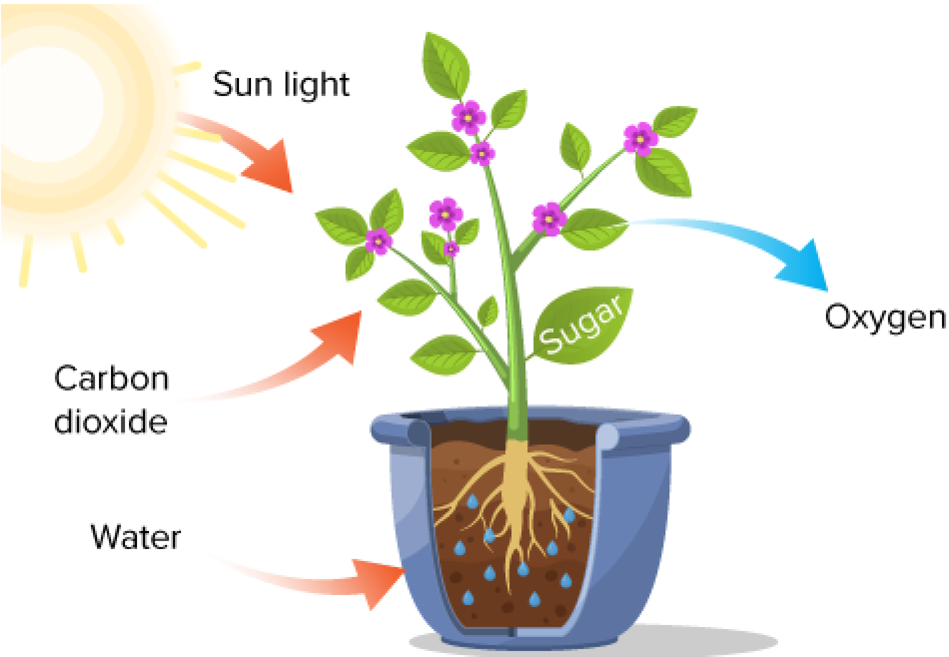
2.21 Photosynthesis

FlexBooks 2.0 > Biology For High School Diploma > Photosynthesis

Last Modified: Nov 23, 2021

What will you learn

- The process of photosynthesis
- How chloroplast capture sunlight
- How light energy is converted into chemical energy



[Figure 1]

Oxygen has been described as a "waste product." Is it?

Essentially, oxygen is a waste product of the **light reactions** of photosynthesis. It is a "leftover" from a necessary part of the process. All the oxygen that is necessary to maintain most forms of life just happens to come about during this process.

Photosynthesis Stage I: The Light Reactions

Chloroplasts Capture Sunlight

Every second, the sun fuses over 600 million tons of hydrogen into 596 tons of helium, converting over 4 tons of helium (4.3 billion kg) into light and heat energy. Countless tiny packets of that light energy travel 93 million miles (150 million km) through space, and about 1% of the light which reaches the Earth's surface participates in photosynthesis. Light is the source of energy for photosynthesis, and the first set of reactions which begin the process requires light – thus the name, **light reactions**, or light-dependent reactions.

When light strikes **chlorophyll** (or an accessory pigment) within the chloroplast, it energizes electrons within that molecule. These electrons jump up to higher energy levels; they have absorbed or captured, and now carry, that energy. High-energy electrons are "excited." Who wouldn't be excited to hold the energy for life?

The excited electrons leave chlorophyll to participate in further reactions, leaving the chlorophyll "at a loss"; eventually they must be replaced. That replacement process also requires light, working with an enzyme complex to split water molecules. In this process of **photolysis** ("splitting by light"), H_2O molecules are broken into hydrogen ion, electrons, and oxygen atoms. The electrons replace those originally lost from chlorophyll. Hydrogen ions and the high-energy electrons from chlorophyll will carry on the energy transformation after the light reactions are over.

DID YOU KNOW?

Elysia chlorotica, a species of green sea slug, takes chloroplasts from alga and places them into its own digestive cell. This enables these animal to capture solar energy and perform photosynthesis.

The oxygen atoms, however, form oxygen gas, which is a waste product of photosynthesis. The oxygen given off supplies most of the oxygen in our atmosphere. Before photosynthesis evolved, Earth's atmosphere lacked oxygen altogether, and this highly reactive gas was toxic to the many organism living at the time. Something had to change! Most contemporary organisms rely on oxygen for efficient respiration. So plants don't just "restore" the air, they also had a major role in creating it!

To summarize, chloroplasts "capture" sunlight energy in two ways. Light ''excites'' electrons in pigment molecules, and light provides the energy to split water molecules, providing more electrons as well as hydrogen ions.

Light Energy to Chemical Energy

Excited electrons that have absorbed light energy are unstable. However, the highly organized electron carrier molecules embedded in chloroplast membranes order the flow of these electrons, directing them through **electron transport chains** (ETCs). At each transfer, small amounts of energy released by the electrons are captured and put to work or stored.

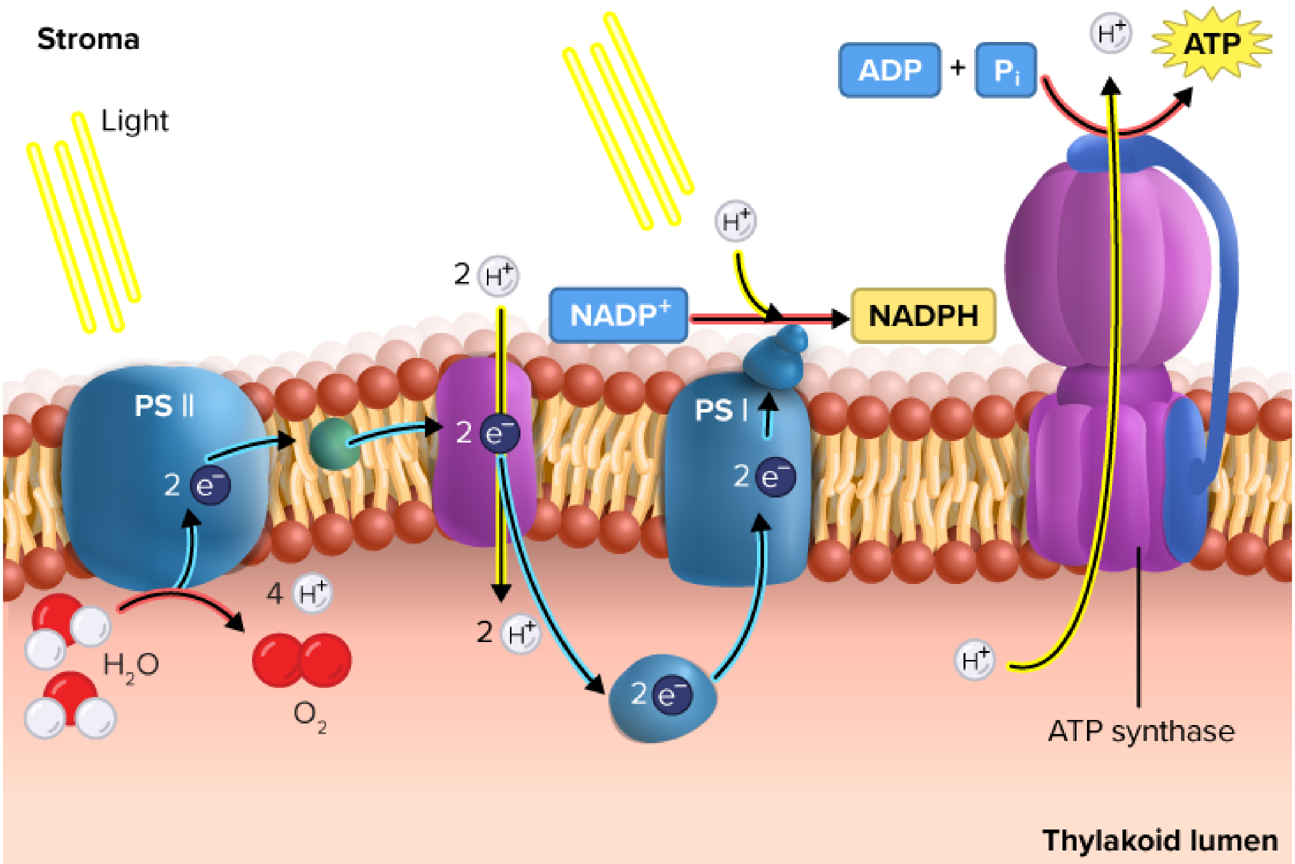
Some is also lost as heat with each transfer, but overall the light reactions are extremely efficient at capturing light energy and transforming it into chemical energy.

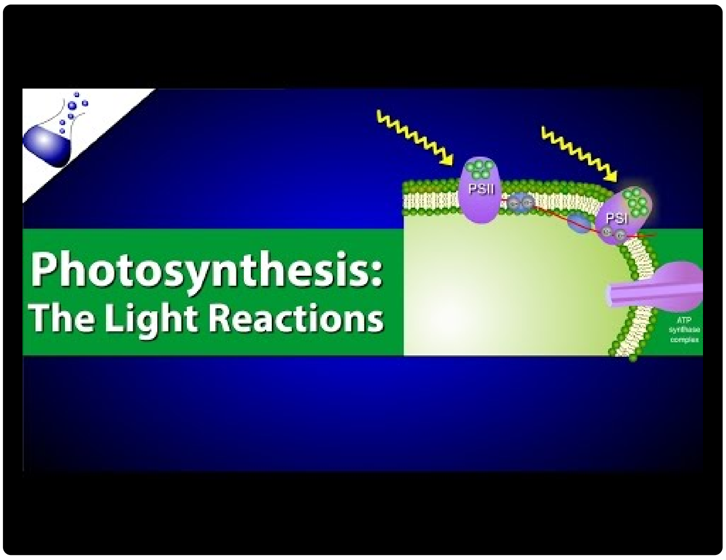
Two sequential transport chains harvest the energy of excited electrons.

(1) First, they pass down an ETC, which captures their energy and uses it to pump hydrogen ions by active transport into the thylakoid. These concentrated ions store potential energy by forming a chemiosmotic or electrochemical gradient – a higher concentration of both positive charge and hydrogen inside the thylakoid than outside. The gradient formed by the H^+ ions is known as a chemiosmotic gradient. Picture this energy buildup of H^+ as a dam holding back a waterfall. Like water flowing through a hole in the dam, hydrogen ions "slide down" their concentration gradient through a membrane protein which acts as both ion channel and enzyme. As they flow, the ion channel/enzyme ATP synthase uses their energy to chemically bond a phosphate group to ADP, making ATP.

(2) Light re-energizes the electrons, and they travel down a second **electron transport chain** (ETC), eventually bonding hydrogen ions to $NADP^+$ to form a more stable energy storage molecule, NADPH. NADPH is sometimes called "hot hydrogen," and its energy and hydrogen atoms will be used to help build sugar in the second stage of photosynthesis.

NADPH and ATP molecules now store the energy from excited electrons – energy which was originally sunlight – in chemical bond. Thus chloroplasts, with their orderly arrangement of pigments, enzymes, and electron transport chains, transform light energy into chemical energy. The first stage of photosynthesis – light-dependent reactions or simply light reactions – is complete.





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Summary

- The light reactions capture energy from sunlight, which they change to chemical energy that is stored in molecules of NADPH and ATP.
- The light reactions also release oxygen gas as a waste product.

Review

1. Summarize what happens during the light reactions of photosynthesis.
2. What is the chemiosmotic gradient?
3. Explain the role of the first electron transport chain in the formation of ATP during the light reactions of photosynthesis.

Report Content Errors

2.22 Calvin Cycle

FlexBooks 2.0 > Biology For High School Diploma > Calvin Cycle

Last Modified: Jan 18, 2022

What you will learn

- How the Calvin cycle fixes carbon and synthesizes glucose
- What happens in the three pathways for **carbon fixation**: C3, C4, and CAM pathways
- How **RuBisCo** fixes carbon

[Figure 1]

Other than being green, what do all these fruits and vegetables have in common?

They are full of energy. Energy in the form of glucose. The energy from sunlight is briefly held in **NADPH** and ATP, which is needed to drive the formation of sugars such as glucose. And this all happens in the Calvin cycle.

The Calvin Cycle

Making Food "From Thin Air"

You've learned that the first, light-dependent stage of photosynthesis uses two of the three reactant, water and light, and produces one of the products, oxygen gas (a waste product of this process). All three necessary conditions are required – chlorophyll pigments, the chloroplast “theater,” and enzyme catalyst. The first stage transforms light energy into chemical energy, stored to this point in molecules of ATP and NADPH. Look again at the overall equation below. What is left?

$$\underset{\text{Carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{6\,H_2O} + \underset{\text{light energy}}{\text{light}} \longrightarrow \underset{\substack{\text{glucose} \\ \text{(stored chemical energy)}}}{C_6H_{12}O_6} + \underset{\text{oxygen gas}}{6\,O_2}$$

[Figure 2]

Waiting in the wing is one more reactant, carbon dioxide, and yet to come is the star product, which is food for all life – glucose. These key players perform in the second act of the photosynthesis drama, in which food is “made from thin air!”

CAN YOU FORM THE EQUATION

Carbon dioxide + Water + Light energy ➔ Glucose + Oxygen gas

? + ? + ? ➔ ? + ?

$6CO_2$ | $C_6H_{12}O_6$ | $6H_2O$ | light | $6O_2$

The second stage of photosynthesis can proceed without light, so its steps are sometimes called “light-independent” or “dark” reactions (though the term ‘‘dark’’ reactions can be misleading). Many biologists honor the scientist, Melvin Calvin, who won a 1961 Nobel Prize for working out this complex set of chemical reaction, naming it the **Calvin cycle**.

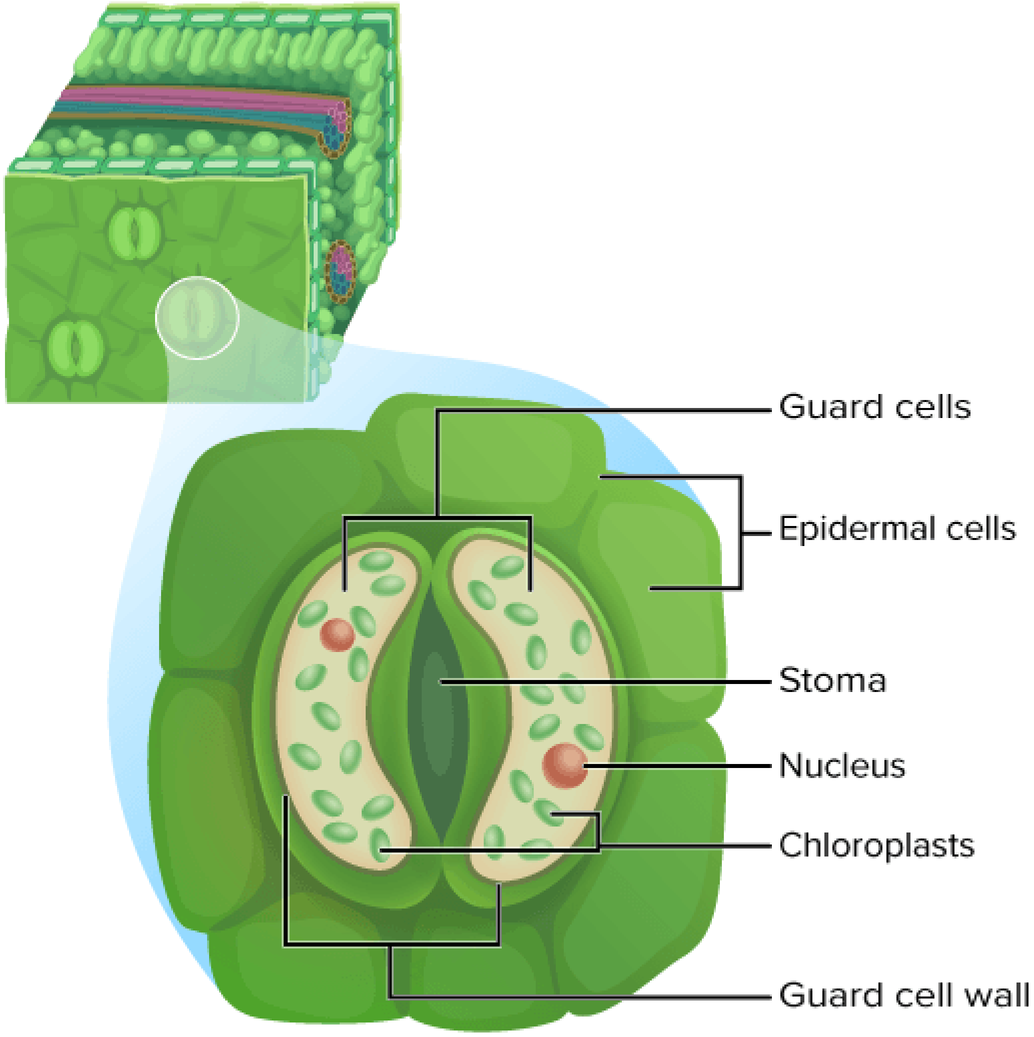
The Calvin cycle has two parts. First carbon dioxide is ‘‘fixed’’. Then ATP and NADPH from the light reactions provide energy to combine the fixed carbons to make sugar.

Carbon Dioxide is “Fixed”

Why does carbon dioxide need to be fixed? Was it ever broken?

Life on Earth is carbon-based. organism need not only energy but also carbon atoms for building bodies. For nearly all life, the ultimate source of carbon is carbon dioxide (CO_2), an inorganic molecule. CO_2 makes up less than 1% of the Earth’s atmosphere.

animal and most other heterotroph cannot take in CO_2 directly. They must eat other organisms or absorb **organic molecule** to get carbon. Only autotroph can build low-energy inorganic CO_2 into high-energy organic molecules like glucose. This process is **carbon fixation**.



[Figure 3]

Stomata on the underside of leaves take in CO2 and release water and O2. Guard cells close the stomata when water is scarce. Leaf cross-section (above) and stoma (below).

Plants have evolved three pathways for carbon fixation.

The most common pathway combines one molecule of CO_2 with a 5-carbon sugar called ribulose biphosphate (RuBP). The enzyme which catalyzes this reaction (nicknamed **RuBisCo**) is the most abundant enzyme on Earth! The resulting 6-carbon molecule is unstable, so it immediately splits into two 3-carbon molecules. The 3 carbons in the first stable molecule of this pathway give this largest group of plants the name "C_3."

Dry air, hot temperatures, and bright sunlight slow the C_3 pathway for carbon fixation. This is because **stoma**, tiny openings under the leaf which normally allow CO_2 to enter and O_2 to leave, must close to prevent loss of water vapor (**Figure** above). Closed stomata lead to a shortage of CO_2. Two alternative pathways for carbon fixation demonstrate biochemical adaptation to differing environments.

Plants such as corn solve the problem by using a separate compartment to fix CO_2. Here CO_2 combines with a 3-carbon molecule, resulting in a 4-carbon molecule. Because the first stable organic molecule has four carbons, this adaptation has the name C_4. Shuttled away from the initial fixation site, the 4-carbon molecule is actually broken back down into CO_2, and when enough accumulates, RuBisCo fixes it a second time! Compartmentalization allows efficient use of low concentrations of carbon dioxide in these specialized plants.

Cacti and succulents such as the jade plant avoid water loss by fixing CO_2 only at night. These plants close their stomata during the day and open them only in the cooler and more humid nighttime hours. Leaf structure differs slightly from that of C_4 plants, but the fixation pathways are similar. The family of plants in which this pathway was discovered gives the pathway its name, Crassulacean Acid metabolism, or CAM (**Figure** below). All three carbon fixation pathways lead to the Calvin cycle to build sugar.

[Figure 4]

Even chemical reactions adapt to specific environments! Carbon fixation pathways vary among three groups. Temperate species use the C3 pathway

[Figure 5]

C4 species concentrate CO2 in a separate compartment to lessen water loss in hot bright climates

[Figure 6]

Desert plants (jade plant, right) fix CO2 only at night, closing stomata in the daytime to conserve water.

How Does the Calvin Cycle Store Energy in Sugar?

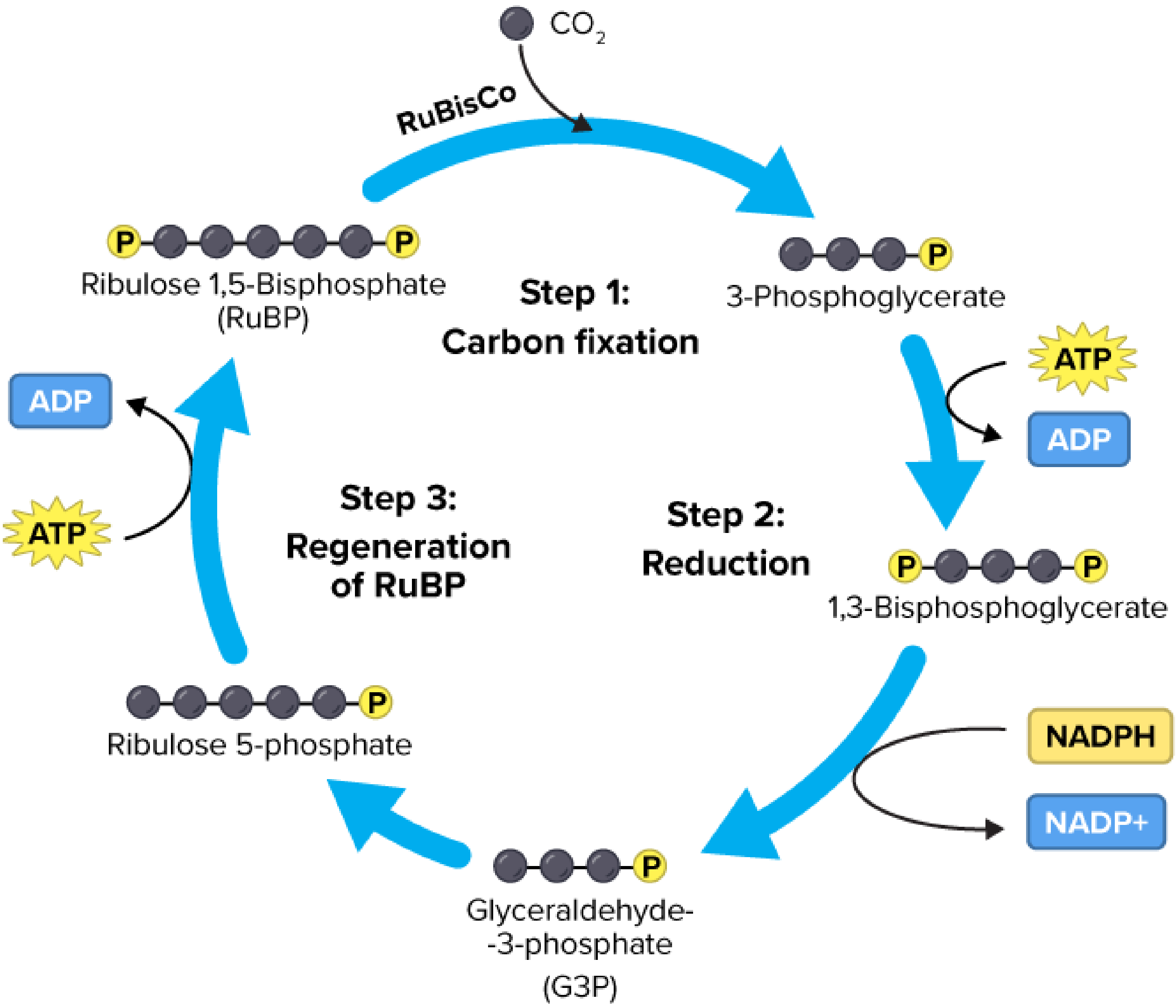
As Melvin Calvin discovered, carbon fixation is the first step of a cycle. Like an electron transport chain, the Calvin cycle, shown in **Figure** below, transfers energy in small, controlled steps. Each step pushes molecules uphill in terms of energy content. Recall that in the electron transport chain, excited electrons lose energy to NADPH and ATP. In the Calvin cycle, NADPH and ATP formed in the light reactions lose their stored chemical energy to build glucose.

DID YOU KNOW?

Scientists have designed artificial photosynthesis which is a way to convert carbon dioxide into fuel that can be used for internal combustion engines by capturing and storing the energy from the sun.

Use the **Figure** below to identify the major aspects of the process:

- the general cycle pattern
- the major reactants
- the products



[Figure 7]

Overview of the Calvin Cycle Pathway

First, notice where carbon is fixed by the enzyme nicknamed RuBisCo. In C_3, C_4, and CAM plants, CO_2 enters the cycle by joining with 5-carbon ribulose bisphosphate to form a 6-carbon intermediate, which splits (so quickly that it isn't even shown!) into two 3-carbon molecules.

Now look for the points at which ATP and NADPH (made in the light reactions) add chemical energy ("Reduction" in the diagram) to the 3-carbon molecules. The resulting "half-sugars" can enter several different metabolic pathways. One recreates the original 5-carbon precursor, completing the cycle. A second combines two of the 3-carbon molecules to form glucose, universal fuel for life.

The cycle begins and ends with the same molecule, but the process combines carbon and energy to build carbohydrate – food for life.

So, how does photosynthesis store energy in sugar? Six "turns" of the Calvin cycle use chemical energy from ATP to combine six carbon atoms from six CO_2 molecules with 12 "hot hydrogens" from NADPH. The result is one molecule of glucose, $C_6H_{12}O_6$.

Check your understanding!

PROGRESS 0 / 3

1. The Calvin cycle is directly driven by light energy.

TRUE

FALSE

Check It

Hint

https://www.ck12.org/assessment/ui/embed.html?test/view/61534a72627c2efcbd71338f&collectionHandle=biology&collectionCreatorID=3&conceptCollectionHandle=biology-::-calvin-cycle&

https://flexbooks.ck12.org/flx/render/embeddedobject/181792

Summary

- The reactions of the Calvin cycle add carbon (from carbon dioxide in the atmosphere) to a simple five-carbon molecule called RuBP.
- These reactions use chemical energy from NADPH and ATP that were produced in the light reactions.
- The final product of the Calvin cycle is glucose.

Review

1. What happens during the carbon fixation step of the Calvin cycle?
2. What is special about RuBisCo?
3. What are stomata?
4. Explain what might happen if the third step of the Calvin cycle did not occur. Why?
5. What is the main final product of the Calvin cycle? How many turns of the Calvin cycle are needed to produce this product?

Report Content Errors

2.23 Photosynthesis Summary

FlexBooks 2.0 > Biology For High School Diploma > Photosynthesis Summary

Last Modified: Nov 23, 2021

What you will learn

- An overview of the light-dependent reactions and light-independent reactions
- Comparison between photosynthesis and cellular respiration

[Figure 1]

What is photosynthesis?

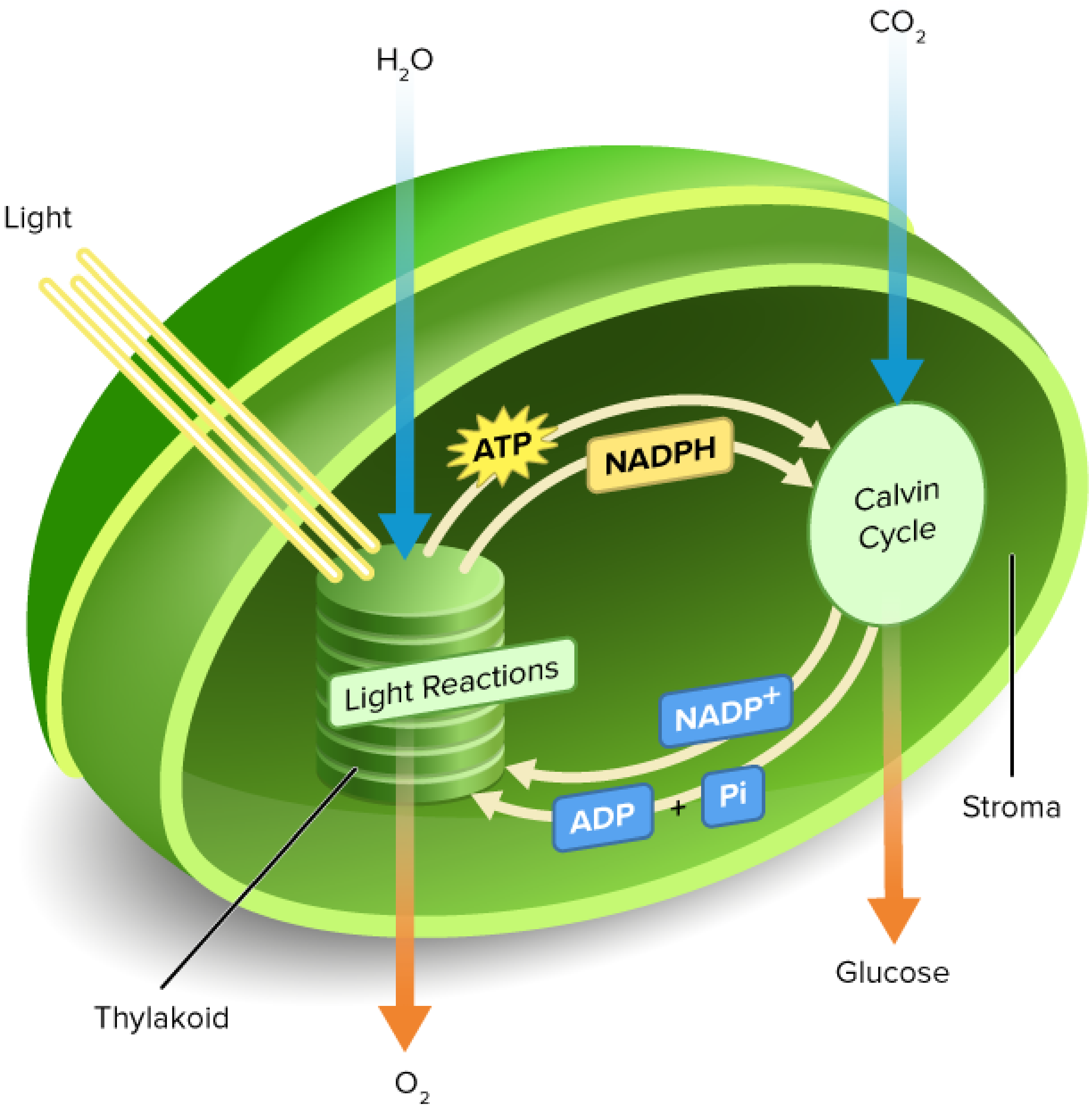
The process of using the energy in sunlight to make food (glucose). Is it really as simple as that? Of course not. As you have seen, photosynthesis includes many steps all conveniently condensed into one simple equation. In the five concepts describing photosynthesis, this process has been presented in an introductory fashion. Obviously, much more details could have been included, though those are beyond the scope of these concepts.

Photosynthesis

The following 10 points summarize photosynthesis.

1. $6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$

2. autotroph store chemical energy in carbohydrate food molecules they build themselves. Most autotrophs make their "food" through photosynthesis using the energy of the sun.
3. Photosynthesis occurs in the chloroplast, an organelle specific to plant cell.
4. The light reactions of photosynthesis occur in the thylakoid membranes of the chloroplast.
5. electron carrier molecules are arranged in electron transport chains that produce ATP and **NADPH**, which temporarily store chemical energy.
6. The light reactions capture energy from sunlight, which they change to chemical energy that is stored in molecules of NADPH and ATP.
7. The light reactions also release oxygen gas as a waste product.
8. The reactions of the Calvin cycle add carbon (from carbon dioxide in the atmosphere) to a simple five-carbon molecule called RuBP.
9. The Calvin cycle reactions use chemical energy from NADPH and ATP that were produced in the light reactions.
10. The final product of the Calvin cycle is glucose.



What is photosynthesis?

The process of using the energy in sunlight to make food (glucose). But of course it is much more complex than that simple statement. Photosynthesis is a multistep biochemical pathway that uses the energy in sunlight to fix carbon dioxide, transferring the energy into carbohydrates, and releasing oxygen in the process.

What is NADPH?

Nicotinamide adenine dinucleotide phosphate, an energy carrier molecule produced in the light reactions of photosynthesis. NADPH is the reduced form of the electron acceptor $NADP^+$. At the end of the light reactions, the energy from sunlight is transferred to $NADP^+$, producing NADPH. This energy in NADPH is then used in the Calvin cycle.

Where do the protons used in the light reactions come from?

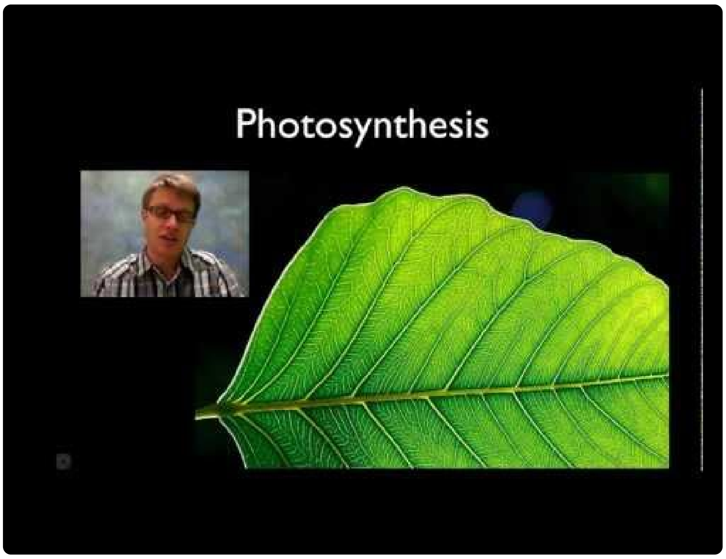
The protons used in the light reactions come from **photolysis**, the splitting of water, in which H_2O molecules are broken into hydrogen ion, electrons, and oxygen atoms. In addition, the energy from sunlight is used to pump protons into the thylakoid lumen during the first electron transport chain, forming a chemiosmotic gradient.

How do you distinguish between the Calvin cycle and the Krebs cycle?

The Calvin cycle is part of the light-independent reactions of photosynthesis. The Calvin cycle uses ATP and NADPH. The Krebs cycle is part of cellular respiration. This cycle makes ATP and NADH.

Do photosynthesis and cellular respiration occur at the same time in a plant?

Yes. Photosynthesis occurs in the chloroplasts, whereas cellular respiration occurs in the mitochondrion. Photosynthesis makes glucose and oxygen, which are then used as the starting products for cellular respiration. Cellular respiration makes carbon dioxide and water (and ATP), which are the starting products (together with sunlight) for photosynthesis.



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Common Misconceptions

- A common student misconception is that plants photosynthesize only during daylight and conduct cellular respiration only at night. Some teaching literature even states this. Though it is true the light reactions can only occur when the sun is out, cellular respiration occurs continuously in plants, not just at night.

- The "dark reactions" of photosynthesis are a misnomer that often leads students to believe that photosynthetic carbon fixation occurs at night. This is not true. It is preferable to use the term Calvin cycle or light-independent reactions instead of dark reactions.

- Though the final product of photosynthesis is glucose, the glucose is conveniently stored as starch. Starch is approximated as $(C_6H_{10}O_5)_n$, where n is in the thousands. Starch is formed by the condensation of thousands of glucose molecules.

Report Content Errors

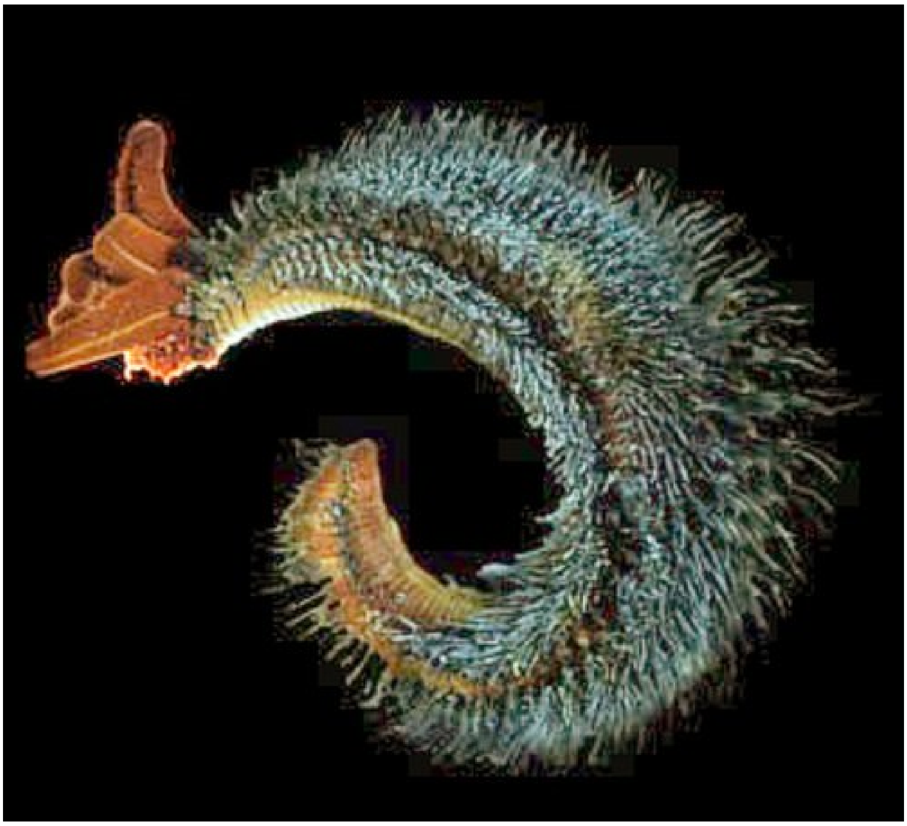
2.24 Chemosynthesis

FlexBooks 2.0 > Biology For High School Diploma > Chemosynthesis

Last Modified: Nov 23, 2021

What will you learn

- The process of chemosynthesis
- How different organism perform chemosynthesis



[Figure 1]

Is it possible to live in temperatures over 175°F?

It is if you're a Pompeii worm. The Pompeii worm, the most heat-tolerant animal on Earth, lives in the deep ocean at super-heated hydrothermal vents. Covering this deep-sea worm's back is a fleece of bacterium. These microbes contain all the gene necessary for life in extreme environments.

Chemosynthesis

Why do bacteria that live deep below the ocean's surface rely on chemical compounds instead of sunlight for energy to make food?

Most autotroph make food by photosynthesis, but this isn't the only way that autotrophs produce food. Some bacteria make food by another process, which uses chemical energy instead of light energy. This process is called **chemosynthesis**. In chemosynthesis, one or more carbon molecules (usually carbon dioxide or methane, CH_4) and nutrient is converted into organic matter, using the oxidation of inorganic molecules (such as hydrogen gas, hydrogen sulfide (H_2S) or ammonia (NH_3)) or methane as a source of energy, rather than sunlight. In hydrogen sulfide chemosynthesis, in the presence of carbon dioxide and oxygen, carbohydrate (CH_2O) can be produced:

$$CO_2 + O_2 + 4H_2S \rightarrow CH_2O + 4S + 3H_2O$$

Many organisms that use chemosynthesis are **extremophile,** living in harsh conditions, such as in the absence of sunlight and a wide range of water temperatures, some approaching the boiling point. Some chemosynthetic bacteria live around deep-ocean vents known as "black smokers." Compounds such as hydrogen sulfide, which flow out of the vents from Earth's interior, are used by the bacteria for energy to make food. Consumers that depend on these bacteria to produce food for them include giant tubeworms, like those pictured in **Figure** below. These organisms are known as **chemoautotroph.** Many chemosynthetic microorganisms are consumed by other organisms in the ocean, and symbiotic associations between these organisms and respiring heterotroph are quite common.

[Figure 2]

Tubeworms deep in the Galapagos Rift get their energy from chemosynthetic bacteria. Tubeworms have no mouth, eyes or stomach. Their survival depends on a symbiotic relationship with the billions of bacteria that live inside them. These bacteria convert the chemicals that shoot out of the hydrothermal vents into food for the worm.

DID YOU KNOW?

The chemosynthetic bacteria present in some deep lakes produce methane. This results in the formation of large bubbles of highly flammable methane gas under the frozen lakes during winter. Lakes such as these and natural wetland contribute to the production of a significant amount of methane, a greenhouse gas.

Summary

- Chemosynthesis is a process in which some organisms use chemical energy instead of light energy to produce "food."

Review

1. What is chemosynthesis?
2. Why do bacteria that live deep below the ocean's surface rely on chemical compounds instead of sunlight for energy to make food?
3. Describe the habitats of extremophiles?

2.25 Cellular Respiration

FlexBooks 2.0 > Biology For High School Diploma > Cellular Respiration

Last Modified: Dec 02, 2021

What will you learn

- How the energy from glucose is released through cellular respiration to form **ATP**
- What happens in the three stages of cellular respiration: glycolysis, Krebs cycle, and electron transport
- The structure of the mitochondrion

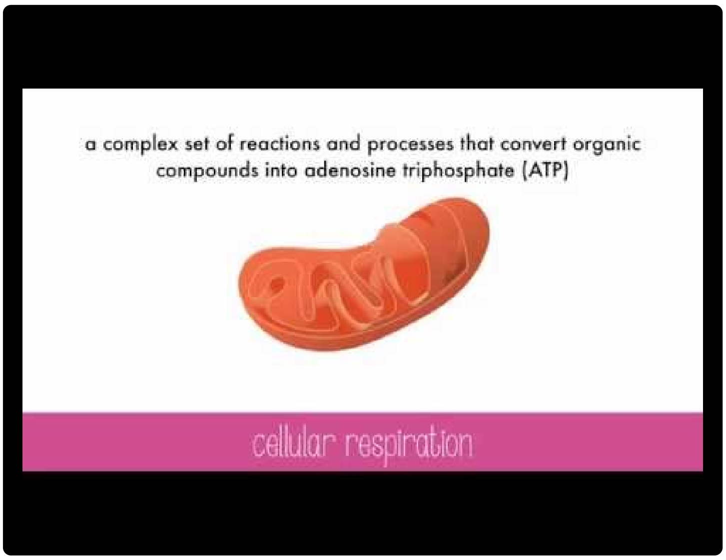
[Figure 1]

Why eat?

Because we're hungry? Not necessarily. But biologically speaking...we eat to get energy. The food we eat is broken down, the glucose extracted, and that energy is converted into ATP.

Cellular Respiration

What happens to the energy stored in glucose during photosynthesis? How do living things make use of this stored energy? The answer is **cellular respiration**. This process releases the energy in glucose to make **ATP** (adenosine triphosphate), the molecule that powers all the work of cell.



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Stages of Cellular Respiration

Cellular respiration involves many chemical reaction. The reactions can be summed up in this equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Chemical Energy (in ATP)}$$

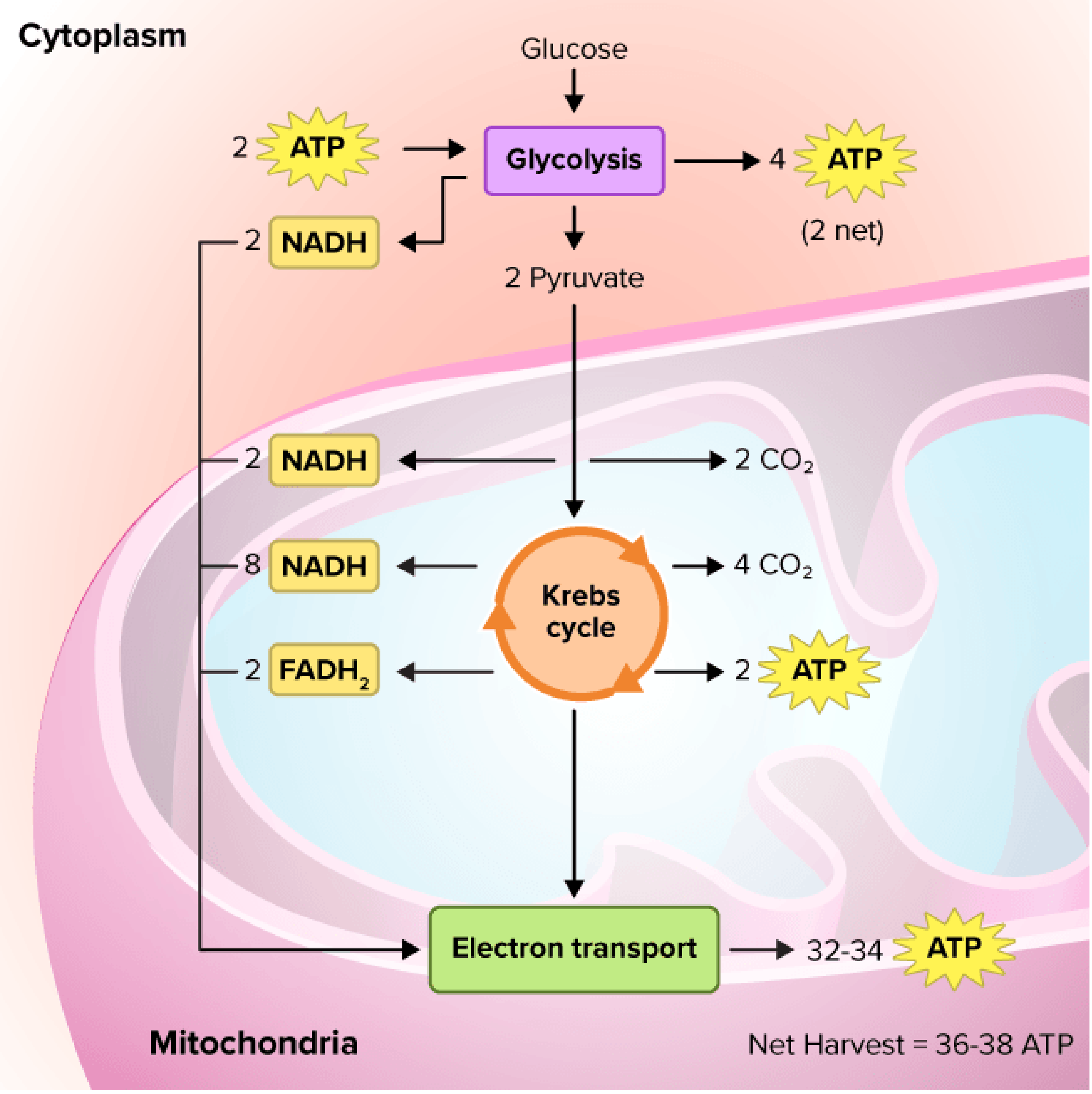
CAN YOU FORM THE EQUATION

Glucose + Oxygen gas ➡ Carbon dioxide + Water + Chemical Energy

? + ? ➡ ? + ? + ?

$C_6H_{12}O_6$ $6CO_2$ $6H_2O$ ATP $6O_2$

The reactions of cellular respiration can be grouped into three stages: glycolysis (stage 1), the Krebs cycle, also called the citric acid cycle (stage 2), and electron transport (stage 3). The **Figure** below gives an overview of these three stages, which are further discussed in the concepts that follow. Glycolysis occurs in the cytoplasm of the cell and does not require oxygen, whereas the Krebs cycle and electron transport occur in the mitochondria and do require oxygen.



[Figure 2]

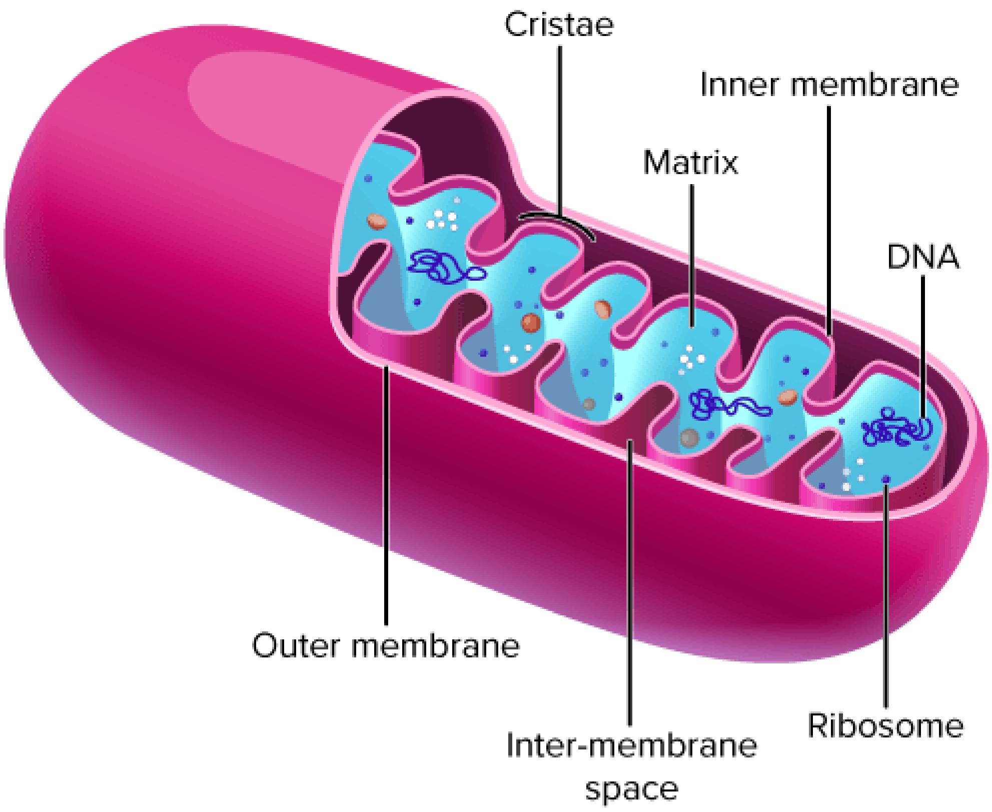
Cellular respiration takes place in the stages shown here. The process begins with a molecule of glucose, which has six carbon atoms. What happens to each of these atoms of carbon?

DID YOU KNOW?

Glucose is a quick source of energy in the body because it can be readily absorbed by the cells and used in cellular respiration. Other complex carbohydrate have to be first processed and converted into glucose by the digestive system to produce energy.

Structure of the Mitochondrion: Key to Aerobic Respiration

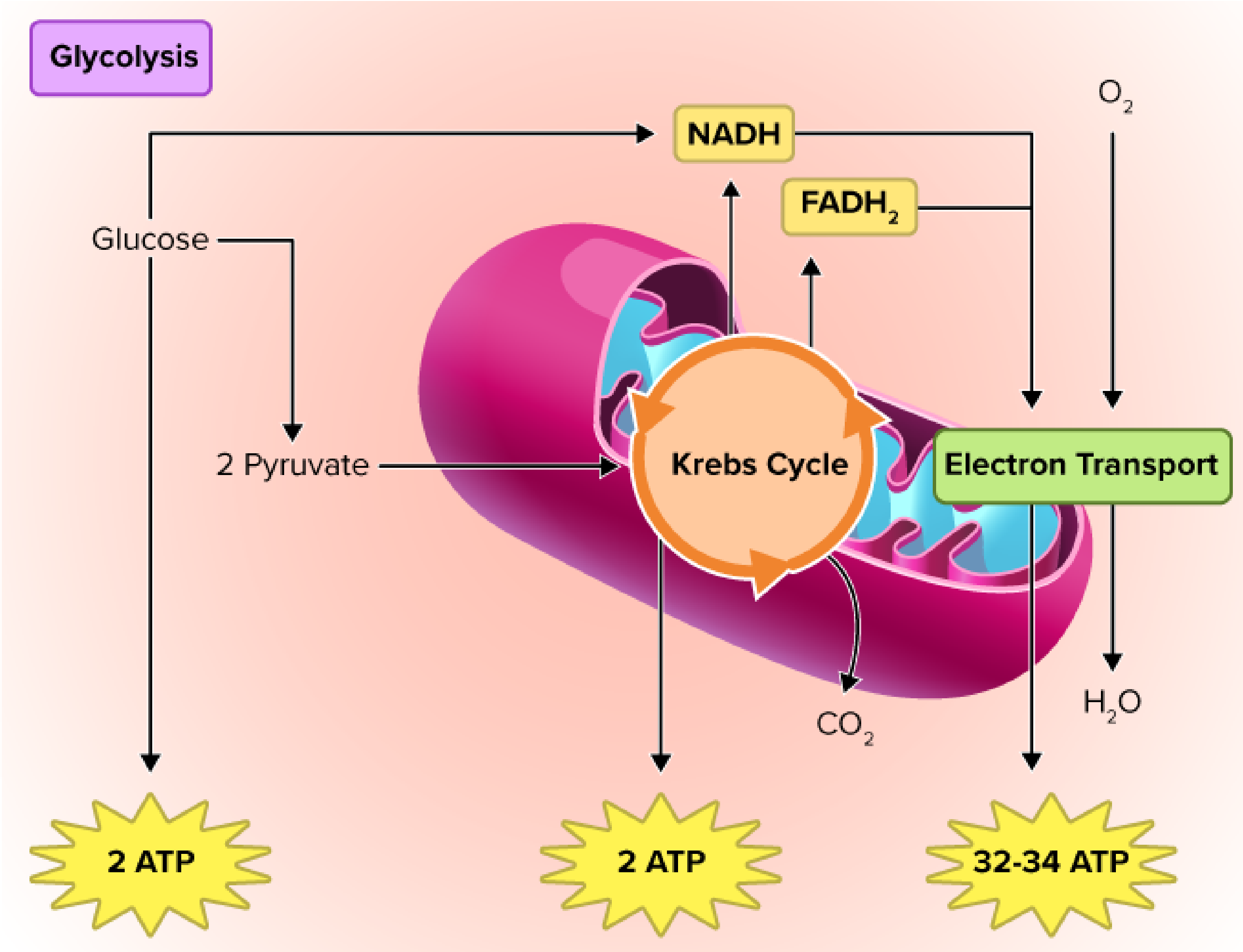
The structure of the mitochondrion is key to the process of **aerobic** cellular respiration, especially the Krebs cycle and electron transport. A diagram of a mitochondrion is shown in the **Figure** below.



[Figure 3]

The structure of a mitochondrion is defined by an inner and outer membrane. This structure plays an important role in aerobic respiration.

As you can see from the **Figure** above, a mitochondrion has an inner and outer membrane. The space between the inner and outer membrane is called the intermembrane space. The space enclosed by the inner membrane is called the **matrix**. The second stage of cellular respiration, the Krebs cycle, takes place in the matrix. The third stage, electron transport, takes place on the inner membrane.



Summary

- Cellular respiration takes the energy stored in glucose and transfers it to ATP.
- Cellular respiration has three stages: glycolysis, Krebs cycle, and electron transport.
- The inner and outer membranes of the mitochondrion play an important roles in aerobic respiration.

Review

1. Define cellular respiration.
2. What are the three stages of cellular respiration?

3. Describe the structure of the mitochondrion and discuss the importance of this structure in cellular respiration.
4. Assume that a new species of organism has been discovered. Scientists have observed its cells under a microscope and determined that they lack mitochondria. What type of cellular respiration would you predict that the new species uses? Explain your prediction.
5. When you exhale onto a cold window pane, water vapor in your breath condenses on the glass. Where does the water vapor come from?

Report Content Errors

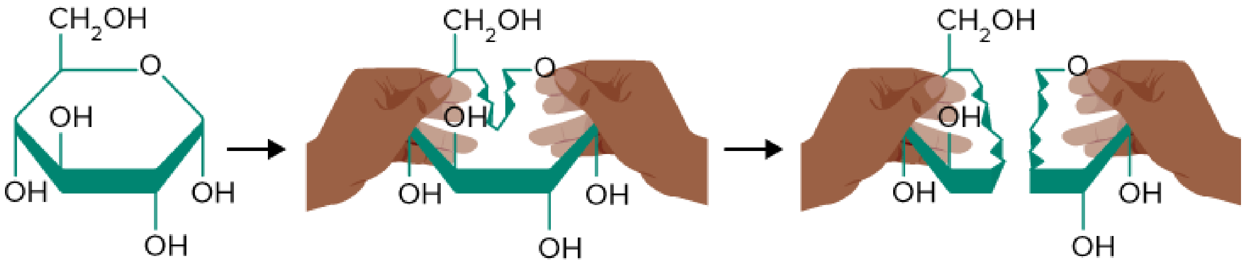
2.26 Glycolysis

FlexBooks 2.0 > Biology For High School Diploma > Glycolysis

Last Modified: Dec 02, 2021

What you will learn

- Steps of the glycolysis pathway
- Energy-carrying molecules formed during glycolysis



[Figure 1]

How do you slice a molecule of glucose in half?

With sharp knives? Not really. But you essentially slice it in half through glycolysis. This is an extremely important part of cellular respiration. It happens all the time, both with and without oxygen. And in the process, transfers some energy to ATP.

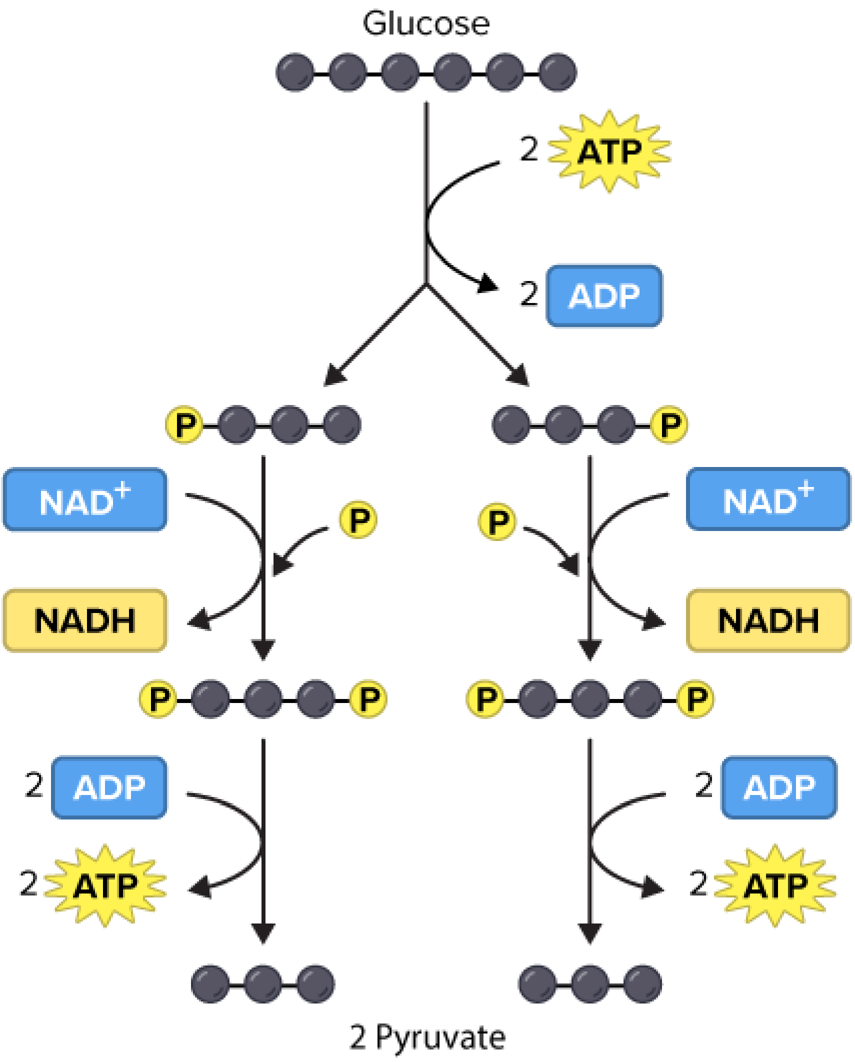
Cellular Respiration Stage I: Glycolysis

The first stage of cellular respiration is **glycolysis**. It does not require oxygen, and it does not take place in the mitochondrion - it takes place in the cytosol of the cytoplasm.

When was the last time you enjoyed yogurt on your breakfast cereal, or had a tetanus shot? These experiences may appear unconnected, but both relate to bacterium which do not use oxygen to make ATP. In fact, tetanus bacteria cannot survive if oxygen is present. However, *Lactobacillus acidophilus* (bacteria which make yogurt) and *Clostridium tetani* (bacteria which cause tetanus or lockjaw) share with nearly all organism the first stage of cellular respiration, glycolysis. Because glycolysis is universal, whereas **aerobic** (oxygen-requiring) cellular respiration is not, most biologists consider it to be the most fundamental and primitive pathway for making ATP.

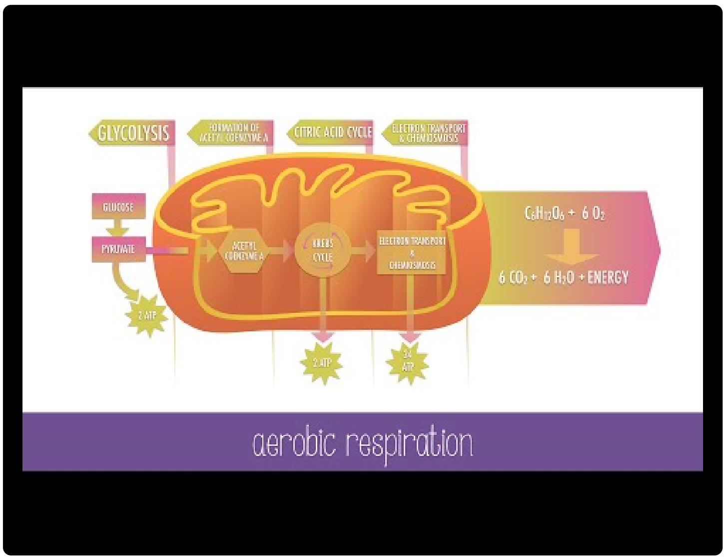
Splitting Glucose

The word *glycolysis* means "glucose splitting," which is exactly what happens in this stage. enzyme split a molecule of glucose into two molecules of **pyruvate** (also known as pyruvic acid). This occurs in several steps, as shown in the **Figure** below.



[Figure 2]

In glycolysis, glucose (C6) is split into two 3-carbon (C3) pyruvate molecules. This releases energy, which is transferred to ATP. How many ATP molecules are made during this stage of cellular respiration?



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Results of Glycolysis

Energy is needed at the start of glycolysis to split the glucose molecule into two pyruvate molecules. These two molecules go on to stage II of cellular respiration. The energy to split glucose is provided by two molecules of ATP. As glycolysis proceeds, energy is released, and the energy is used to make four molecules of ATP. As a result, there is a net gain of two ATP molecules during glycolysis. During this stage, high-energy electrons are also transferred to molecules of NAD^+ to produce two molecules of **NADH**, another energy-carrying molecule. NADH is used in stage III of cellular respiration to make more ATP.

DID YOU KNOW?

The most common pathway of glycolysis was described by Gustav Embden, Otto Meyerhof, and Jakub Karol Parnas. Glycolysis is therefore known as the Embden–Meyerhof–Parnas (EMP) pathway.

Summary

- The first stage of cellular respiration is glycolysis. It does not require oxygen.
- During glycolysis, one glucose molecule is split into two pyruvate molecules, using 2 ATP while producing 4 ATP and 2 NADH molecules.

Review

1. What is glycolysis?
2. Describe what happens during glycolysis. How many ATP and NADH molecules are gained during this stage?
3. Defend this statement: ‘‘Glycolysis is a universal and ancient pathway for making ATP’’.

Report Content Errors

2.27 Krebs Cycle

FlexBooks 2.0 > Biology For High School Diploma > Krebs Cycle

Last Modified: Dec 02, 2021

What will you learn

- The role of the Krebs cycle in cellular respiration

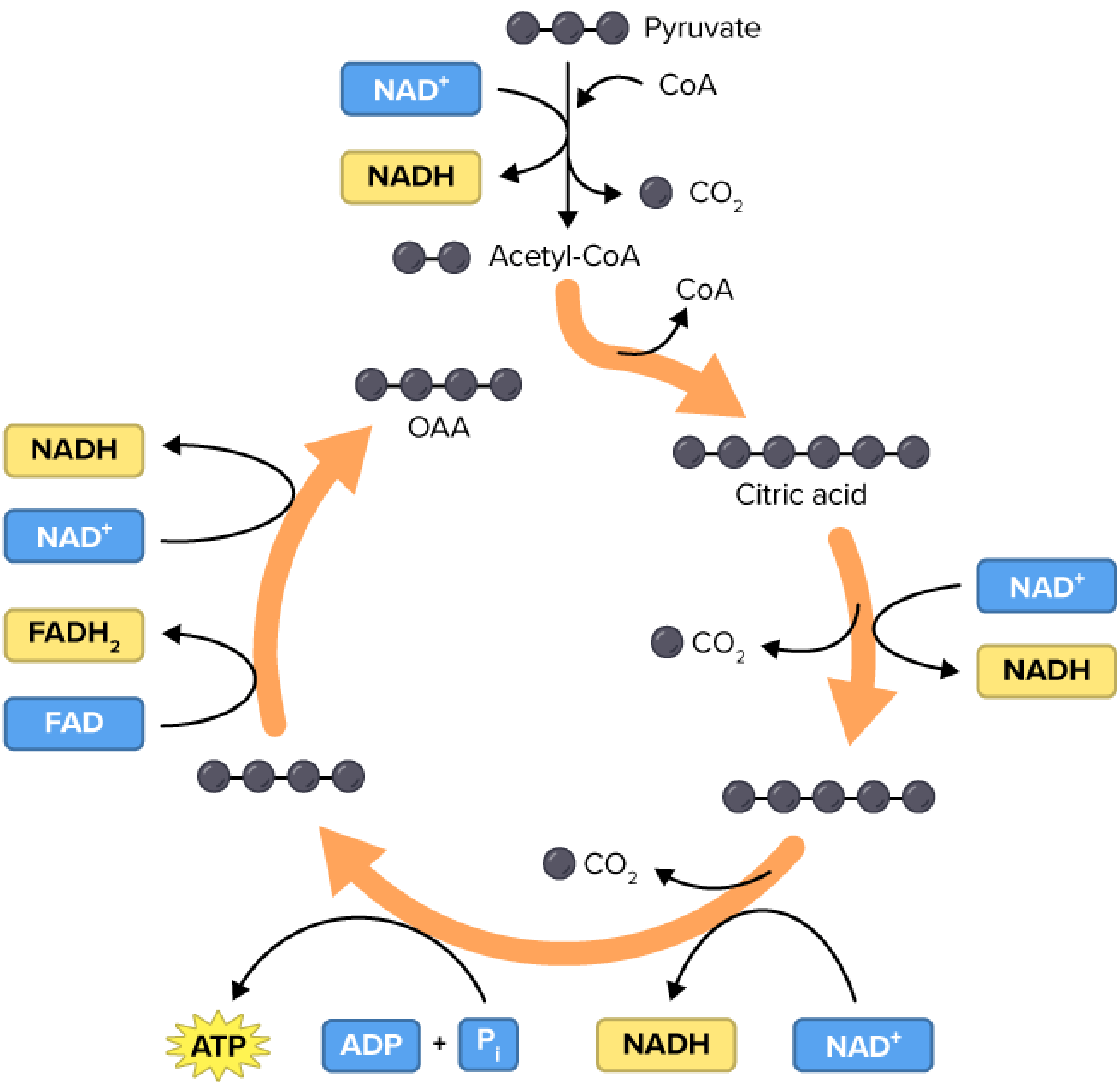
[Figure 1]

What type of acid do these fruits contain?

Citric acid. Citric acid is also the first product formed in the Krebs cycle, and therefore this acid occurs in the metabolism of virtually all living things.

Cellular Respiration Stage II: The Krebs Cycle

Recall that glycolysis, stage I of cellular respiration, produces two molecules of **pyruvate** (also known as pyruvic acid). These molecules enter the matrix of a mitochondrion, where they start the **Krebs cycle**. The reactions that occur next are shown in the **Figure** below.



[Figure 2]

The Krebs Cycle

The Krebs cycle starts with pyruvate from glycolysis. Each small circle in the diagram represents one carbon atom. For example, citric acid is a six-carbon molecule, and OAA (oxaloacetate) is a four-carbon molecule. Follow what happens to the carbon atoms as the cycle proceeds. In one turn through the cycle, how many molecules are produced of ATP? How many molecules of **NADH** and $FADH_2$ are produced?

Before the Krebs cycle begins, pyruvate, which has three carbon atoms, is split apart and combined with an enzyme known as CoA, which stands for coenzyme A. The product of this reaction is a two-carbon molecule called acetyl-CoA. The third carbon from pyruvate combines with oxygen to form carbon dioxide, which is released as a waste product. High-energy electrons are also released and captured in NADH.

Steps of the Krebs Cycle

The Krebs cycle itself actually begins when acetyl-CoA combines with a four-carbon molecule called OAA (oxaloacetate) (see the **Figure** above). This produces citric acid, which has six carbon atoms. This is why the Krebs cycle is also called the citric acid cycle.

After citric acid forms, it goes through a series of reactions that release energy. The energy is captured in molecules of NADH, ATP, and $FADH_2$, another energy-carrying compound. Carbon dioxide is also released as a waste product of these reactions.

The final step of the Krebs cycle regenerates OAA, the molecule that began the Krebs cycle. This molecule is needed for the next turn through the cycle. Two turns are needed because glycolysis produces two pyruvate molecules when it splits glucose.

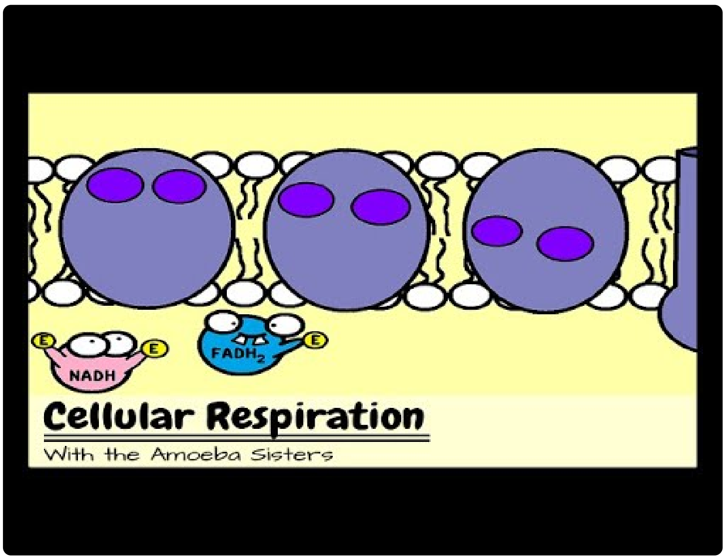
Results of the Krebs Cycle

After the second turn through the Krebs cycle, the original glucose molecule has been broken down completely. All six of its carbon atoms have combined with oxygen to form carbon dioxide. The energy from its chemical bond has been stored in a total of 16 energy-carrier molecules. These molecules are:

- 4 ATP (including 2 from glycolysis)
- 10 NADH (including 2 from glycolysis)
- 2 $FADH_2$

DID YOU KNOW?

The Krebs cycle is an important process not just for cellular respiration. The intermediate compounds in the Krebs cycle are used in the synthesis of other important biomolecules like amino acid and fatty acid.



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Summary

- The Krebs cycle is the second stage of cellular respiration.
- During the Krebs cycle, energy stored in pyruvate is transferred to NADH and $FADH_2$, and some ATP is produced.

Review

1. What is the Krebs cycle?
2. What are the products of the Krebs cycle?
3. Explain why two turns of the Krebs cycle are needed for each molecule of glucose.

Report Content Errors

2.28 Electron Transport

FlexBooks 2.0 > Biology For High School Diploma > Electron Transport

Last Modified: Dec 02, 2021

What you will learn

- The process of transport of high energy electrons along the **electron transport chain**
- Creation of the chemiosmotic gradient through electron transport
- Production of ATP using the chemiosmotic gradient

[Figure 1]

Train, truck, boat or plane?

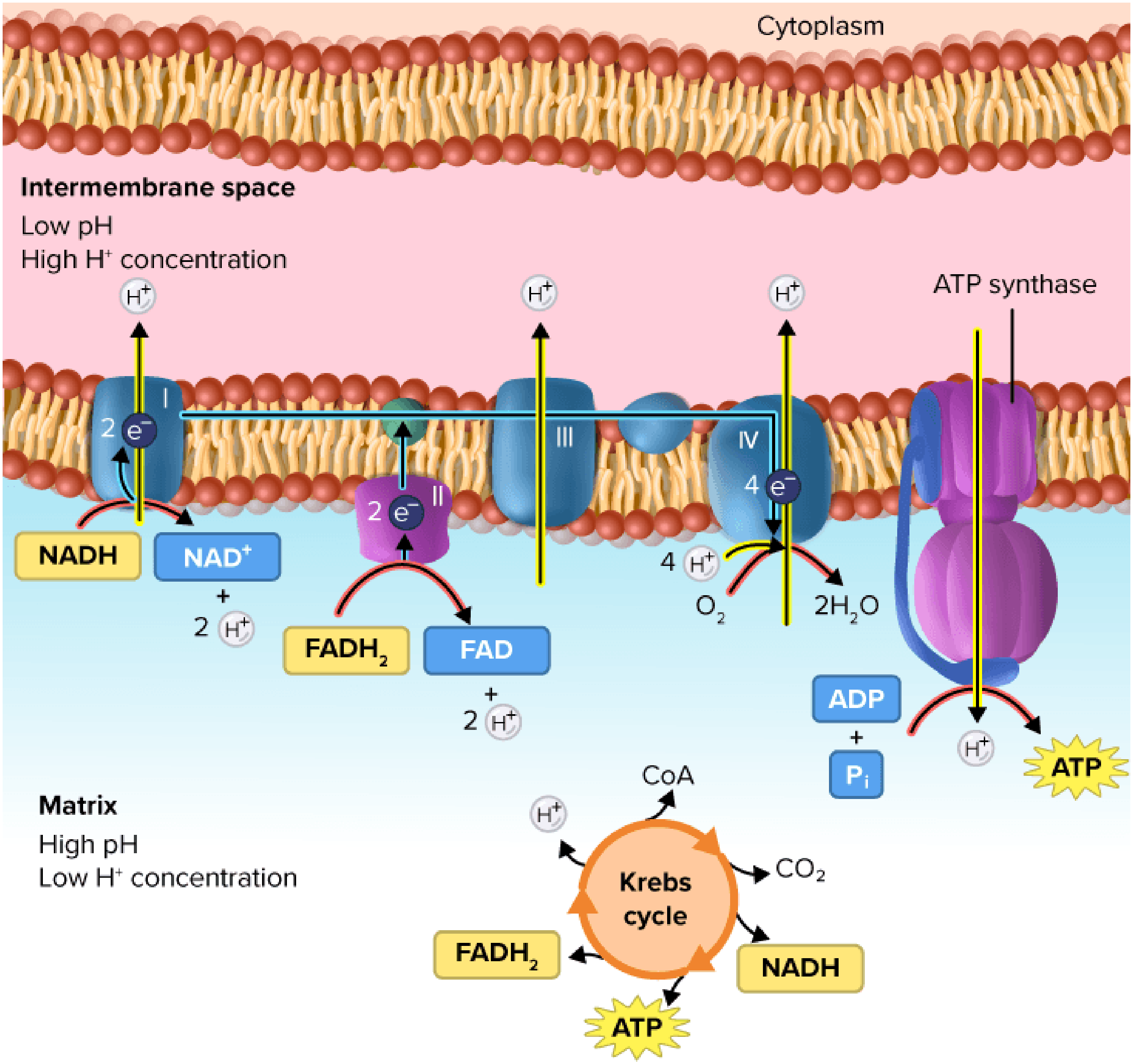
Ways to transport. To make ATP, energy must be "transported" - first from glucose to **NADH**, and then somehow passed to ATP. How is this done? With an electron transport chain.

Cellular Respiration Stage III: Electron Transport

Electron transport is the final stage of aerobic respiration. In this stage, energy from NADH and $FADH_2$, which result from glycolysis and the Krebs cycle, is transferred to ATP. Can you predict how this happens? (*Hint:* How does electron transport occur in photosynthesis?)

Transporting Electrons

High-energy electrons are released from NADH and $FADH_2$, and they move along **electron transport chains**, like those used in photosynthesis. The electron transport chains are on the inner membrane of the mitochondrion. As the high-energy electrons are transported along the chains, some of their energy is captured. This energy is used to pump hydrogen ion (from NADH and $FADH_2$) across the inner membrane, from the matrix into the intermembrane space. Electron transport in a mitochondrion is shown in the **Figure** below.



[Figure 2]

The electron transport chains on the inner membrane of the mitochondrion carry out the last stage of cellular respiration.

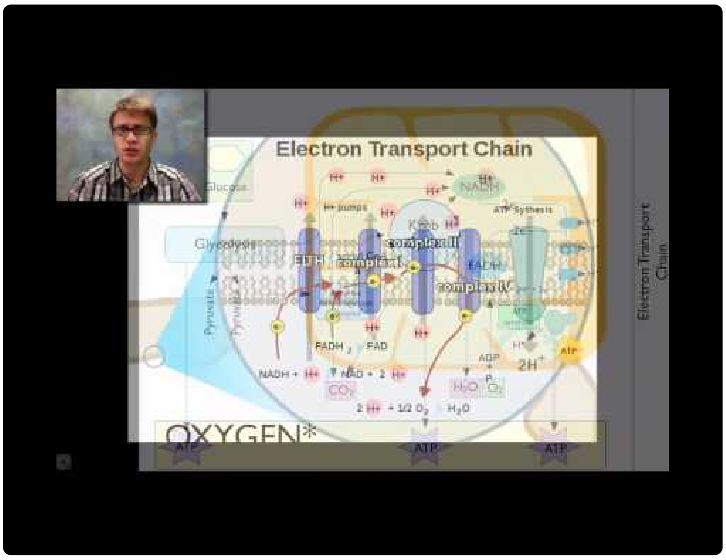
Making ATP

The pumping of hydrogen ions across the inner membrane creates a greater concentration of the ions in the intermembrane space than in the matrix. This **chemiosmotic gradient** causes the ions to flow back across the membrane into the matrix, where their concentration is lower. **ATP synthase** acts as a channel protein, helping the hydrogen ions to cross the membrane. It also acts as an enzyme, forming ATP from ADP and inorganic phosphate. After passing through the electron transport chain, the "spent" electrons combine with oxygen to form water. This is why oxygen is needed; in the absence of oxygen, this process cannot occur.

DID YOU KNOW?

In anaerobic environments, molecules other than oxygen like nitrate, iron(III), sulfate, and carbon dioxide are used that produce less energy as compared to aerobic respiration.

How much ATP is produced? The two NADH produced in the cytoplasm produces 2 to 3 ATP each (4 to 6 total) by the electron transport system, the 8 NADH produced in the mitochondria produces three ATP each (24 total), and the 2 $FADH_2$ adds its electrons to the electron transport system at a lower level than NADH, so they produce two ATP each (4 total). This results in the formation of 34 ATP during the electron transport stage.



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Summary

- Electron transport is the final stage of aerobic respiration. In this stage, energy from NADH and $FADH_2$ is transferred to ATP.
- During electron transport, energy is used to pump hydrogen ions across the mitochondrial inner membrane, from the matrix into the intermembrane space.
- A chemiosmotic gradient causes hydrogen ions to flow back across the mitochondrial membrane into the matrix, through ATP synthase, producing ATP.

Review

1. Summarize the overall task of Stage III of aerobic respiration.
2. Explain the chemiosmotic gradient.
3. What is the maximum number of ATP molecules that can be produced during the electron transport stage of aerobic respiration?

Report Content Errors

2.29 Fermentation

FlexBooks 2.0 > Biology For High School Diploma > Fermentation

Last Modified: Dec 02, 2021

What you will learn

- How fermentation makes ATP using only the glycolysis pathway
- What happens in lactic acid and **alcoholic fermentation**

[Figure 1]

When you combine grapes and yeast, what have you begun to make?

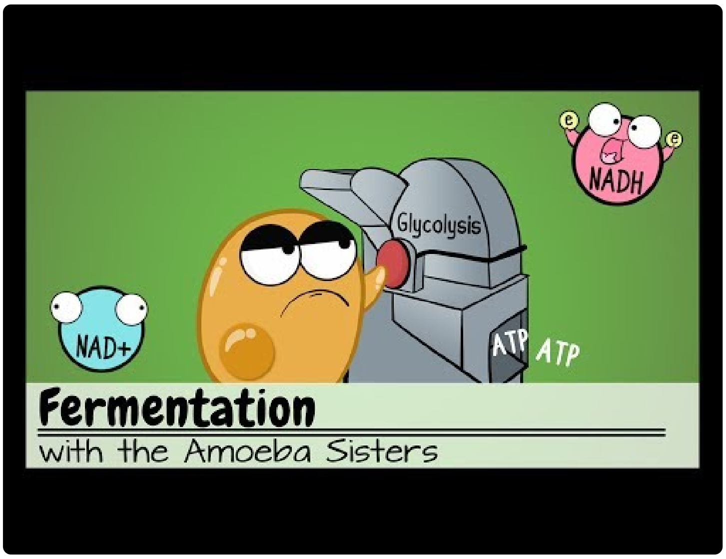
Wine. It may be slightly more complicated than that, but you need to start with grapes and yeast, and allow a natural fermentation process to occur. Essentially, this is respiration without oxygen.

Anaerobic Respiration: Fermentation

Today, most living things use oxygen to make ATP from glucose. However, many living things can also make ATP without oxygen. This is true of some plants and fungus and also of many bacterium. These organism use aerobic respiration when oxygen is present, but when oxygen is in short supply, they use **anaerobic respiration** instead. Certain bacteria can only use anaerobic respiration. In fact, they may not be able to survive at all in the presence of oxygen.

An important way of making ATP without oxygen is called **fermentation**. It involves glycolysis, but not the other two stages of aerobic respiration. Many bacteria and yeasts carry out fermentation. People use these organisms to make yogurt, bread, wine, and biofuels. Human muscle cell also use fermentation. This occurs when muscle cells cannot get oxygen fast enough to meet their energy needs through aerobic respiration.

There are two types of fermentation: **lactic acid fermentation** and alcoholic fermentation. Both types of fermentation are described below.



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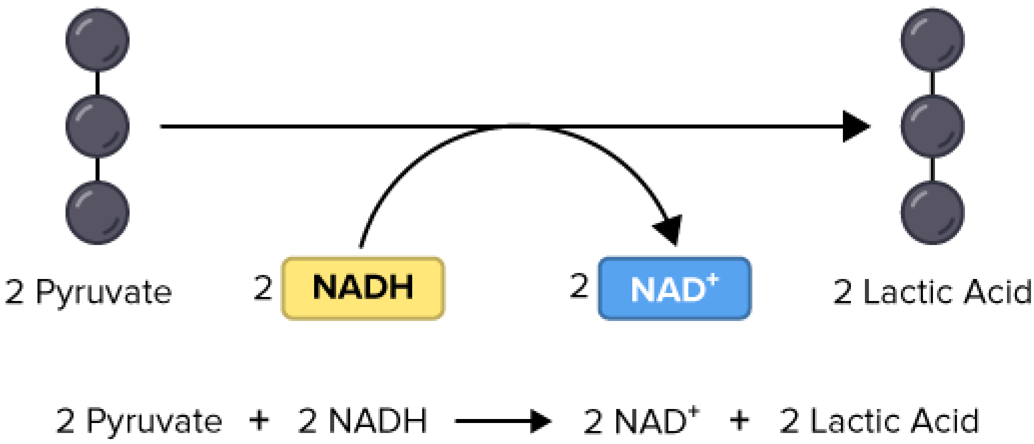
Lactic Acid Fermentation

In **lactic acid fermentation**, **pyruvate** (also known as pyruvic acid) from glycolysis changes to lactic acid. This is shown in the **Figure** below. In the process, NAD^+ forms from NADH. NAD^+, in turn, lets glycolysis continue. This results in additional molecules of ATP. This type of fermentation is carried out by the bacteria in yogurt. It is also used by your own muscle cells when you work them hard and fast.



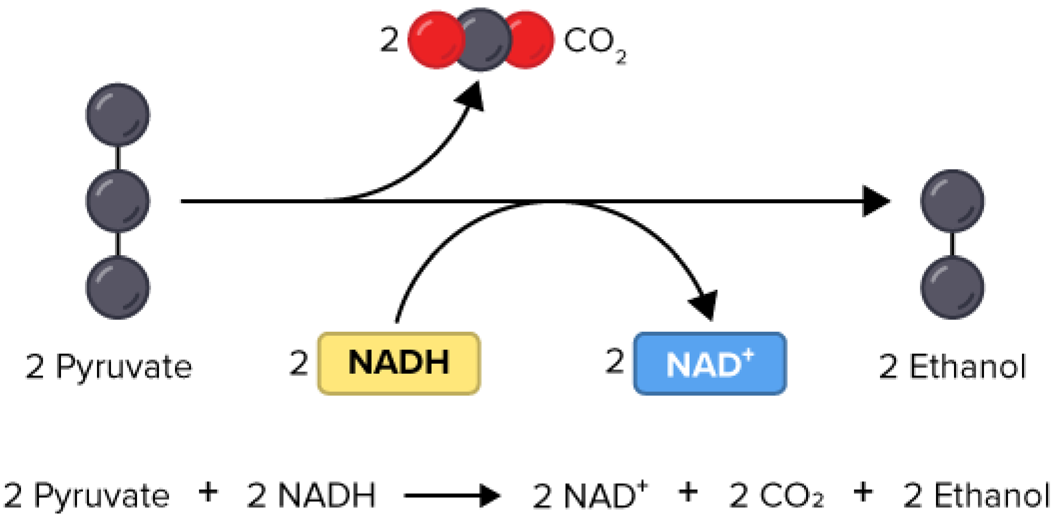
[Figure 2]

Lactic acid fermentation produces lactic acid and NAD^+. The NAD^+ cycles back to allow glycolysis to continue so more ATP is made. Each circle represents a carbon atom.

Did you ever run a race and notice that your muscles feel tired and sore afterward? This is because your muscle cells used lactic acid fermentation for energy. This causes lactic acid to build up in the muscles. It is the buildup of lactic acid that makes the muscles feel tired and sore.

Alcoholic Fermentation

In **alcoholic fermentation**, pyruvate changes to alcohol and carbon dioxide. This is shown in the **Figure** below. NAD^+ also forms from NADH, allowing glycolysis to continue making ATP. This type of fermentation is carried out by yeasts and some bacteria. It is used to make bread, wine, and biofuels.



[Figure 3]

Alcoholic fermentation produces ethanol and NAD+. The NAD+ allows glycolysis to continue making ATP.

Have your parents ever put corn in the gas tank of their car? They did if they used gas containing ethanol. Ethanol is produced by alcoholic fermentation of the glucose in corn or other plants. This type of fermentation also explains why bread dough rises. Yeasts in bread dough use alcoholic fermentation and produce carbon dioxide gas. The gas forms bubbles in the dough, which cause the dough to expand. The bubbles also leave small holes in the bread after it bakes, making the bread light and fluffy. Do you see the small holes in the slice of bread in the **Figure** below?

[Figure 4]

The small holes in bread are formed by bubbles of carbon dioxide gas. The gas was produced by alcoholic fermentation carried out by yeast.

https://flexbooks.ck12.org/flx/render/embeddedobject/313085

DID YOU KNOW?

During the 1850s, the renowned French microbiologist Louis Pasteur was the first person to describe the role of microorganisms in starting the fermentation process.

Summary

- Fermentation makes ATP without oxygen, which involves glycolysis only.
- Fermentation recycles NAD^+, and produces 2 ATPs.
- In lactic acid fermentation, pyruvate from glycolysis changes to lactic acid. This type of fermentation is carried out by the bacteria in yogurt, and by your own muscle cells.
- In alcoholic fermentation, pyruvate changes to alcohol and carbon dioxide. This type of fermentation is carried out by yeasts and some bacteria.

Review

1. What is fermentation?
2. Name two types of fermentation.
3. What is the main advantage of aerobic respiration? Of anaerobic respiration?
4. What process produces fuel for motor vehicles from living plant products? What is the waste product of this process?
5. Compare and contrast lactic acid fermentation and alcoholic fermentation. Include examples of organisms that use each type of fermentation.

Report Content Errors

2.30 Anaerobic and Aerobic Respiration

FlexBooks 2.0 > Biology For High School Diploma > Anaerobic and Aerobic Respiration

Last Modified: Dec 02, 2021

What will you learn

- The difference between **aerobic** and **anaerobic respiration**
- Advantages of aerobic and anaerobic respiration

[Figure 1]

Why oxygen?

Oxygen is the final electron acceptor at the end of the electron transport chain of **aerobic respiration**. In the absence of oxygen, only a few ATP are produced from glucose. In the presence of oxygen, many more ATP are made.

The Presence of Oxygen

There are two types of cellular respiration: aerobic and **anaerobic**. One occurs in the presence of oxygen (**aerobic**), and one occurs in the absence of oxygen (**anaerobic**). Both begin with **glycolysis** - the splitting of glucose.

Glycolysis is an anaerobic process - it does not need oxygen to proceed. This process produces a minimal amount of ATP. The Krebs cycle and electron transport do need oxygen to proceed, and in the presence of oxygen, these processes produce much more ATP than glycolysis alone.

Scientists think that glycolysis evolved before the other stages of cellular respiration. This is because the other stages need oxygen, whereas glycolysis does not, and there was no oxygen in Earth's atmosphere when life first evolved about 3.5 to 4 billion years ago. Cellular respiration that proceeds without oxygen is called **anaerobic respiration**.

Then, about 2 or 3 billion years ago, oxygen was gradually added to the atmosphere by early photosynthetic bacterium (cyanobacteria). After that, living things could use oxygen to break down glucose and make ATP. Today, most organism make ATP with oxygen. They follow glycolysis with the Krebs cycle and electron transport to make more ATP than by glycolysis alone. Cellular respiration that proceeds in the presence of oxygen is called **aerobic respiration**.

Aerobic vs. Anaerobic Respiration: A Comparison

Aerobic respiration, which takes place in the presence of oxygen, evolved after oxygen was added to Earth's atmosphere. This type of respiration is useful today because the atmosphere is now 21% oxygen. However, some anaerobic organisms that evolved before the atmosphere contained oxygen have survived to the present. Therefore, anaerobic respiration, which takes place without oxygen, must also have advantages.

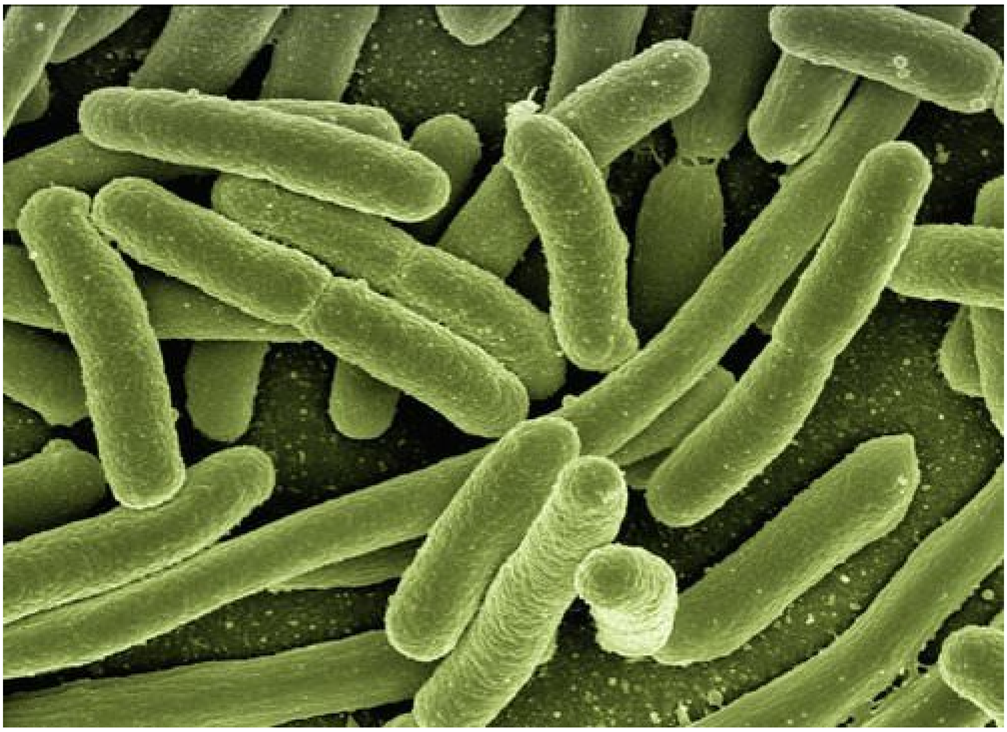
Advantages of Aerobic Respiration

A major advantage of aerobic respiration is the amount of energy it releases. Without oxygen, organisms can split glucose into just two molecules of pyruvate. This releases only enough energy to make two ATP molecules. With oxygen, organisms can break down glucose all the way to carbon dioxide. This releases enough energy to produce up to 38 ATP molecules. Thus, aerobic respiration releases much more energy than anaerobic respiration.

The amount of energy produced by aerobic respiration may explain why aerobic organisms came to dominate life on Earth. It may also explain how organisms were able to become multicellular and increase in size.

Advantages of Anaerobic Respiration

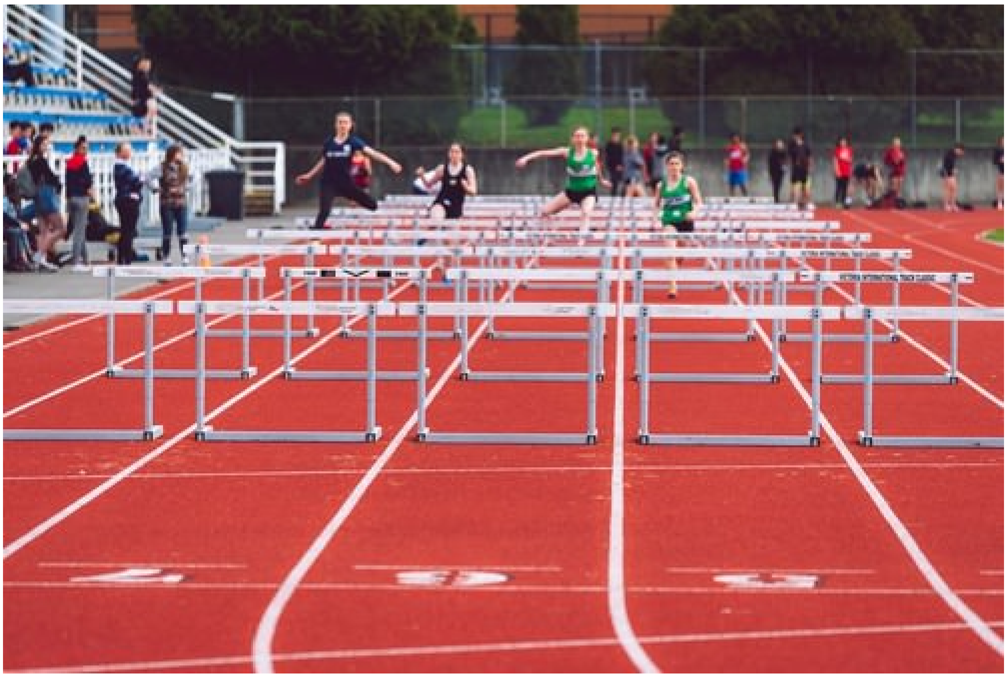
One advantage of anaerobic respiration, also known as fermentation, is obvious. It lets organisms live in places where there is little or no oxygen. Such places include deep water, soil, and the digestive tracts of animal such as humans (see the **Figure** below).



[Figure 2]

E. coli bacteria are anaerobic bacteria that live in the human digestive tract.

Another advantage of anaerobic respiration is its speed. It produces ATP very quickly. For example, it lets your muscles get the energy they need for short bursts of intense activity (see the **Figure** below). Aerobic respiration, on the other hand, produces ATP more slowly.



[Figure 3]

The muscles of these hurdlers need to use anaerobic respiration for energy. It gives them the energy they need for the short-term, intense activity of this sport.

DID YOU KNOW?

Anaerobic bacteria can grow in injured human tissue that do not have oxygen supply through blood due to damaged blood vessel. This results in infections like tetanus and gangrene.

Summary

- Cellular respiration always begins with glycolysis, which can occur either in the absence or presence of oxygen.
- Cellular respiration that proceeds in the absence of oxygen is anaerobic respiration.
- Cellular respiration that proceeds in the presence of oxygen is aerobic respiration.
- Anaerobic respiration evolved prior to aerobic respiration.
- Aerobic respiration produces much more ATP than anaerobic respiration.
- Anaerobic respiration occurs more quickly than aerobic respiration.

Review

1. Define aerobic and anaerobic respiration.
2. What process is common to both aerobic and anaerobic respiration?
3. Why do scientists think that glycolysis evolved before the other stages of cellular respiration?
4. What is the main advantage of aerobic respiration? Of anaerobic respiration?
5. Tanya is on the high school track team and runs the 100-meter sprint. Marissa is on the cross-country team and runs 5-kilometer races. Explain which type of respiration the muscle cells in each runner's legs use.

Report Content Errors

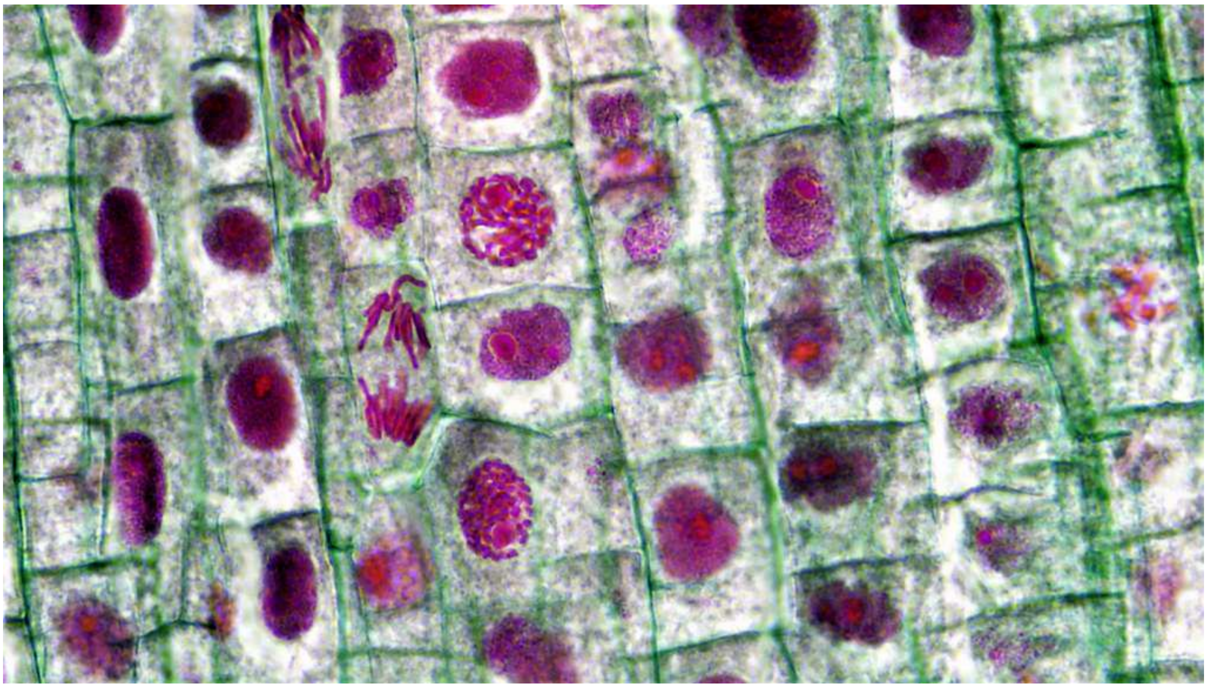
2.31 Cell Division

FlexBooks 2.0 > Biology For High School Diploma > Cell Division

Last Modified: Feb 08, 2022

What you will learn

- What is cell division
- Cell division process in prokaryote and eukaryote



[Figure 1]

Where do cells come from?

No matter what the cell, all cells come from preexisting cells through the process of cell division. The cell may be the simplest bacterium, or a complex muscle, bone, or blood cell. The cell may comprise the whole organism, or be just one cell of trillions.

Cell Division

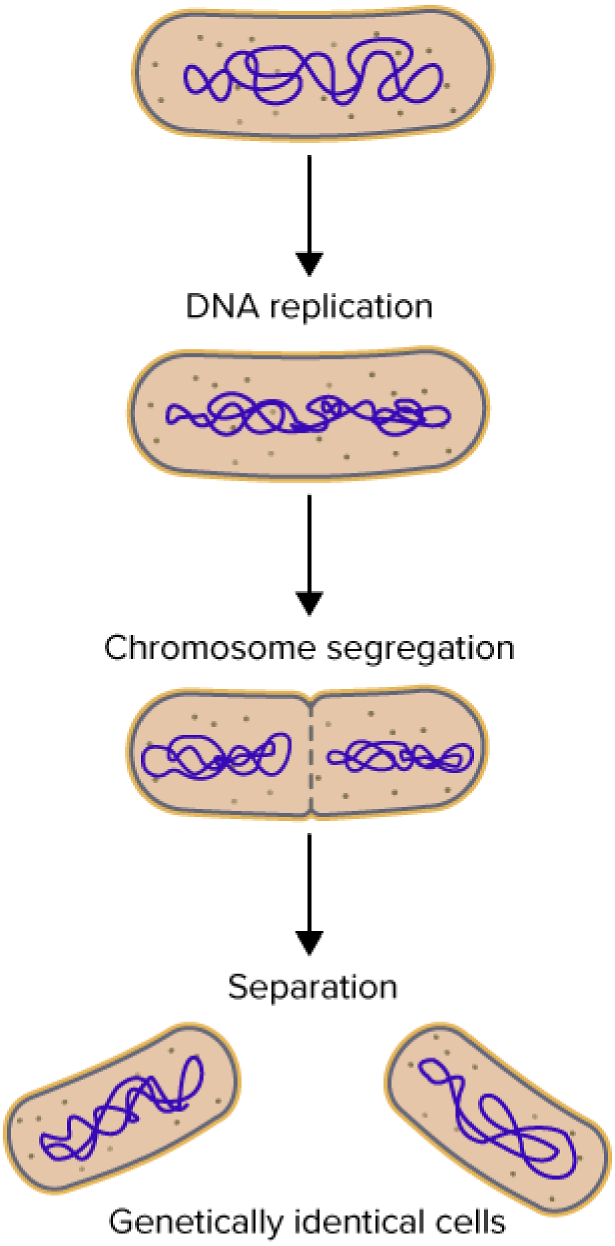
You consist of a great many cells, but like all other organisms, you started life as a single cell. How did you develop from a single cell into an organism with trillions of cells? The answer is cell division. After cells grow to their maximum size, they divide into two new cells. These new cells are small at first, but they grow quickly and eventually divide and produce more new cells. This process keeps repeating in a continuous cycle.

Cell division is the process in which one cell, called the **parent cell**, divides to form two new cells, referred to as **daughter cell**. How this happens depends on whether the cell is prokaryotic or eukaryotic.

Cell division is simpler in prokaryotes than eukaryotes because prokaryotic cell themselves are simpler. Prokaryotic cells have a single circular **chromosome**, no nucleus, and few other cell structures. eukaryotic cell, in contrast, have multiple chromosomes contained within a nucleus, and many other organelle. All of these cell parts must be duplicated and then separated when the cell divides. A **chromosome** is a coiled structure made of DNA and protein, and will be the focus of a subsequent concept.

Cell Division in Prokaryotes

Most prokaryotic cells divide by the process of **binary fission**.



[Figure 2]

Steps of Binary Fission. Prokaryotic cells divide by binary fission. This is also how many single-celled organisms reproduce.

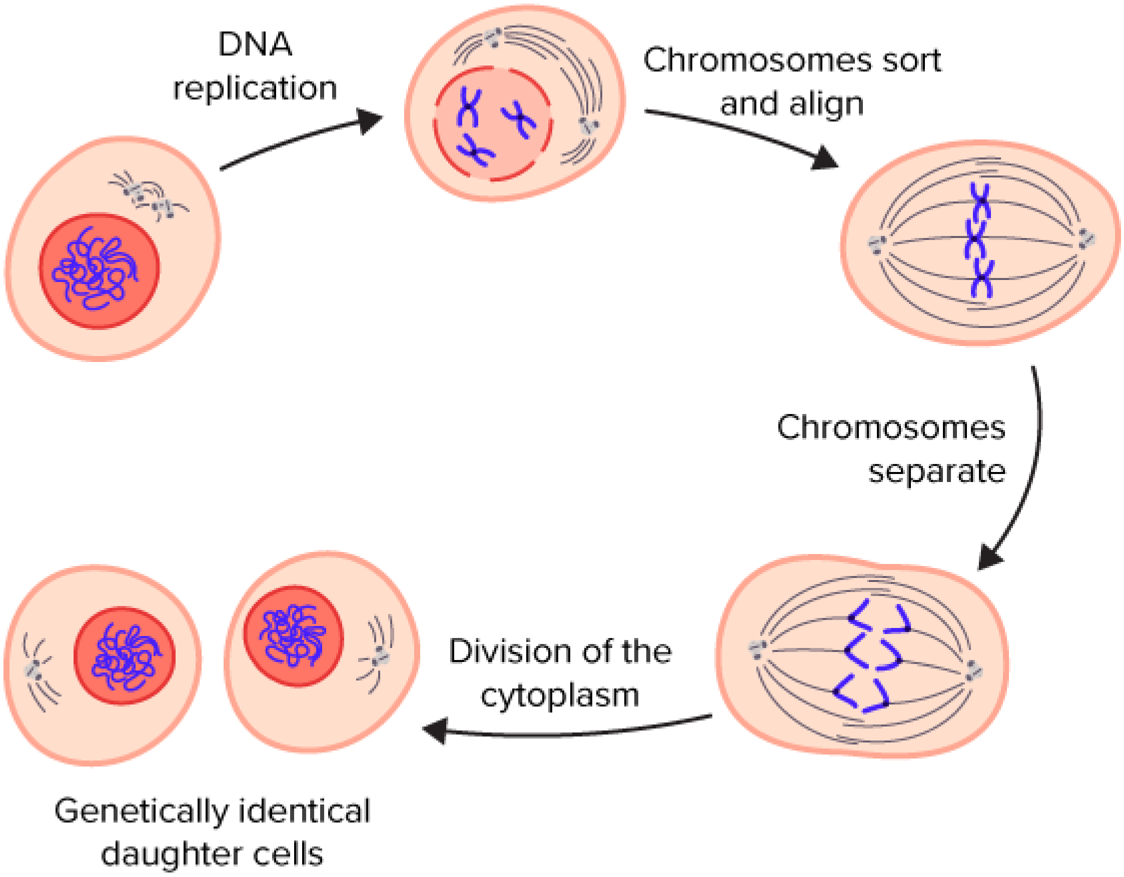
Binary fission can be described as a series of steps, although it is actually a continuous process. The steps are described below and also illustrated in the **Figure** above. They include DNA replication, chromosome segregation, and finally the separation into two daughter cells.

- Step 1: DNA Replication. Just before the cell divides, its DNA is copied in a process called DNA replication. This results in two identical chromosomes instead of just one. This step is necessary so that when the cell divides, each daughter cell will have its own chromosome.
- Step 2: Chromosome Segregation. The two chromosomes segregate, or separate, and move to opposite ends (known as "poles") of the cell. This occurs as each copy of DNA attaches to different parts of the cell membrane.
- Step 3: Separation. A new plasma membrane starts growing into the center of the cell, and the cytoplasm splits apart, forming two daughter cells. As the cell begins to pull apart, the new and the original chromosomes are separated. The two daughter cells that result are genetically identical to each other and to the parent cell. New cell wall must also form around the two cells.

Cell Division in Eukaryotes

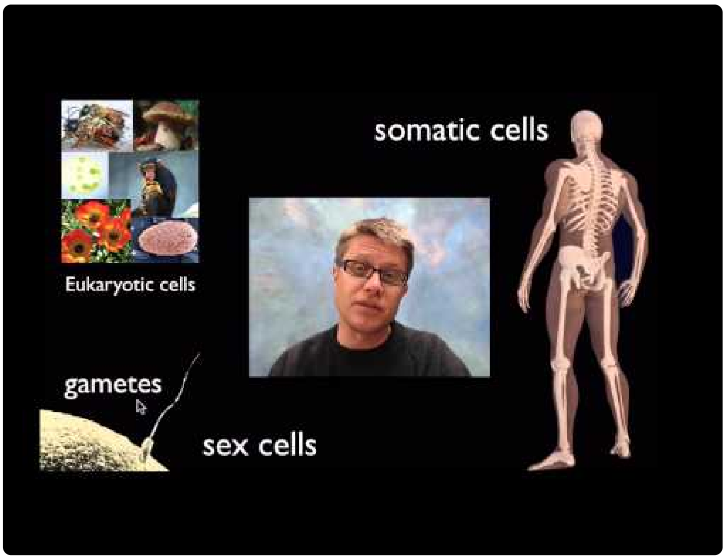
Cell division is more complex in eukaryotes than prokaryotes. Prior to dividing, all the DNA in a eukaryotic cell's multiple chromosomes is replicated. Its organelles are also duplicated. Then, when the cell divides, it occurs in two major steps:

1. The first step is **mitosis**, a multi-phase process in which the nucleus of the cell divides. During mitosis, the nuclear membrane breaks down and later reforms. The chromosomes are also sorted and separated to ensure that each daughter cell receives a diploid number (2 sets) of chromosomes. In humans, that number of chromosomes is 46 (23 pairs). Mitosis is described in greater detail in a subsequent concept.
2. The second major step is **cytokinesis**. As in prokaryotic cells, the cytoplasm must divide. Cytokinesis is the division of the cytoplasm in eukaryotic cells, resulting in two genetically identical daughter cells.



[Figure 3]

Steps of cell division in eukaryotes.



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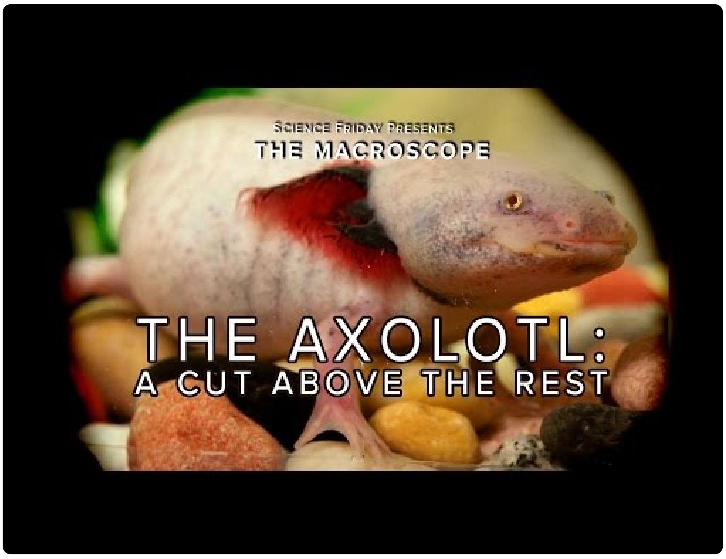
Science Friday: The Axolotl: A Cut Above the Rest

The axolotl is an animal with the incredible ability to regenerate its legs. In this video by science Friday, Dr. Susan Bryant discusses the research on how these animals are able to accomplish this amazing feat.



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Summary

- Cell division is part of the life cycle of virtually all cells. Cell division is the process in which one cell divides to form two new cells.
- Most prokaryotic cells divide by the process of binary fission.
- In eukaryotes, cell division occurs in two major steps: mitosis and cytokinesis.

Review

1. Describe binary fission.

2. What is mitosis?
3. Contrast cell division in prokaryotes and eukaryotes. Why are the two types of cell division different?

Report Content Errors

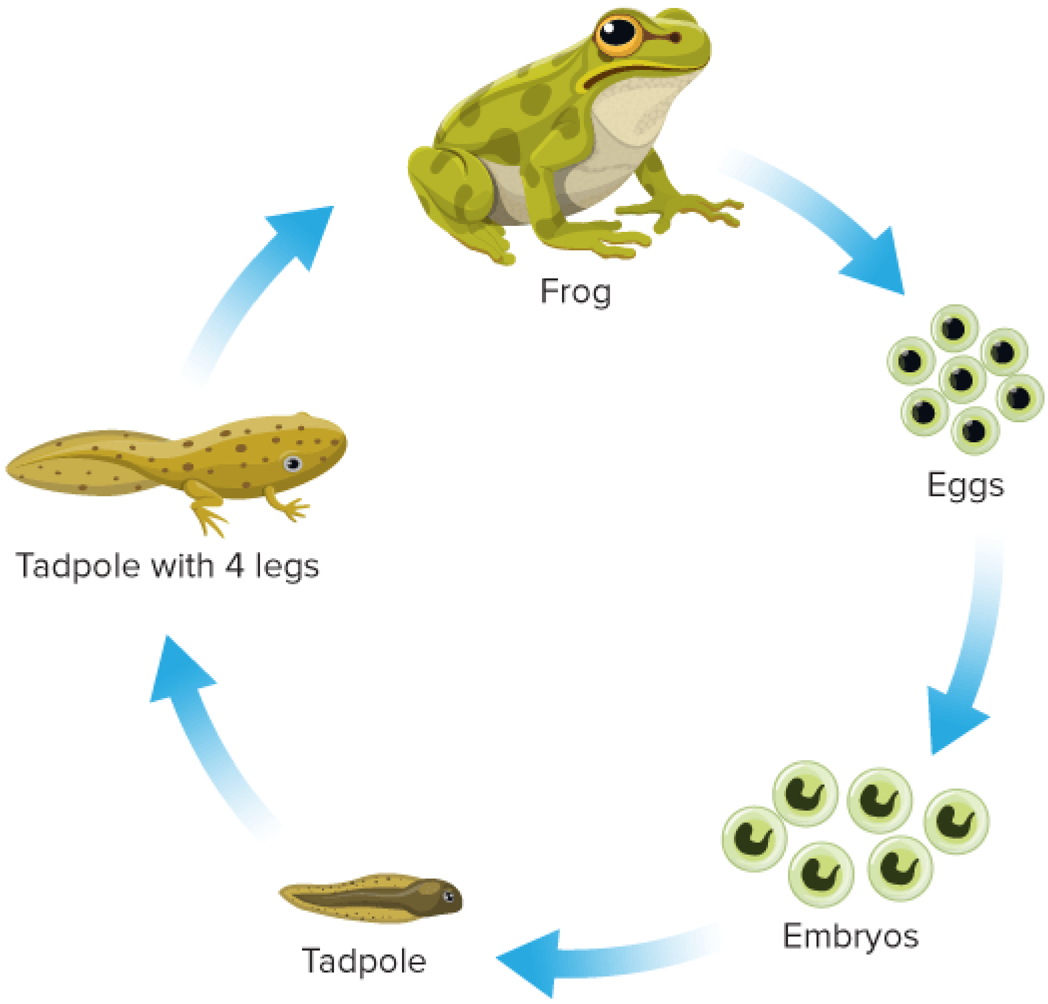
2.32 Cell Cycle

FlexBooks 2.0 > Biology For High School Diploma > Cell Cycle

Last Modified: Apr 25, 2022

What you will learn

- Phases in the cell cycle of eukaryotes
- How the cell cycle is regulated



[Figure 1]

Do cells have a life cycle?

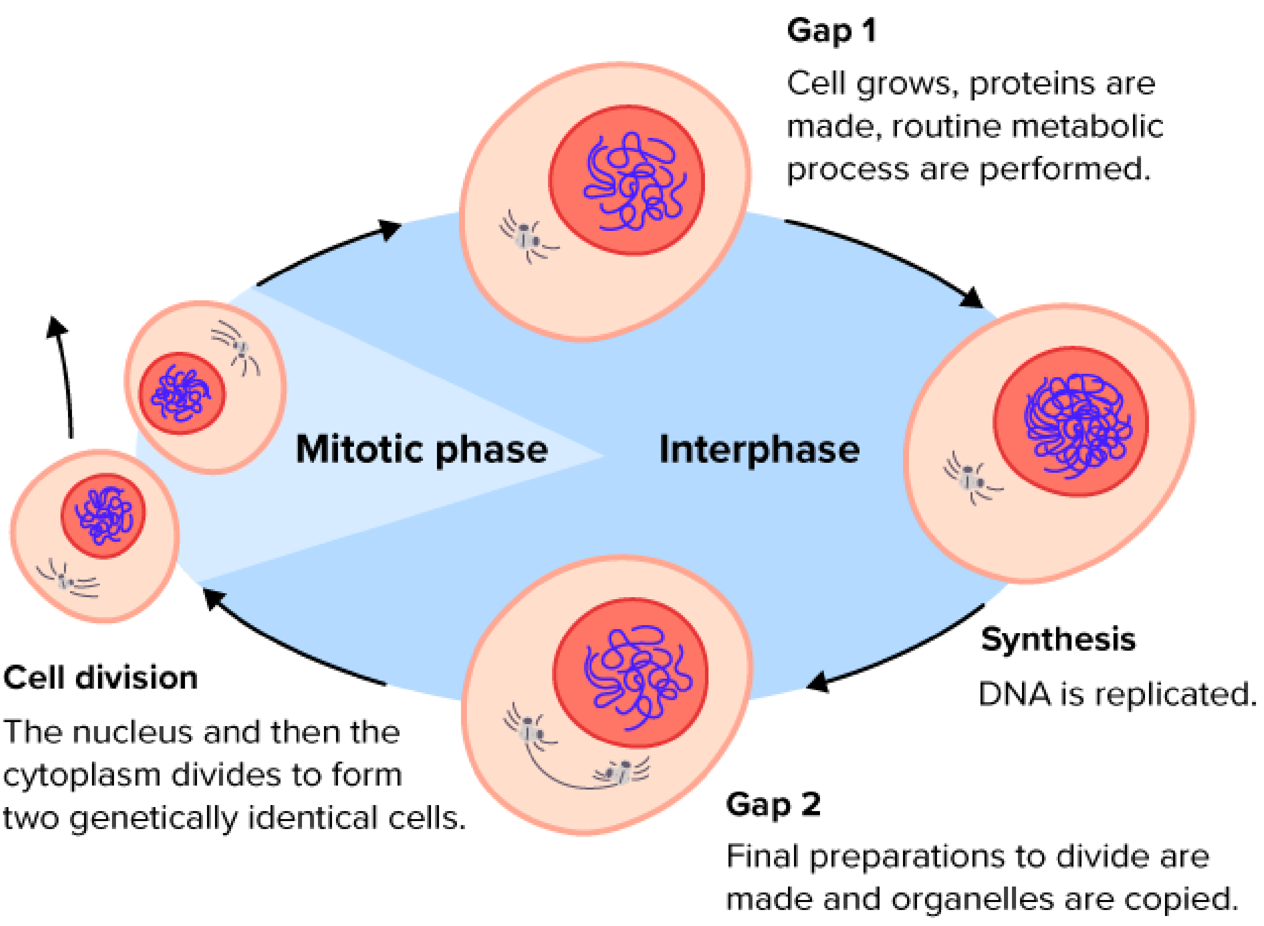
Yes, just like a frog passes through different phases from a tadpole to an adult frog, there are a series of phases in a cell's life as it gets ready to divide. The sequence of phases leading up to cell division and then ending with cell division itself is called the cell cycle.

The Cell Cycle

The **cell cycle** is a repeating series of events that includes growth, DNA synthesis, and cell division. The eukaryotic cell spends most of its "life" in **interphase** of the cell cycle, which can be subdivided into the three phases, G1, S and G2. Cell division is just one of several stages that a cell goes through during its lifetime. The cell cycle in prokaryote is quite simple: the cell grows, its DNA replicates, and the cell divides. In eukaryote, the cell cycle is more complicated.

The Eukaryotic Cell Cycle

The cell cycle of a eukaryotic cell is represented below. As you can see, the eukaryotic cell cycle has several phases. The **mitotic phase** (M) actually includes both mitosis and cytokinesis. This is when the nucleus and then the cytoplasm divide. The other three phases (G1, S, and G2) are generally grouped together as **interphase**. During interphase, the cell grows, performs routine life processes, and prepares to divide. These phases are discussed below.



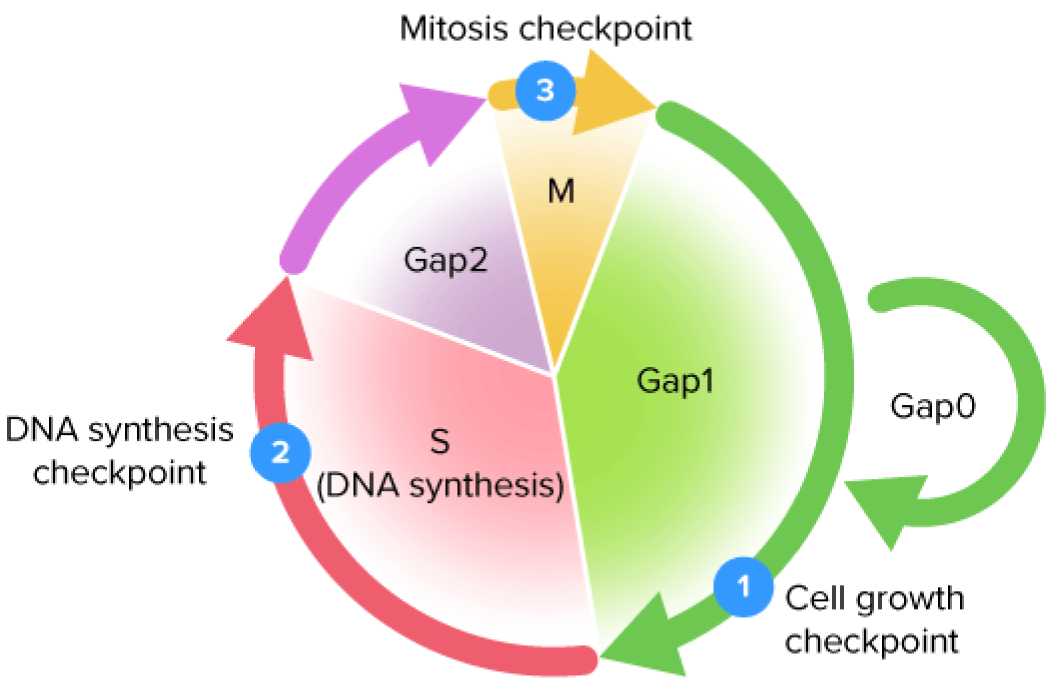
Interphase

Interphase of the eukaryotic cell cycle can be subdivided into the following three phases:

- **Gap 1 (G1):** during this phase, the cell grows rapidly, while performing routine metabolic processes. It also makes protein needed for **DNA replication** and copies some of its organelle in preparation for cell division. This phase is sometimes referred to as Growth Phase 1.
- **synthesis phase (S):** during this phase, the cell's DNA is copied in the process of **DNA replication**.
- **Gap 2 (G2):** during this phase, the cell makes final preparations to divide. For example, it makes additional proteins and organelles. This phase is sometimes referred to as Growth Phase 2.

Control of the Cell Cycle

If the cell cycle occurred without regulation, cells might go from one phase to the next before they were ready. What controls the cell cycle? How does the cell know when to grow, synthesize DNA, and divide? The cell cycle is controlled mainly by regulatory protein. These proteins control the cycle by signaling the cell to either start or delay the next phase of the cycle. They ensure that the cell completes the previous phase before moving on. Regulatory proteins control the cell cycle at key checkpoints, which are shown in the **Figure** below. There are a number of main checkpoints.



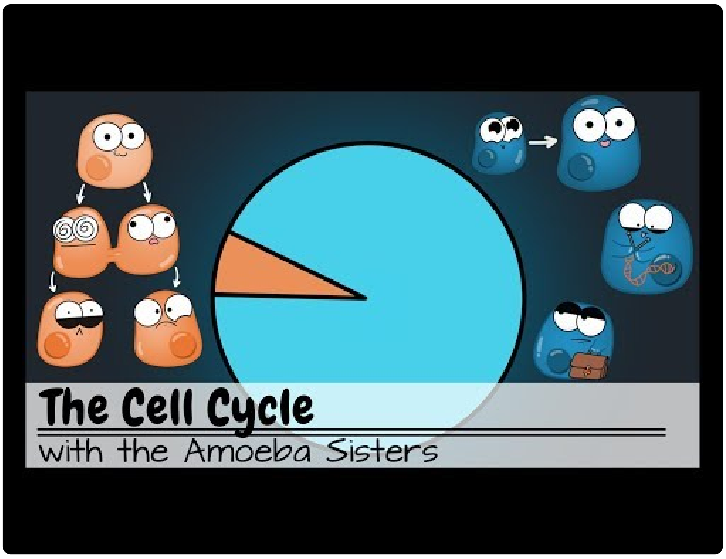
[Figure 2]

Checkpoints in the eukaryotic cell cycle ensure that the cell is ready to proceed before it moves on to the next phase of the cycle.

1. **Cell growth checkpoint (G1 checkpoint):** The G1 checkpoint, just before entry into S phase, makes the key decision of whether the cell should divide.
2. **DNA synthesis checkpoint (S checkpoint):** The S checkpoint determines if the DNA has been replicated properly.
3. **Mitosis checkpoint (Mitotic spindle checkpoint):** The mitotic spindle checkpoint occurs at the point in metaphase where all the chromosome should have aligned at the mitotic plate.

Cancer and the Cell Cycle

cancer is a disease that occurs when the cell cycle is no longer regulated. This may happen because a cell's DNA becomes damaged. Damage can occur due to exposure to hazards such as radiation or toxic chemicals. Cancerous cells generally divide much faster than normal cells. They may form a mass of abnormal cells called a **tumor**. The rapidly dividing cells take up nutrient and space that normal cells need. This can damage tissue and organ and eventually lead to death.



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DID YOU KNOW?

A group of proteins called cyclins along with enzyme known as cyclin-dependent kinases regulate the cell cycle checkpoints. The concentration of cyclin proteins varies during the cell cycle.

Summary

- The cell cycle is a repeating series of events that cells go through. It includes growth, DNA synthesis, and cell division. In eukaryotic cells, there are two growth phases, and cell division includes mitosis and cytokinesis.
- The cell cycle is controlled by regulatory proteins at three key checkpoints in the cycle. The proteins signal the cell to either start or delay the next phase of the cycle.
- Cancer is a disease that occurs when the cell cycle is no longer regulated. Cancer cells grow rapidly and may form a mass of abnormal cells called a tumor.

Review

1. Identify the phases of the eukaryotic cell cycle.
2. What happens during interphase?
3. Define cancer.
4. Cells go through a series of events that include growth, DNA synthesis, and cell division. Why are these events best represented by a cycle diagram?
5. Explain how the cell cycle is regulated.
6. Why is DNA replication essential to the cell cycle?

Report Content Errors

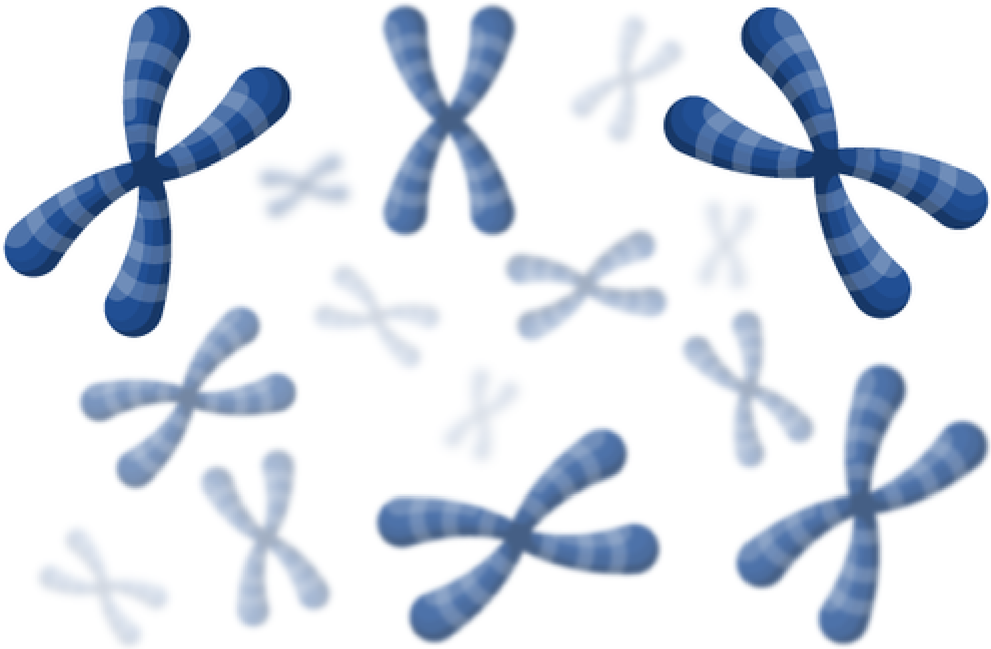
2.33 Chromosomes

FlexBooks 2.0 > Biology For High School Diploma > Chromosomes

Last Modified: Jan 25, 2022

What you will learn

- Chromosomes and their structure
- How **gene** are related to chromosomes
- The number of chromosomes in human cell



[Figure 1]

How is it assured that every cell in your body has the same DNA?

Chromosomes, like those shown here, must form prior to cell division, to ensure that each daughter cell receives a complete set of **genetic material**. Essentially, each new cell receives half of each "X-shaped" chromosome.

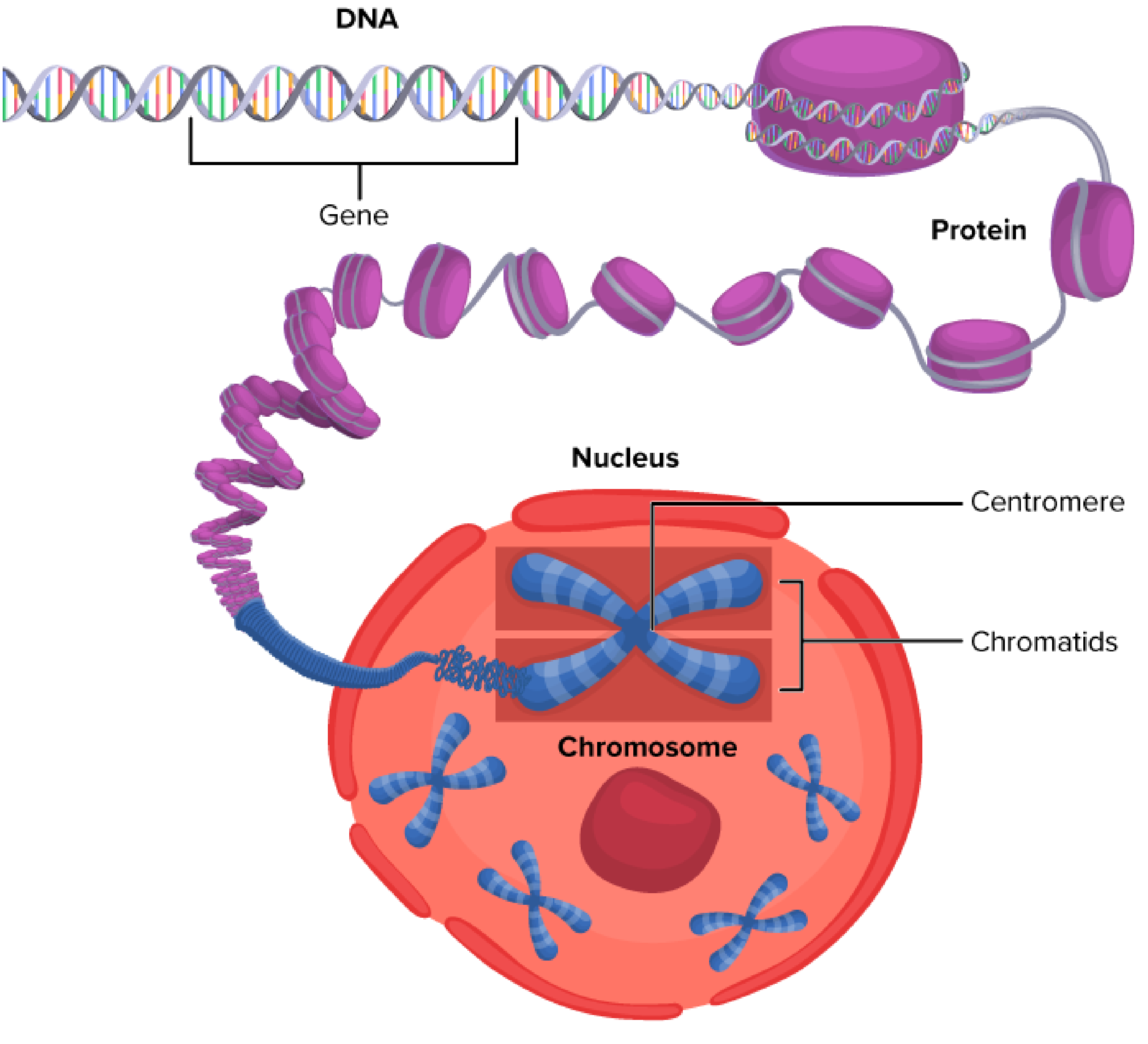
Chromosomes

In eukaryotic cell, the nucleus divides before the cell itself divides. The process in which the nucleus divides is called mitosis. Before mitosis occurs, a cell's DNA is replicated. This is necessary so that each daughter cell will have a complete copy of the genetic material from the parent cell. How is the replicated DNA sorted and separated so that each daughter cell gets a complete set of the genetic material? To understand how this happens, you need to know more about chromosomes.

Chromosomes are coiled structures made of DNA and protein. Chromosomes are the form of the genetic material of a cell during cell division. It is this coiled structure that ensures the proper segregation of the chromosomes during cell division. During other phases of the cell cycle, DNA is not coiled into chromosomes. Instead, it exists as a grainy material called **chromatin**.

Chromatids and the Centromere

DNA condenses and coils into the familiar X-shaped form of a chromosome only after it has replicated. Because DNA has already replicated, each chromosome actually consists of two identical copies. The two copies are called sister **chromatids**. They are attached to one another at a region called the **centromere**.

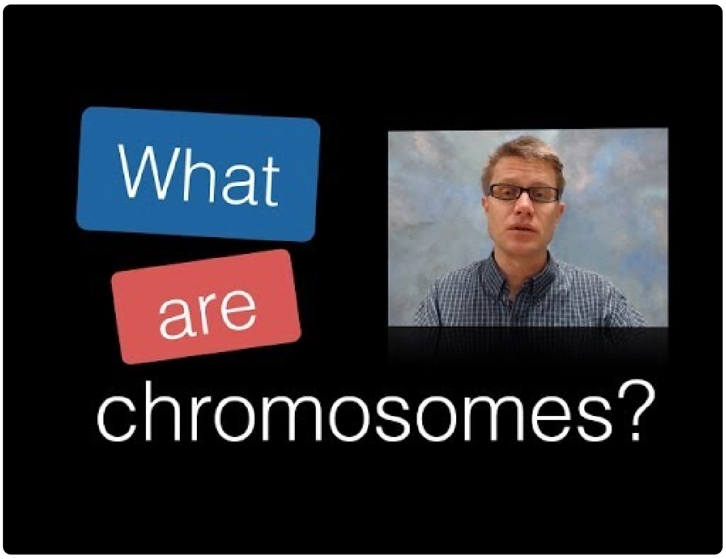


Chromosomes and Genes

The DNA of a chromosome is encoded with genetic instructions for making proteins. These instructions are organized into units called **genes**. Most genes contain the instructions for a single protein. There may be hundreds or even thousands of genes on a single chromosome.

Human Chromosomes

Human cells normally have two sets of chromosomes, one set inherited from each parent. There are 23 chromosomes in each set, for a total of 46 chromosomes per cell. Each chromosome in one set is matched by a chromosome of the same type in the other set, so there are actually 23 pairs of chromosomes per cell. Each pair consists of chromosomes of similar size and shape that also contain the same genes, but different allele (alternate forms of a gene). The chromosomes in a pair are known as **homologous chromosomes**.



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DID YOU KNOW?

The number of chromosomes in an organism is not related to how big or complex the organism is. The largest number of chromosomes for an organism is present in a plant, *Ophioglossum reticulatum*, commonly known as the adder's tongue fern.

Summary

- Chromosomes are coiled structures made of DNA and proteins.
- Chromosomes form after DNA replicates; prior to replication, DNA exists as chromatin.
- Chromosomes contain genes, which code for proteins.
- Human cells normally have 46 chromosomes, made up of two sets of chromosomes, one set inherited from each parent.

Review

1. What are chromosomes? When do they form?
2. Identify the chromatids and the centromere of a chromosome.
3. Explain how chromosomes are related to chromatin. Why are chromosomes important for mitosis?
4. How many chromosomes are in a normal human cell?

Report Content Errors

2.34 Mitosis

FlexBooks 2.0 > Biology For High School Diploma > Mitosis

Last Modified: Mar 28, 2022

What you will learn

- The process of cell division in eukaryotic cell through mitosis
- The four phases of mitosis
- How **cytokinesis** occurs differently in plant and animal cell

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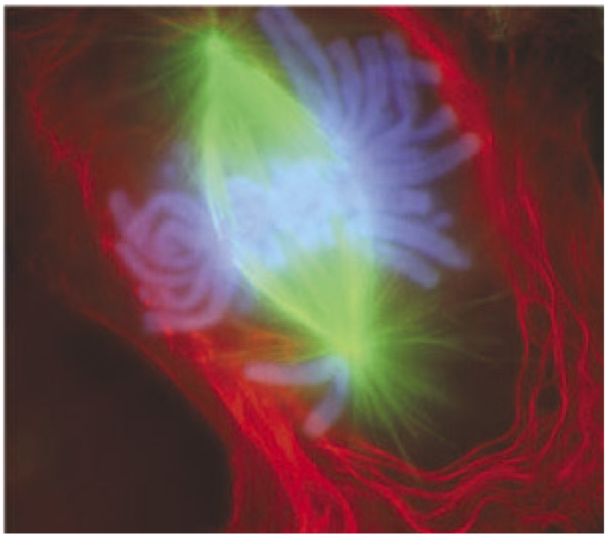


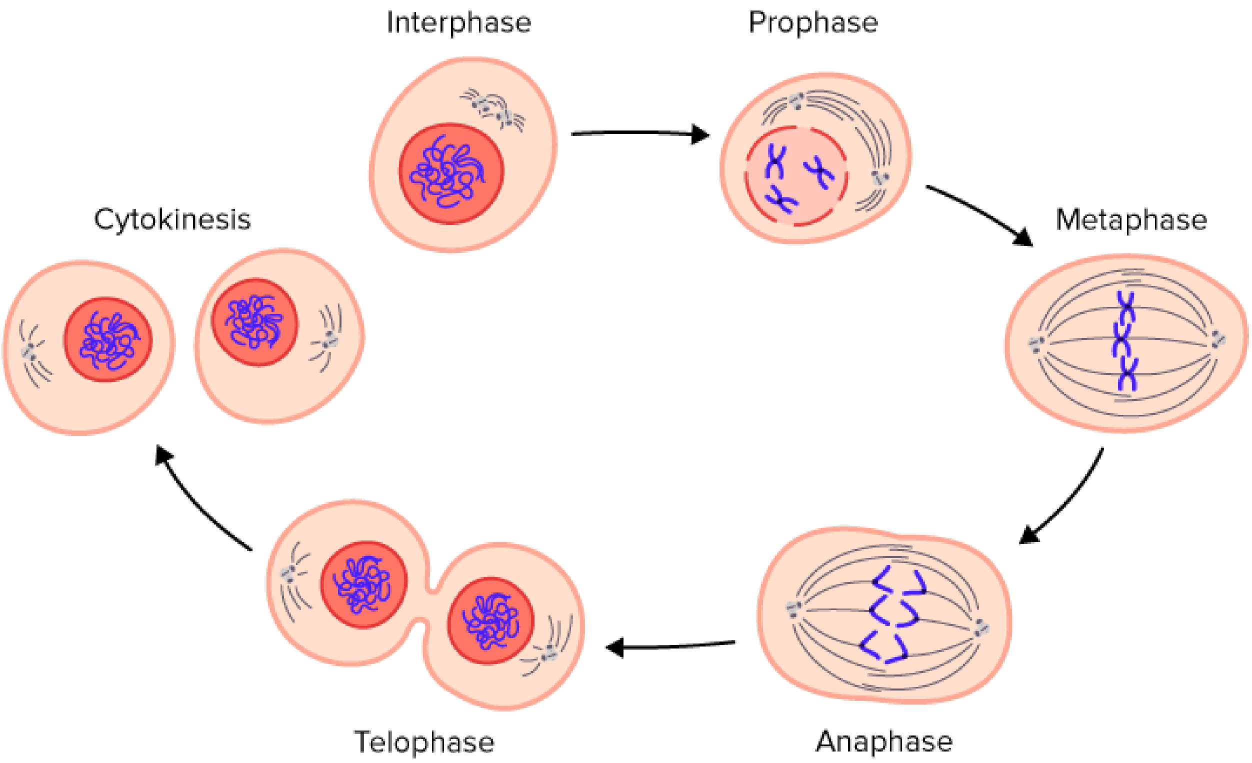
[Figure 1]

What is meant by the "division of the nucleus"?

What do you think this colorful picture shows? If you guessed that it's a picture of a cell undergoing cell division, you are right. But more specifically, the image is a lung cell stained with fluorescent dyes undergoing mitosis, during early **anaphase**.

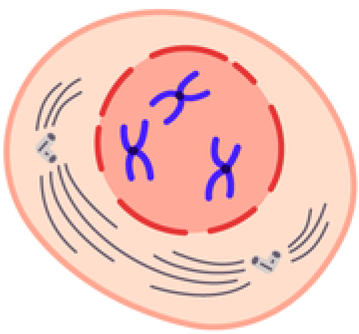
Mitosis and Cytokinesis

During **mitosis**, the division of the nucleus in a eukaryotic cell occurs in four phases. The phases are called **prophase**, **metaphase**, anaphase, and **telophase**. These phases, along with the main cellular structures observed during mitosis, are shown below and are described in greater detail in the following sections.



Prophase

The first and longest phase of mitosis is **prophase** (**Figure** below). During prophase, chromatin condenses into chromosome, and the nuclear envelope, or membrane, breaks down. In animal cells, the **centriole** near the nucleus begin to separate and move to opposite poles (sides) of the cell. As the centrioles move, a **spindle** starts to form between them. The spindle consists of fibers made of microtubule that pull chromosomes apart during cell division.

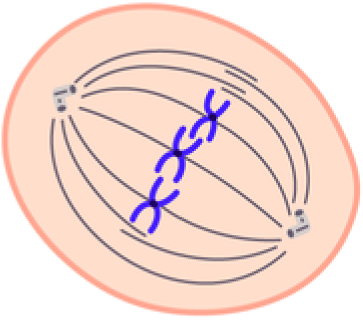


[Figure 2]

Prophase: chromosomes are visible, nuclear membrane breaks down, spindle fibers begin to form.

Metaphase

During **metaphase**, spindle fibers attach to the centromere of each pair of sister chromatids (**Figure** below). The sister chromatids line up at the equator, or center, of the cell. This is also known as the metaphase plate. The spindle fibers ensure that sister chromatids will separate and go to different daughter cell when the cell divides.

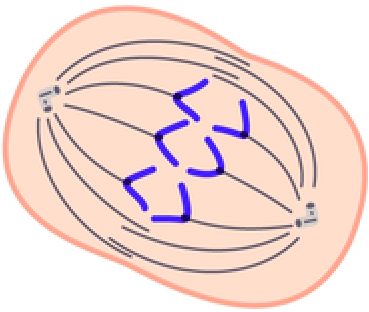


[Figure 3]

Metaphase: sister chromatids line up at the center of the cell.

Anaphase

During **anaphase** (**Figure** below), sister chromatids separate and the centromeres divide. The sister chromatids are pulled apart by the shortening of the spindle fibers. This is like reeling in a fish by shortening the fishing line. One sister chromatid moves to one pole of the cell, and the other sister chromatid moves to the opposite pole. At the end of anaphase, each pole of the cell has a complete set of chromosomes.

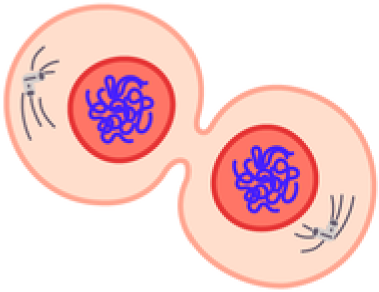


[Figure 4]

Anaphase: sister chromatids are pulled apart and move to opposite poles of the cell.

Telophase

During **telophase** (**Figure** below), the chromosomes begin to uncoil and form chromatin. This prepares the genetic material for directing the metabolic activities of the new cells. The spindle also breaks down, and new nuclear membranes (nuclear envelope) form.

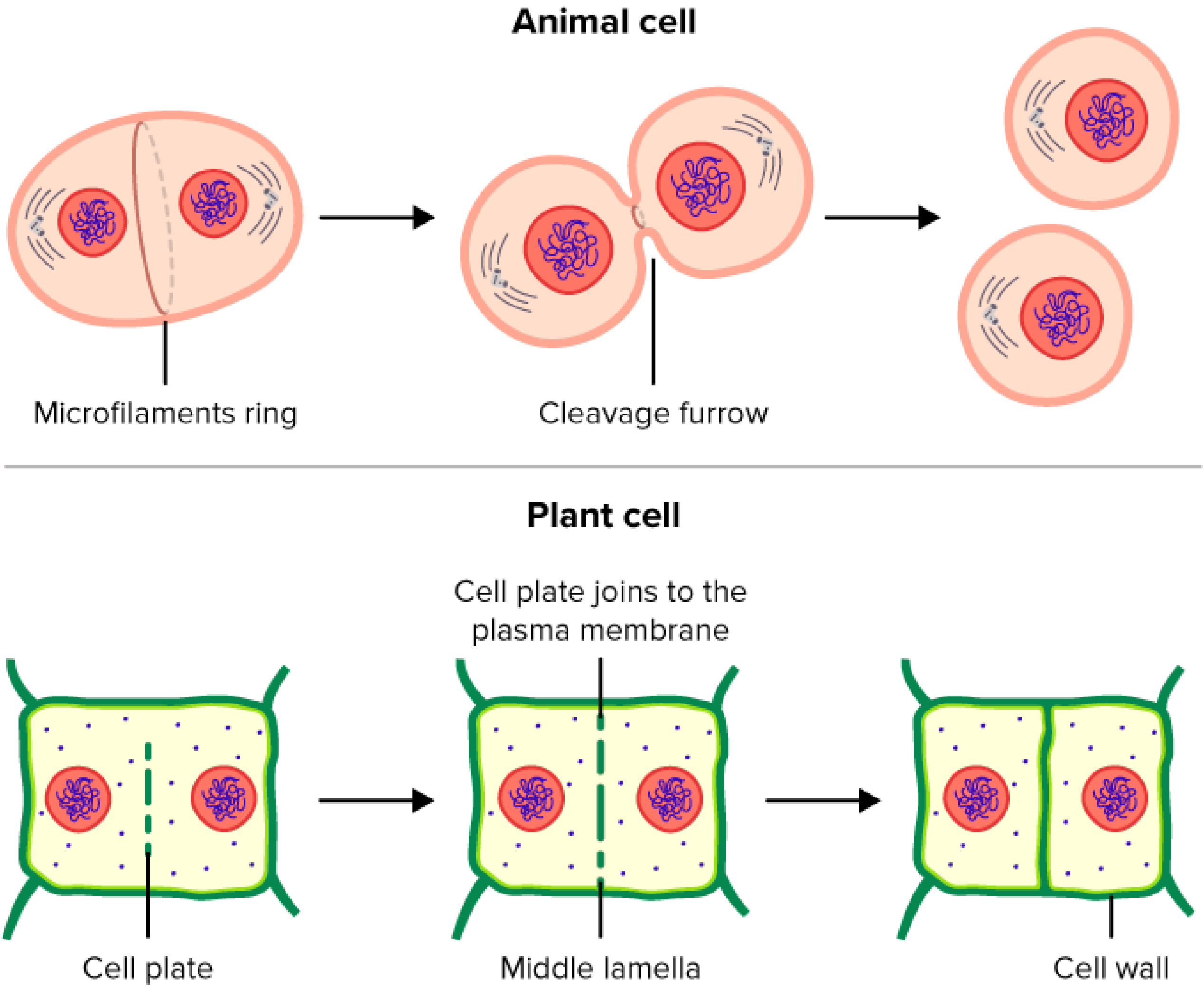


[Figure 5]

Telophase: spindle fibers break down, nuclear membrane forms, and chromosomes begin to uncoil and form chromatin.

Cytokinesis

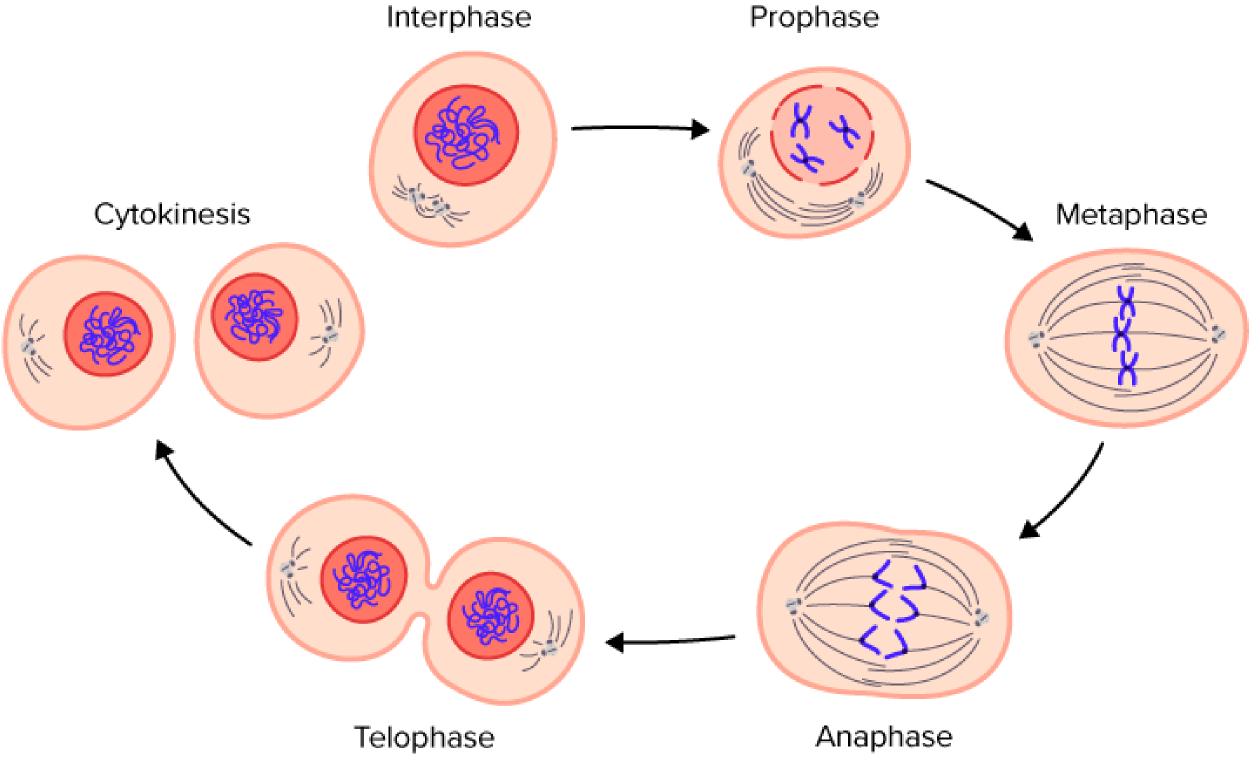
Cytokinesis is the final stage of cell division in eukaryote as well as prokaryote. During cytokinesis, the cytoplasm splits in two and the cell divides. Cytokinesis occurs somewhat differently in plant and animal cells, as shown in the **Figure** below. In animal cells, the cell membrane of the parent cell pinches inward along the cell's equator until two daughter cells form. In plant cells, a cell plate forms along the equator of the parent cell. Then, a new cell membrane and cell wall form along each side of the cell plate.



[Figure 6]

Cytokinesis occurs differently in animal cells and plant cells.

A summary of how a cell undergoes mitosis to produce two identical daughter cells is shown below.



PROGRESS 0 / 5

1. Which is the first and longest phase of mitosis?

a Prophase

b Telophase

c Anaphase

d Metaphase

Check It

Hint

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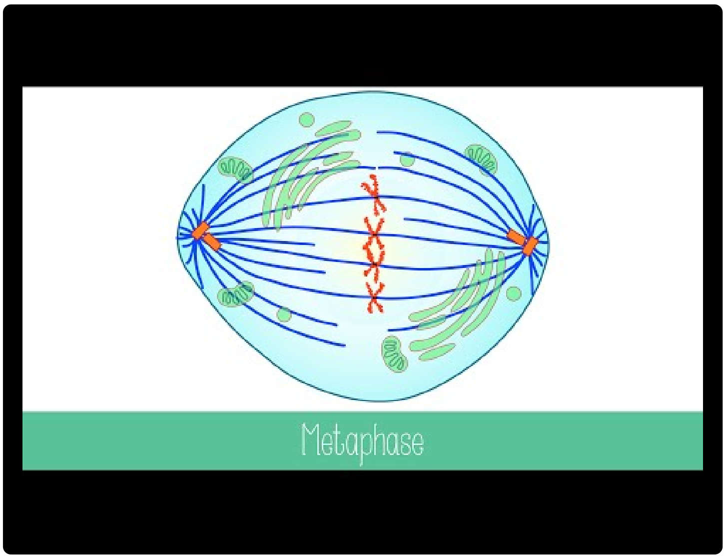

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Summary

- The reasons for cell division include growth, repair, and maintenance of cells that are worn out and need to be regenerated.
- Cell division in eukaryotic cells includes mitosis, in which the nucleus divides, and cytokinesis, in which the cytoplasm divides and daughter cells form.
- Mitosis occurs in four phases, called prophase, metaphase, anaphase, and telophase.
- Not all the cells in your body divide at the same rate.

Review

1. List the phases of mitosis.
2. What happens during the prophase of mitosis?

3. During which phase of mitosis do sister chromatids separate?
4. Describe what happens during cytokinesis in animal cells.
5. If a cell skipped metaphase during mitosis, how might this affect the two daughter cells?
6. Explain the significance of the spindle fibers in mitosis.

Report Content Errors

2.35 Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Reproduction

Last Modified: Jan 18, 2022

What you will learn

- Difference between asexual and **sexual reproduction**
- Major types of **asexual reproduction**
- What happens in sexual reproduction

[Figure 1]

One parent or two?

That is the main difference between sexual and asexual reproduction. Sexual reproduction just means combining genetic material from two parents. Asexual reproduction produces offspring genetically identical to the one parent.

Reproduction: Asexual vs. Sexual

cell division is how organism grow and repair themselves. It is also how many organisms produce offspring. For many single-celled organisms, reproduction is a similar process. The parent cell simply divides to form two daughter cell that are identical to the parent. In many other organisms, two parents are involved, and the offspring are not identical to the parents.

In fact, each offspring is unique. Look at the family in the **Figure** below. The children resemble their parents, but they are not identical to them. Instead, each has a unique combination of characteristics inherited from both parents.

[Figure 2]

Family Portrait: Mother, Daughter, Father, and Son. Children resemble their parents, but they are never identical to them. Do you know why this is the case?

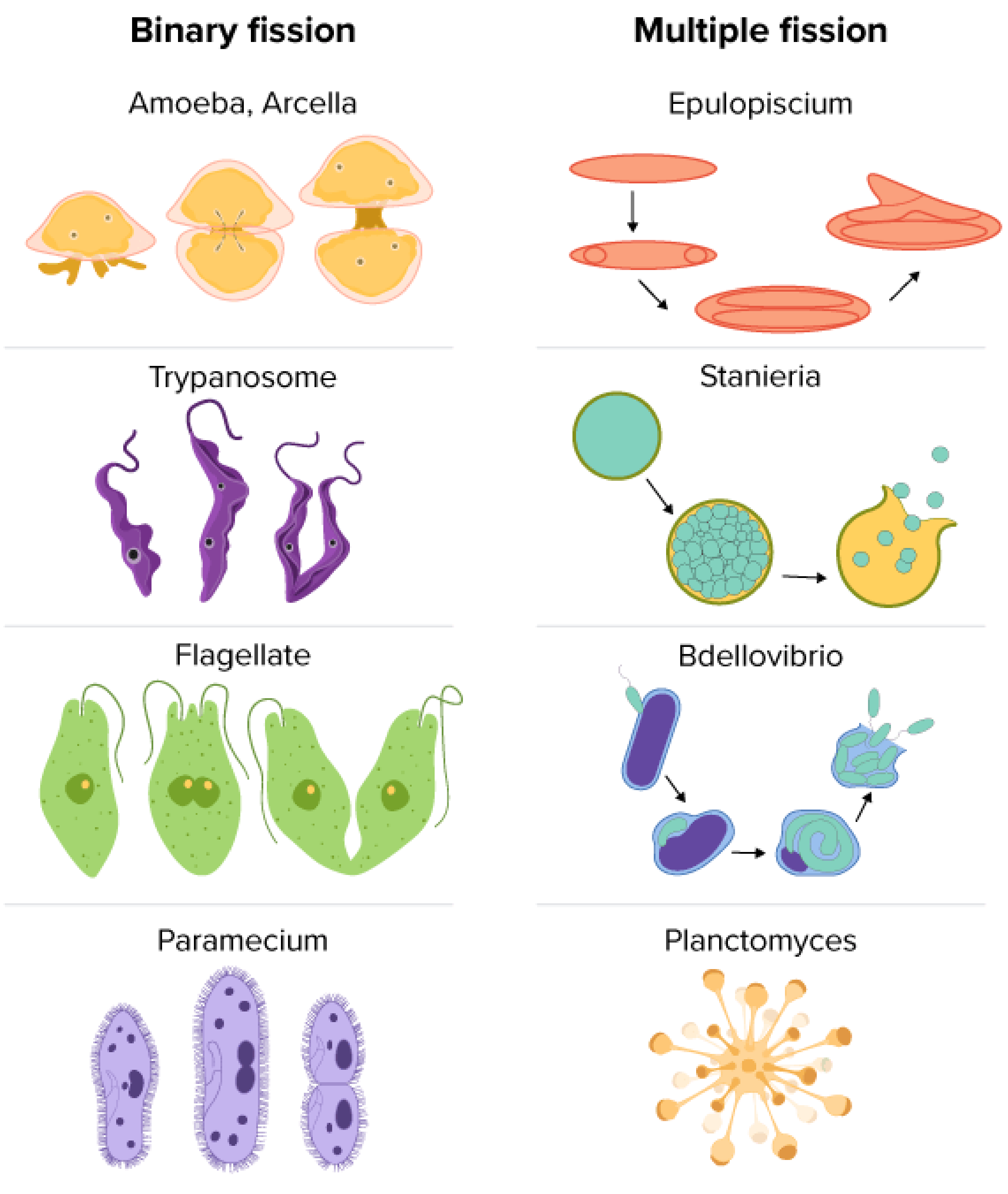
Reproduction is the process by which organisms give rise to offspring. It is one of the defining characteristics of living things. There are two basic types of reproduction: asexual reproduction and sexual reproduction.

Asexual Reproduction

Asexual reproduction involves a single parent. It results in offspring that are genetically identical to each other and to the parent. All prokaryote and some eukaryote reproduce this way. There are several different methods of asexual reproduction. They include **binary fission**, **fragmentation**, and **budding**.

- **Binary fission** occurs when a parent cell splits into two identical daughter cells of the same size.

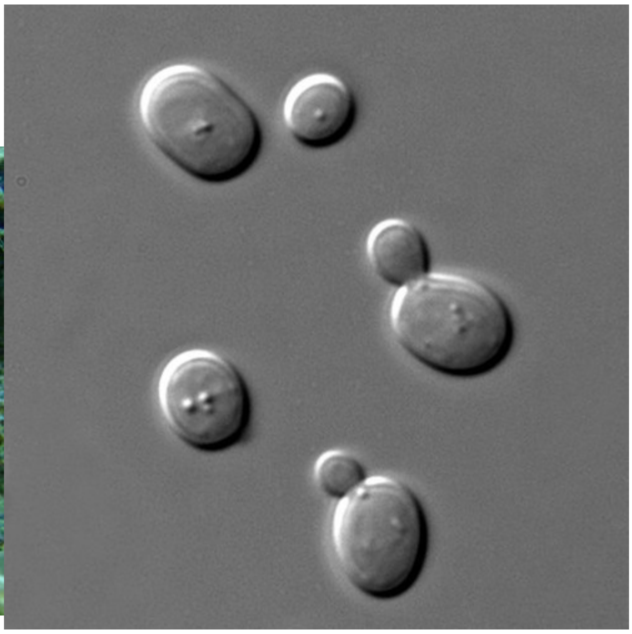
- **Fragmentation** occurs when a parent organism breaks into fragments, or pieces, and each fragment develops into a new organism. Starfish, like the one in the **Figure** below, reproduce this way. A new starfish can develop from a single ray, or arm. Starfish, however, are also capable of sexual reproduction.
- **Budding** occurs when a parent cell forms a bubble-like bud. The bud stays attached to the parent cell while it grows and develops. When the bud is fully developed, it breaks away from the parent cell and forms a new organism. Budding in yeast is shown in the **Figure** below.



[Figure 3]

Binary Fission in various single-celled organisms (left). Cell division is a relatively simple process in many single-celled organisms. Eventually the parent cell will pinch apart to form two identical daughter cells. In multiple fission (right), a multinucleated cell can divide to form more than one daughter cell. Multiple fission is more often observed among protists.

[Figure 4]



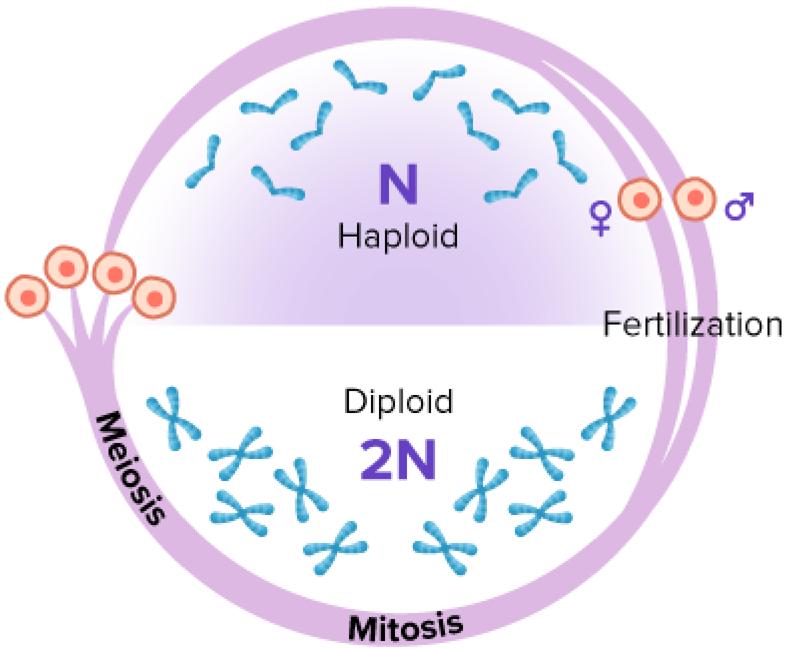
[Figure 5]

Starfish reproduce by fragmentation and yeasts reproduce by budding. Both are types of asexual reproduction.

Asexual reproduction can be very rapid. This is an advantage for many organisms. It allows them to crowd out other organisms that reproduce more slowly. bacterium, for example, may divide several times per hour. Under ideal conditions, 100 bacteria can divide to produce millions of bacterial cell in just a few hours! However, most bacteria do not live under ideal conditions. If they did, the entire surface of the planet would soon be covered with them. Instead, their reproduction is kept in check by limited resources, predator, and their own wastes. This is true of most other organisms as well.

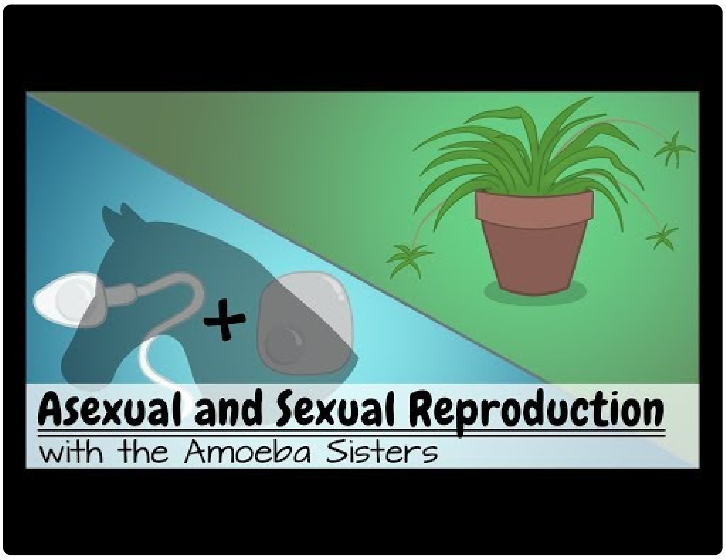
Sexual Reproduction

Sexual reproduction involves two parents. As you can see from the **Figure** below, in sexual reproduction, parents produce reproductive cells—called **gamete**—that unite to form an offspring. Gametes are **haploid** cells. This means they contain only half the number of chromosome found in other cells of the organism. Gametes are produced by a type of cell division called **meiosis**. The process in which two gametes unite is called **fertilization**. The fertilized cell that results is referred to as a **zygote**. A zygote is **diploid** cell, which means that it has twice the number of chromosomes as a gamete.



[Figure 6]

Cycle of Sexual Reproduction. Sexual reproduction involves the production of haploid gametes by meiosis. This is followed by fertilization and the formation of a diploid zygote. The number of chromosomes in a gamete is represented by the letter n. Why does the zygote have 2n, or twice as many, chromosomes?



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DID YOU KNOW?

Asexual reproduction in vertebrate occurs rarely. Some vertebrates like Komodo dragons reproduce asexually by **parthenogenesis**. In this process, females produce egg that develop into offspring without being fertilized by sperm.

Check your understanding!

PROGRESS 0 / 4

1. What happens during asexual reproduction?

SELECT ALL THAT APPLY

a It results in offspring being genetically identical to the parents.

b This is a very rapid process.

c Gametes are formed.

d Prokaryotes and some unicellular eukaryotes undergo this type of reproduction.

Check It

Hint

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Summary

- Asexual reproduction involves one parent and produces offspring that are genetically identical to each other and to the parent.
- Sexual reproduction involves two parents and produces offspring that are genetically unique.
- During sexual reproduction, two haploid gametes join in the process of fertilization to produce a diploid zygote.
- Meiosis is the type of cell division that produces gametes.

Review

1. What are three types of asexual reproduction?
2. Define gamete and zygote. What number of chromosomes does each have (in humans)?
3. What happens during fertilization?
4. Compare and contrast asexual and sexual reproduction.

Report Content Errors

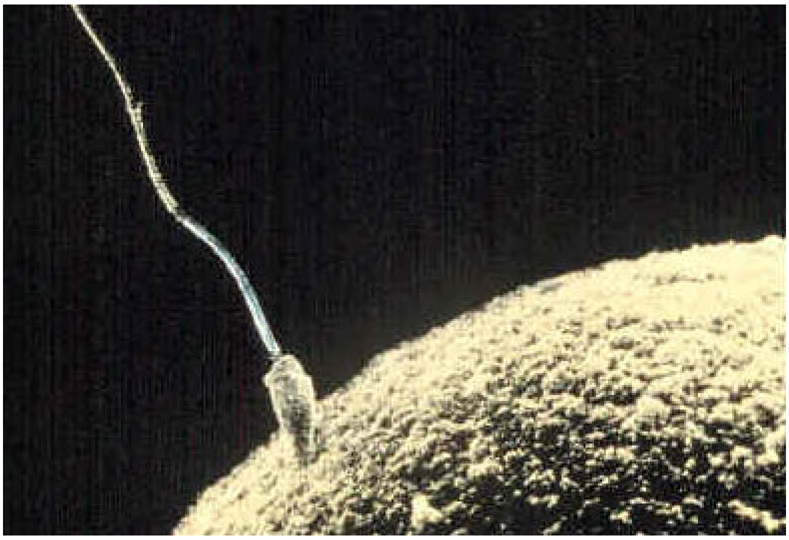
2.36 Meiosis

FlexBooks 2.0 > Biology For High School Diploma > Meiosis

Last Modified: Dec 14, 2021

What will you learn

- The process of meiosis
- Different phases of meiosis
- How **crossing over** happens during meiosis



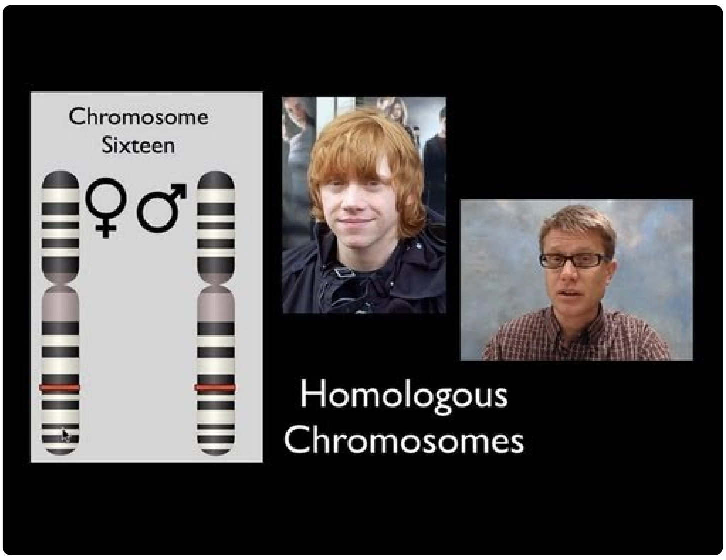
[Figure 1]

How do you make a cell with half the DNA?

Meiosis. This allows cell to have half the number of chromosome, so two of these cells can come back together to form a new organism with the complete number of chromosomes. This process not only helps produce gamete, it also ensures genetic variation.

Meiosis

The process that produces **haploid** gametes is meiosis. **Meiosis** is a type of cell division in which the number of chromosomes is reduced by half. Meiosis is specific to gamete producing cells in the gonad. Meiosis begins with a diploid cell and ends with four haploid cells. These cells eventually differentiate into mature sperm or egg cells. During meiosis, homologous chromosomes separate, and **haploid** cells form that have only one chromosome from each pair. Two cell divisions occur during meiosis, meiosis I and meiosis II.



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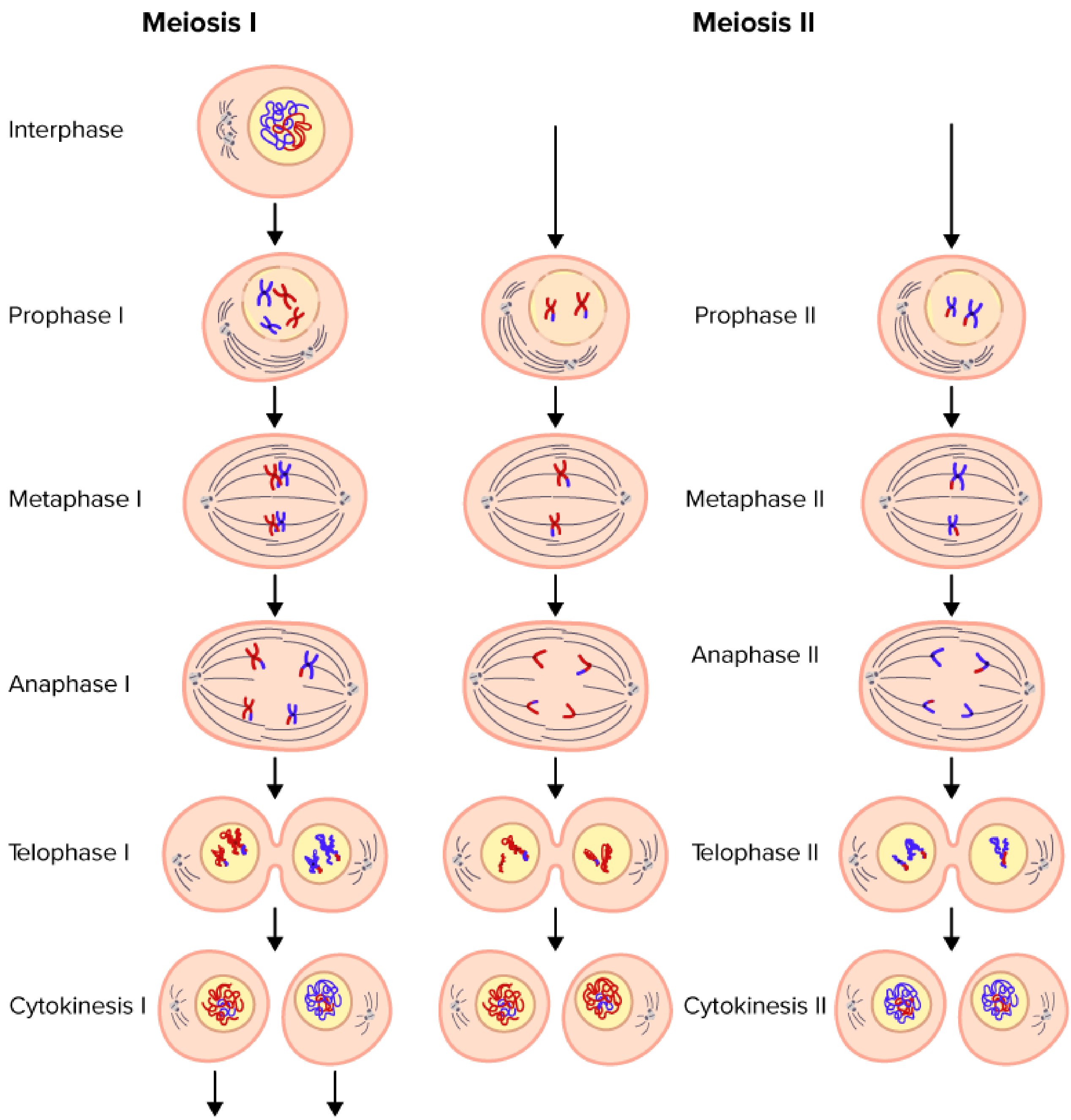
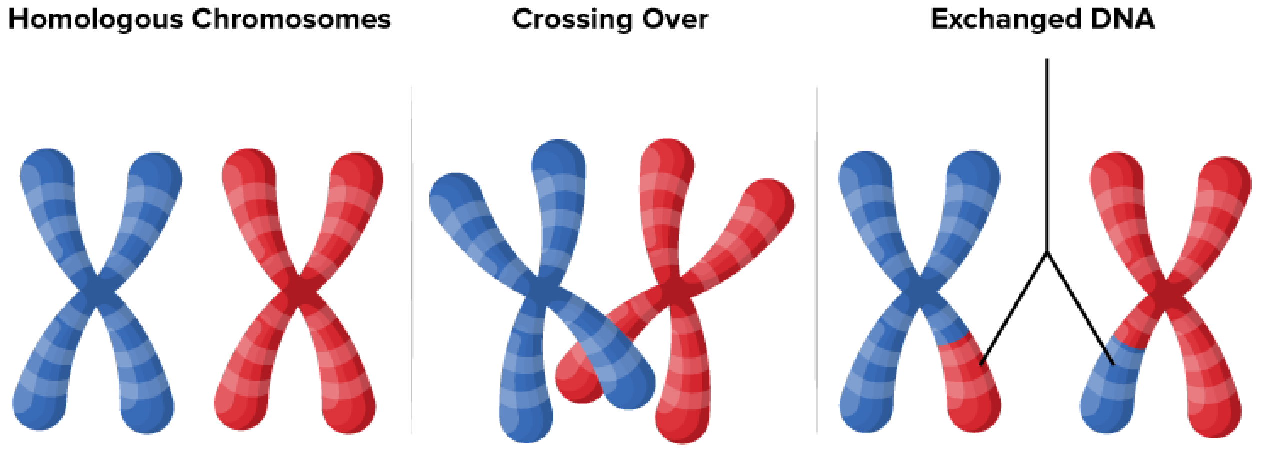
Phases of Meiosis

Meiosis I begins after DNA replicates during interphase of the cell cycle. In both meiosis I and meiosis II, cells go through the same four phases as mitosis - prophase, metaphase, anaphase and telophase. However, there are important differences between meiosis I and mitosis. The animation below shows what happens in both meiosis I and II.



How does meiosis I differ from mitosis? Notice at the beginning of meiosis (prophase I), homologous chromosomes exchange segments of DNA. This is known as **crossing over**, and is unique to this phase of meiosis.



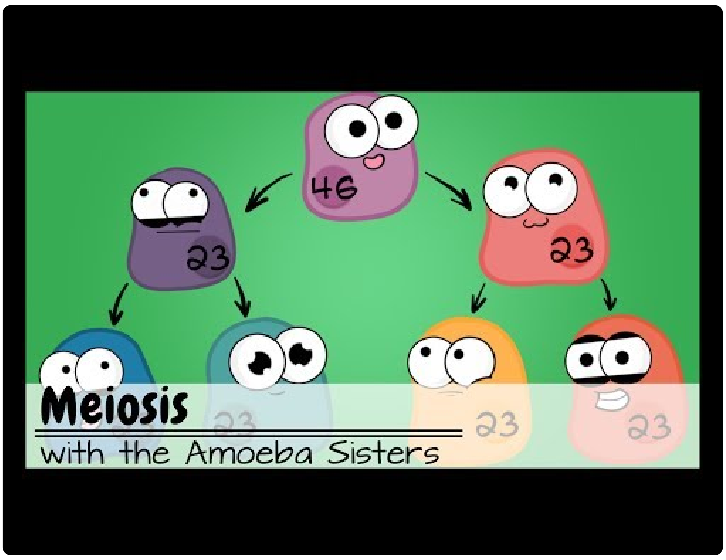
Meiosis I

1. Prophase I: The nuclear envelope begins to break down, and the chromosomes condense. centriole start moving to opposite poles of the cell, and a **spindle** begins to form. Importantly, homologous chromosomes pair up, which is unique to prophase I. In prophase of mitosis and meiosis II, homologous chromosomes do not form pairs in this way. Crossing over occurs during this phase.
2. Metaphase I: Spindle fibers attach to the paired homologous chromosomes. The paired chromosomes line up along the equator (middle) of the cell. This occurs only in metaphase I. In metaphase of mitosis and meiosis II, it is sister chromatids that line up along the equator of the cell.
3. Anaphase I: Spindle fibers shorten, and the chromosomes of each homologous pair start to separate from each other. One chromosome of each pair moves toward one pole of the cell, and the other chromosome moves toward the opposite pole.
4. Telophase I and cytokinesis: The spindle breaks down, and new nuclear membranes form. The cytoplasm of the cell divides, and two haploid daughter cell result. The daughter cells each have a random assortment of chromosomes, with one from each homologous pair. Both daughter cells go on to meiosis II. The DNA does not replicate between meiosis I and meiosis II.

Meiosis II

1. Prophase II: The nuclear envelope breaks down and the spindle begins to form in each haploid daughter cell from meiosis I. The centrioles also start to separate.
2. Metaphase II: Spindle fibers line up the sister chromatids of each chromosome along the equator of the cell.
3. Anaphase II: Sister chromatids separate and move to opposite poles.
4. Telophase II and Cytokinesis: The spindle breaks down, and new nuclear membranes form. The cytoplasm of each cell divides, and four haploid cells result. Each cell has a

unique combination of chromosomes.



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Summary

- Meiosis is the type of cell division that produces gametes.
- Meiosis involves two cell divisions and produces four haploid cells.
- Sexual reproduction has the potential to produce tremendous genetic variation in offspring. This is due in part to crossing over during meiosis.

Review

1. What is meiosis?
2. Compare the events of metaphase I to metaphase II?
3. Create a diagram to show how crossing over occurs and how it creates new gene combinations on each chromosome.
4. Explain why sexual reproduction results in genetically unique offspring.
5. Explain how meiosis I differs from mitosis.

Report Content Errors

2.37 Gametogenesis

FlexBooks 2.0 > Biology For High School Diploma > Gametogenesis

Last Modified: Dec 14, 2021

What you will learn

- How gamete are formed through **spermatogenesis** and **oogenesis**

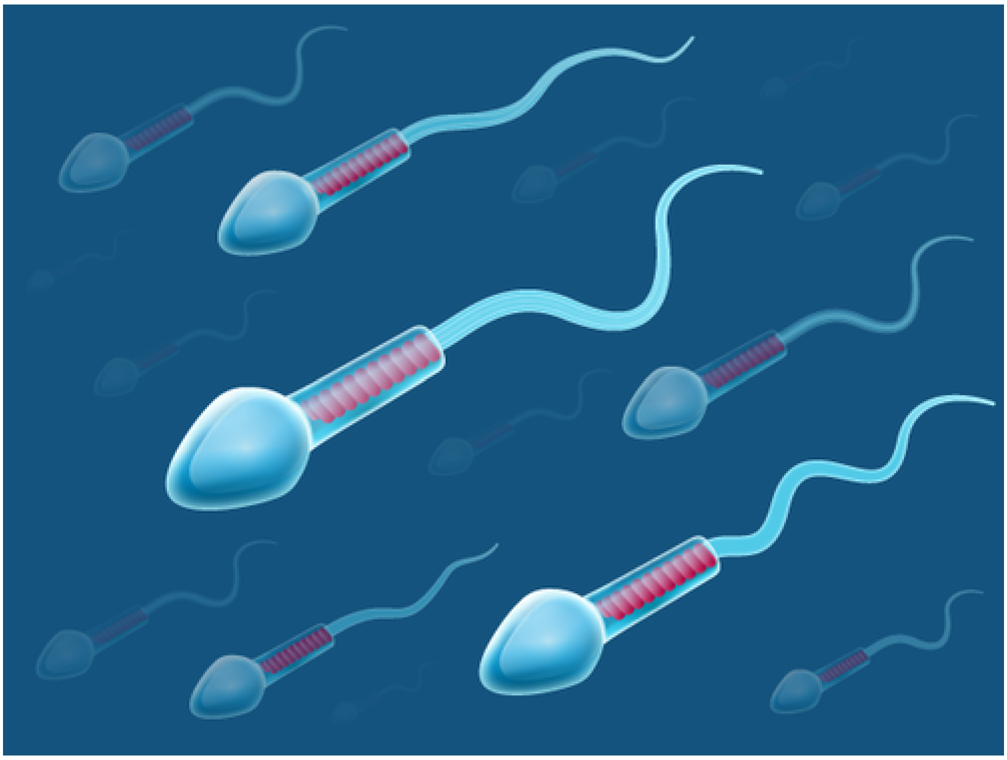
[Figure 1]

What's the biggest cell on Earth?

The ostrich **egg** - unfertilized, of course. Yes, this egg, just like a human **ovum**, is just one cell. The egg shell membrane encloses the nucleus containing the genetic material and the cytoplasm.

Gametogenesis

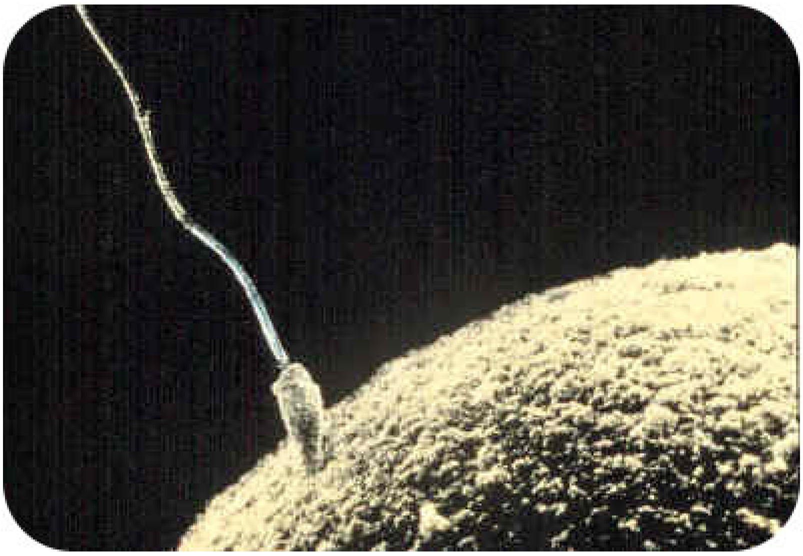
At the end of meiosis, four haploid cells have been produced, but the cells are not yet gametes. The cells need to develop before they become mature gametes capable of fertilization. The development of haploid cells into gametes is called **gametogenesis**.



[Figure 2]

How much DNA is in a gamete? The sperm cell forms by meiosis and spermatogenesis. Because it forms by meiosis, the sperm cell has only half as much DNA as a body cell. Notice the three distinct segments: a head piece, a flagella tail and a midpiece of mostly mitochondria. What is the role of each section?

Gametogenesis may differ between males and females. Male gametes are called **sperm**. Female gametes are called **eggs**. In human males, for example, the process that produces mature sperm cells is called **spermatogenesis**. During this process, sperm cells grow a tail and gain the ability to "swim," like the human sperm cell shown in the **Figure** above. In human females, the process that produces mature eggs is called **oogenesis**. Just one egg is produced from the four haploid cells that result from meiosis. The single egg is a very large cell, as you can see from the human egg in the **Figure** below.



[Figure 3]

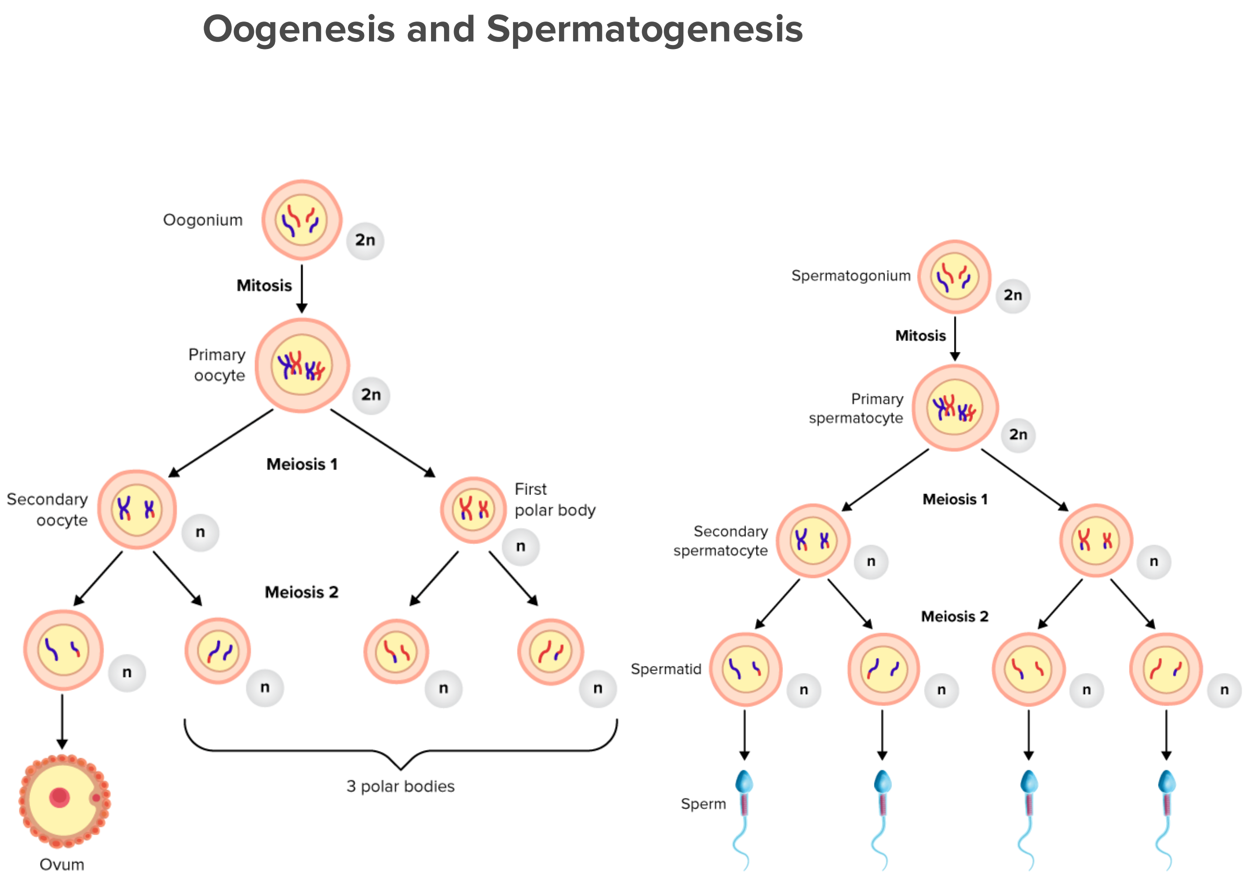
A human sperm is a tiny cell with a tail. A human egg is much larger. Both cells are mature haploid gametes that are capable of fertilization. What process is shown in this photograph? Notice the sperm with the head piece containing the genetic material, a flagella tail that propels the sperm, and a midpiece of mostly mitochondria, supplying ATP.

Spermatogenesis and Oogenesis

During spermatogenesis, primary **spermatocytes** go through the first cell division of meiosis to produce **secondary spermatocyte**. These are haploid cells. Secondary spermatocytes then quickly complete the meiotic division to become **spermatid**, which are also haploid cells. The four haploid cells produced from meiosis develop a flagellum tail and compact head piece to become mature sperm cells, capable of swimming and fertilizing an egg. The compact head, which has lost most of its cytoplasm, is key in the formation of a streamlined shape. The middle piece of the sperm, connecting the head to the tail, contains many mitochondrion, providing energy to the cell. The sperm cell essentially contributes only DNA to the zygote.

On the other hand, the egg provides the other half of the DNA, but also organelle, building blocks for compounds such as protein and nucleic acid, and other necessary materials. The egg, being much larger than a sperm cell, contains almost all of the cytoplasm a developing embryo will have during its first few days of life. Therefore, oogenesis is a much more complicated process than spermatogenesis.

Oogenesis begins before birth and is not completed until after fertilization. Oogenesis begins when **oogonium** (singular, oogonium), which are the immature eggs that form in the ovary before birth and have the diploid number of chromosome, undergo mitosis to form primary **oocytes**, also with the diploid number. Oogenesis proceeds as a **primary oocyte** undergoes the first cell division of meiosis to form secondary oocytes with the haploid number of chromosomes. A secondary oocyte only undergoes the second meiotic cell division to form a haploid ovum if it is fertilized by a sperm. The one egg cell that results from meiosis contains most of the cytoplasm, nutrient, and organelles. This unequal distribution of materials produces one large cell, and one cell with little more than DNA. This other cell, known as a **polar body**, eventually breaks down. The larger cell undergoes meiosis II, once again producing a large cell and a polar body. The large cell develops into the mature gamete, called an **ovum** (**Figure** below). The unequal distribution of the cytoplasm during oogenesis is necessary as the zygote that results from fertilization receives all of its cytoplasm from the egg. So the egg needs to have as much cytoplasm as possible.

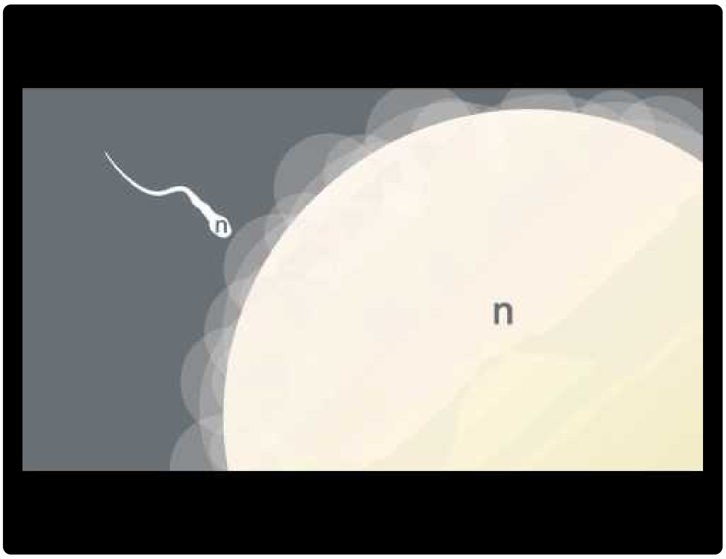


[Figure 4] [Figure 5]

Maturation of the ovum and sperms. Notice only one mature ovum, or egg, forms during meiosis from the primary oocyte. Three polar bodies may form during oogenesis. These polar bodies will not form mature gametes. Conversely, four haploid spermatids form during meiosis from the primary spermatocyte.

DID YOU KNOW?

Oogenesis begins in the fetus and all the primary oocytes are formed prior to birth. After a prolonged growth phase, a single mature ovum is released in a cyclic manner after puberty. In contrast, spermatogenesis begins at puberty, and spermatocytes are continuously created.



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Summary

- At the end of meiosis, four haploid cells have been produced, but the cells are not yet gametes. The development of haploid cells into gametes is called gametogenesis.
- Spermatogenesis produces four haploid sperm cells, while oogenesis produces one mature ovum.

Review

1. What is gametogenesis, and when does it occur?
2. What are the main differences between oogenesis and spermatogenesis?
3. How many chromosomes are in a human oogonia?
4. Why is there unequal distribution of the cytoplasm during oogenesis?

Report Content Errors

2.38 Genetic Variation

FlexBooks 2.0 > Biology For High School Diploma > Genetic Variation

Last Modified: Dec 14, 2021

What you will learn

- How **sexual reproduction** results in genetic variation
- The role of **crossing over** in creating unique combinations of gene

---

[Figure 1]

What helps ensure the survival of a species?

Genetic variation. It is this variation that is the essence of evolution. Without genetic differences among individuals, "survival of the fittest" would not be likely. Either all survive, or all perish.

Genetic Variation

Sexual reproduction results in infinite possibilities of genetic variation. In other words, sexual reproduction results in offspring that are genetically unique. They differ from both parents and also from each other. This occurs for a number of reasons.

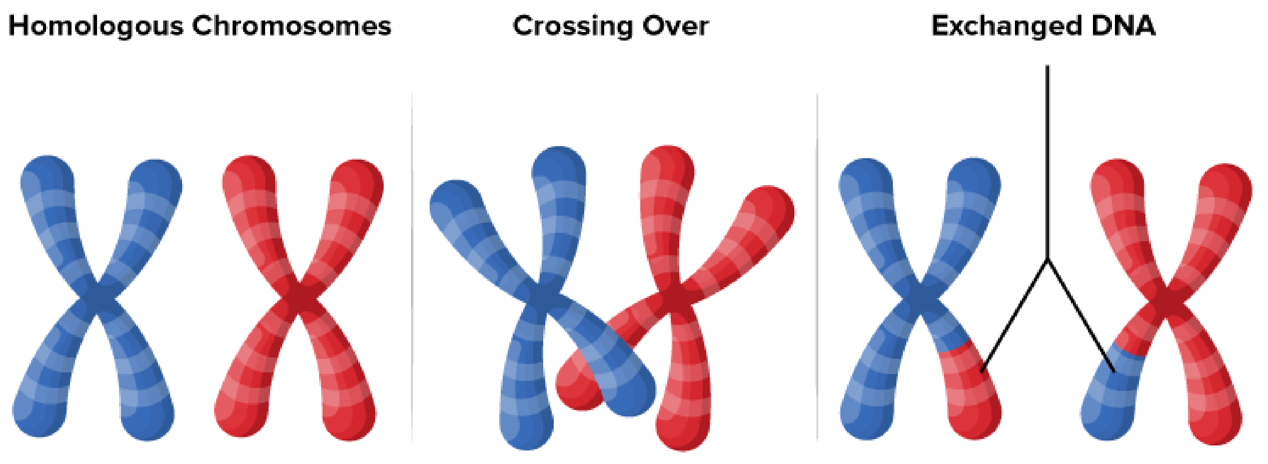
- When homologous chromosomes form pairs during prophase I of meiosis I, crossing over can occur. **Crossing over** is the exchange of genetic material between homologous chromosomes. It results in new combinations of genes on each chromosome.

- When cell divide during meiosis, homologous chromosomes are randomly distributed to daughter cell, and different chromosomes segregate independently of each other. This is called **independent assortment**. It results in gamete that have unique combinations of chromosomes.
- In sexual reproduction, two gametes unite to produce offspring. But which two of the millions of possible gametes will it be? This is likely to be a matter of chance. It is obviously another source of genetic variation in offspring. This is known as **random fertilization.**

All of these mechanisms working together result in an amazing amount of potential variation. Each human couple, for example, has the potential to produce more than 64 trillion genetically unique children. No wonder we are all different!

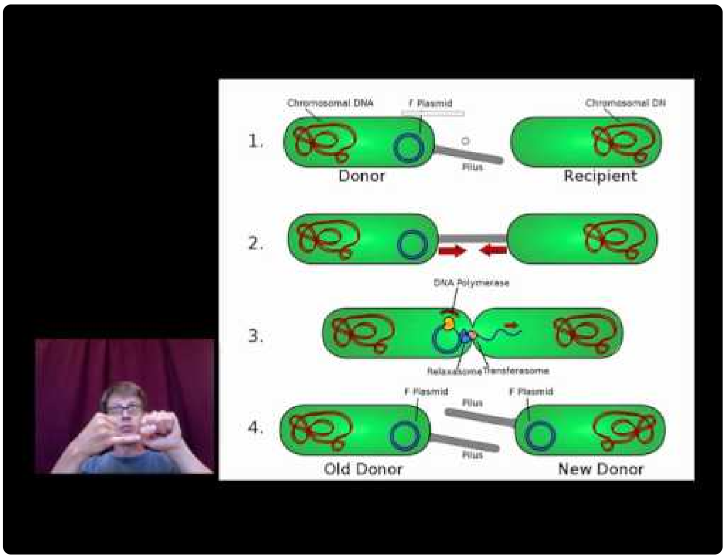
Crossing Over

Crossing over occurs during prophase I, and it is the exchange of genetic material between non-sister chromatids of homologous chromosomes. Recall during prophase I, homologous chromosomes line up in pairs, gene-for-gene down their entire length, forming a configuration with four chromatids, known as a **tetrad**. At this point, the chromatids are very close to each other and some material from two chromatids switch chromosomes, that is, the material breaks off and reattaches at the same position on the homologous chromosome. This exchange of genetic material can happen many times within the same pair of homologous chromosomes, creating unique combinations of genes, as shown in the animation below. This process is also known as **recombination**.



Independent Assortment and Random Fertilization

In humans, there are over 8 million configurations in which the chromosomes can line up during metaphase I of meiosis. It is the specific processes of meiosis, resulting in four unique haploid cells, that result in these many combinations. This independent assortment, in which the chromosome inherited from either the father or mother can sort into any gamete, produces the potential for tremendous genetic variation. Together with random fertilization, more possibilities for genetic variation exist between any two people than the number of individuals alive today. Sexual reproduction is the random fertilization of a gamete from the female using a gamete from the male. In humans, over 8 million (2^{23}) chromosome combinations exist in the production of gametes in both the male and female. A sperm cell, with over 8 million chromosome combinations, fertilizes an egg cell, which also has over 8 million chromosome combinations. That is over 64 trillion unique combinations, not counting the unique combinations produced by crossing over. In other words, each human couple could produce a child with over 64 trillion unique chromosome combinations!



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DID YOU KNOW?

Single nucleotide Polymorphisms (SNPs) are the most common type of genetic variation among people. SNPs involve variation in a single base pair that occurs naturally in the genome.

Summary

- Sexual reproduction has the potential to produce tremendous genetic variation in offspring.

- This variation is due to independent assortment and crossing over during meiosis, and random union of gametes during fertilization.

Review

1. What is crossing over and when does it occur?
2. Describe how crossing over, independent assortment, and random fertilization lead to genetic variation.
3. How many combinations of chromosomes are possible from sexual reproduction in humans?
4. Create a diagram to show how crossing over occurs and how it creates new gene combinations on each chromosome.

Report Content Errors

2.39 Life Cycle

FlexBooks 2.0 > Biology For High School Diploma > Life Cycle

Last Modified: Feb 08, 2022

What will you learn

- haploid and diploid life cycles
- The **alternation of generations** life cycle

[Figure 1]

Young to old. A life cycle?

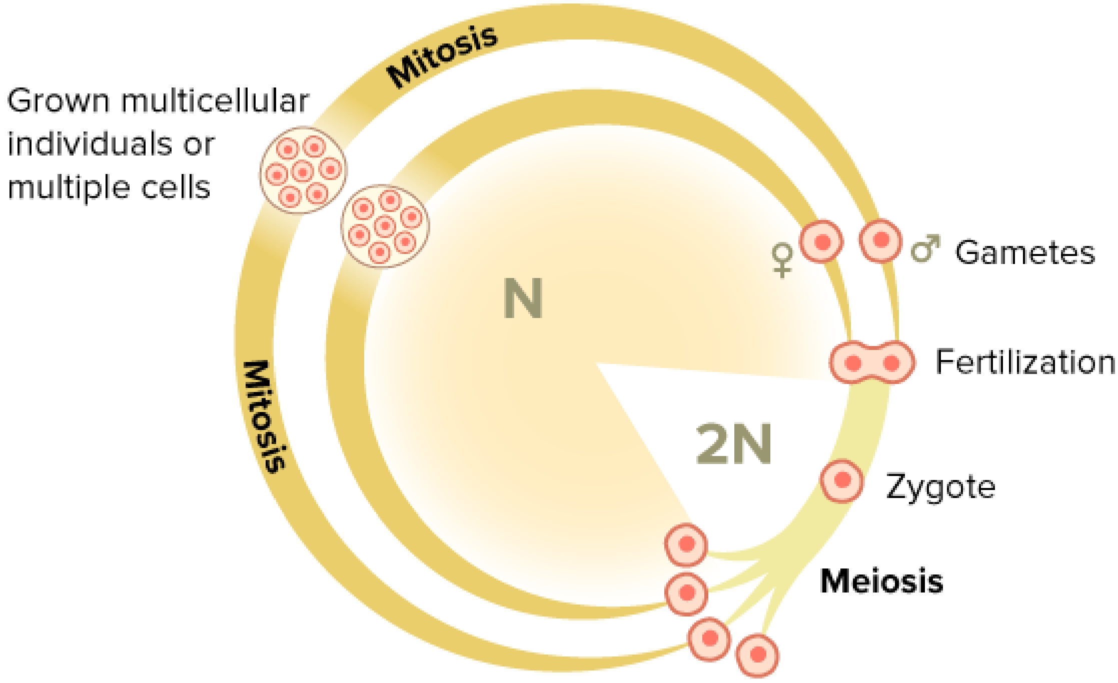
Not in the biological sense. Life cycles describe the amount of DNA present at a specific stage or time in the life of an organism. Is there a haploid or diploid amount of DNA? That is the key question.

Life Cycles

sexual reproduction occurs in a cycle. Diploid parents produce haploid gamete that unite and develop into diploid adults, which repeat the cycle. This series of life stages and events that a sexually reproducing organism goes through is called its **life cycle**. Sexually reproducing organisms can have different types of life cycles. These are described in the following sections.

Haploid Life Cycle

The **haploid life cycle** is the simplest life cycle (**Figure** below). It is found in many single-celled eukaryotic organisms. Organisms with a haploid life cycle spend the majority of their lives as haploid gametes. When the haploid gametes fuse, they form a diploid zygote. It quickly undergoes meiosis to produce more haploid gametes that repeat the life cycle.

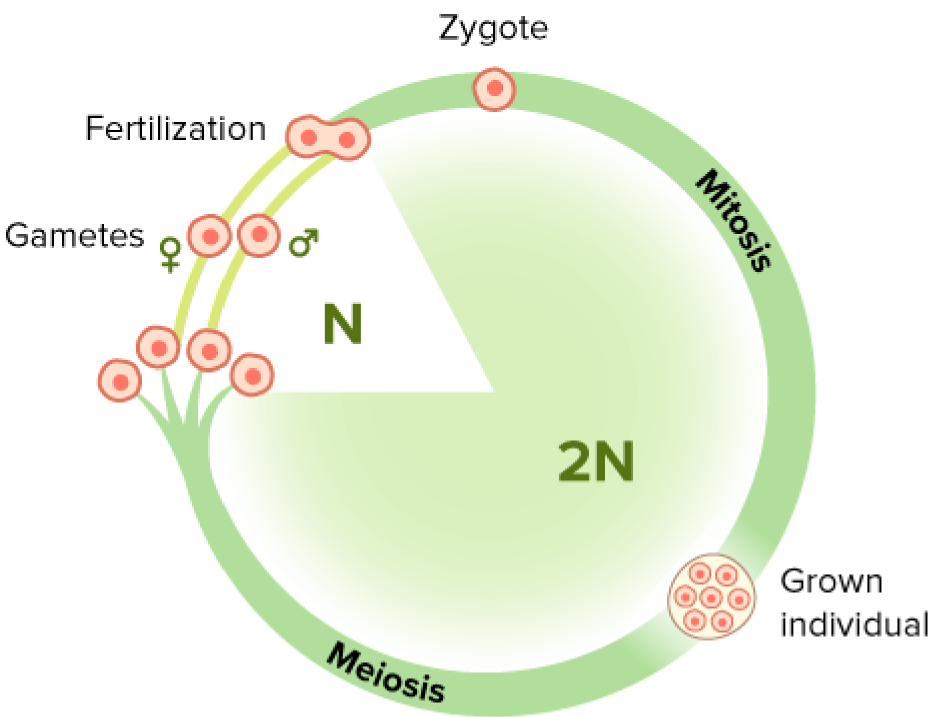


[Figure 2]

The haploid life cycle.

Diploid Life Cycle

Organisms with a **diploid life cycle** (**Figure** below)spend the majority of their lives as diploid adults. When they are ready to reproduce, they undergo meiosis and produce haploid gametes. Gametes then unite in fertilization and form a diploid zygote, which immediately enters G_1 of the cell cycle. Next, the zygote's DNA is replicated. Finally, the processes of mitosis and cytokinesis produce two genetically identical diploid cell. Through repeated rounds of growth and division, this organism becomes a diploid adult and the cycle continues. Can you think of an organism with a diploid life cycle? (*Hint:* What type of life cycle do humans have?)

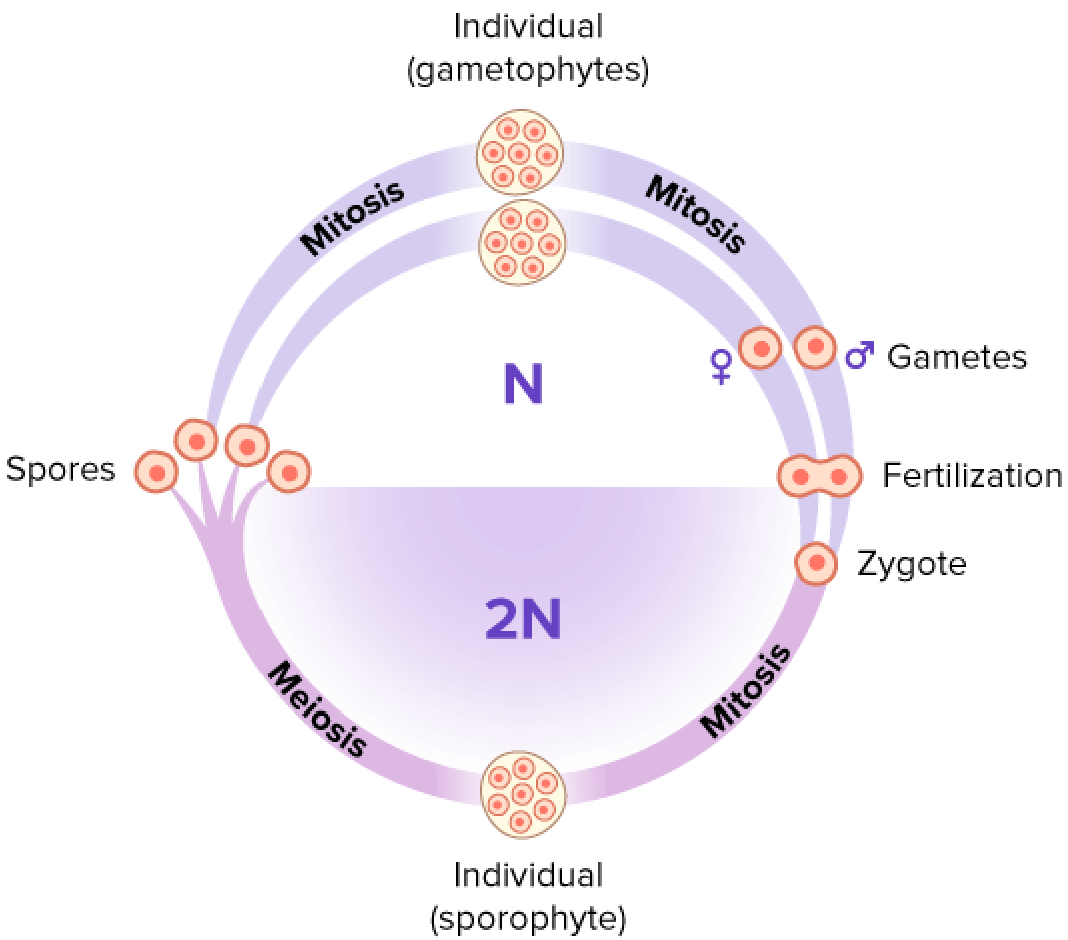


[Figure 3]

The diploid life cycle.

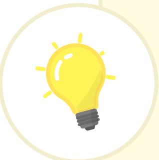
Alternation of Generations

Plants, alga, and some protist have a life cycle that alternates between diploid and haploid phases, known as **alternation of generations** (**Figure** below). In plants, the life cycle alternates between the diploid sporophyte and haploid **gametophyte**. Spore-forming cells in the diploid sporophyte undergo meiosis to produce **spores**, a haploid reproductive cell. Spores can develop into an adult without fusing with another cell. The spores give rise to a multicellular haploid **gametophyte**, which produces gametes by mitosis. The gametes fuse, producing a diploid zygote, which grows into the diploid sporophyte. These life cycles may be quite complicated. You can read about them in additional concepts.



[Figure 4]

The alternation of generations.



DID YOU KNOW?

The jellyfish life cycle involves the alternation of generations between stationary, asexually reproducing polyp and mobile, sexually reproducing medusa.

Summary

- A life cycle is the sequence of stages an organism goes through from one generation to the next.
- Organisms that reproduce sexually can have different types of life cycles, such as haploid or diploid life cycles.

Review

1. What is a life cycle?
2. An adult organism produces gametes that quickly go through fertilization and form diploid zygotes. The zygotes mature into adults, which live for many years. Eventually, the adults produce gametes, and the cycle repeats. What type of life cycle does this organism have? Explain your answer.
3. Which life cycle is the simplest? Why?
4. Describe the life cycle with alternation of generations.

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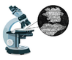
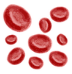
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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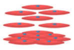
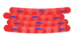
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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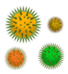	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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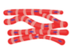	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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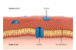
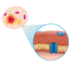
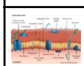
	**Credit:** CK-12 **Source:** CK-12 **License:** CC BY-NC 4.0
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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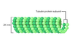	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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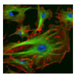
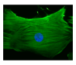
	**Credit:** unknown **Source:** https://commons.wikimedia.org/wiki/File:FluorescentCells.jpg **License:** Public Domain
	**Credit:** Weerapong Prasongchean **Source:** https://commons.wikimedia.org/wiki/File:E7_amnion_cells.png **License:** CC0
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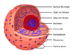	**Credit:** CK-1 2 Foundation **Source:** CK-1 2 Foundation **License:** CK-12 Curriculum Materials License
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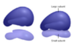	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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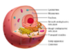
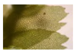
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** WikimediaImages **Source:** https://pixabay.com/photos/bazzania-flaccida-microscopic-cells-903623/ **License:** Pixabay License
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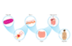	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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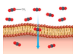
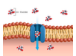
	**Credit:** CK-12 **Source:** CK-12 **License:** CC BY-NC 4.0
	**Credit:** CK-12 **Source:** CK-12 **License:** CC BY-NC 4.0
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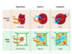
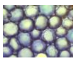
	**Credit:** CK12 Foundation **Source:** CK12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Krishna satya 333 **Source:** https://commons.wikimedia.org/wiki/File:Vacuoles_in_Aloe_vera_leaf_cells.jpg **License:** CC BY 4.0
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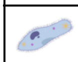	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

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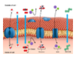
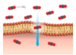
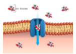
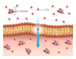
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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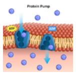
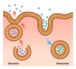
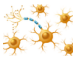
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK12 Foundation **Source:** CK12 Foundation **License:** CK-12 Curriculum Materials License
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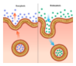
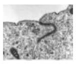
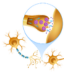
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Louisa Howard, Miguel Marin-Padilla **Source:** https://commons.wikimedia.org/wiki/File:Junctional_complex_and_pinocytotic_vesicles_-_embryonic_brain-TEM.jpg **License:** Public Domain
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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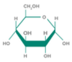
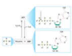
	**Credit:** CK12 Foundation **Source:** CK12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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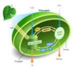	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

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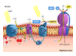	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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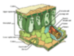
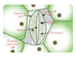
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** cK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Christopher Auyeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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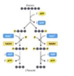	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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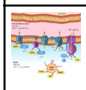	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

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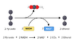	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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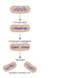
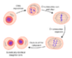
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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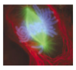
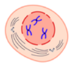
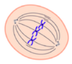
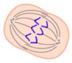
	**Credit:** National Institutes of Health **Source:** https://commons.wikimedia.org/wiki/File:Mitosis-fluorescent.jpg **License:** Public Domain
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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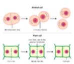	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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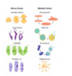	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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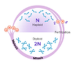	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

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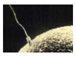	**Credit:** Unknown author **Source:** http://commons.wikimedia.org/wiki/File:Sperm-egg.jpg **License:** Public Domain
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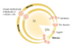	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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CHAPTER 3

Genetics

Chapter Outline

3.1 Pea Plants

FlexBooks 2.0 > Biology For High School Diploma > Pea Plants

Last Modified: Jan 25, 2022

What you will learn

- Gregor **Mendel** and his contribution to **genetics**
- Why Mendel chose pea plants for his experiment
- How Mendel used controlled **pollination** to produce hybrids

---

[Figure 1]

What's so interesting about pea plants?

These purple-flowered plants are not just pretty to look at. Plants like these led to a huge leap forward in biology. The plants are common garden pea plants, and they were studied in the mid-1800s by an Austrian monk named Gregor Mendel. With his careful experiments, Mendel uncovered the secrets of heredity, or how parents pass characteristics to their offspring.

You may not care much about heredity in pea plants, but you probably care about your own heredity. Mendel's discoveries apply to you as well as to peas—and to all other living things that reproduce sexually.

Mendel and His Pea Plants

People have long known that the characteristics of living things are similar in parents and their offspring. Whether it's the flower color in pea plants or nose shape in people, it is obvious that offspring resemble their parents. However, it wasn't until the experiments of Gregor Mendel that scientists understood how characteristics are inherited. Mendel's discoveries formed the basis of **genetics**, the science of heredity. That's why Mendel is often called the "father of genetics." It's not common for a single researcher to have such an important impact on science. The importance of Mendel's work was due to three things: a curious mind, sound scientific methods, and good luck. You'll see why when you read about Mendel's experiments.

Gregor Mendel (**Figure** below) was born in 1822 and grew up on his parents' farm in Austria. He did well in school and became a monk. He also went to the University of Vienna, where he studied science and math. His professors encouraged him to learn science through experimentation and to use math to make sense of his results. Mendel is best known for his experiments with the pea plant *Pisum sativum*.

[Figure 2]

The Austrian monk Gregor Mendel experimented with pea plants. He did all of his research in the garden of the monastery where he lived.

Blending Theory of Inheritance

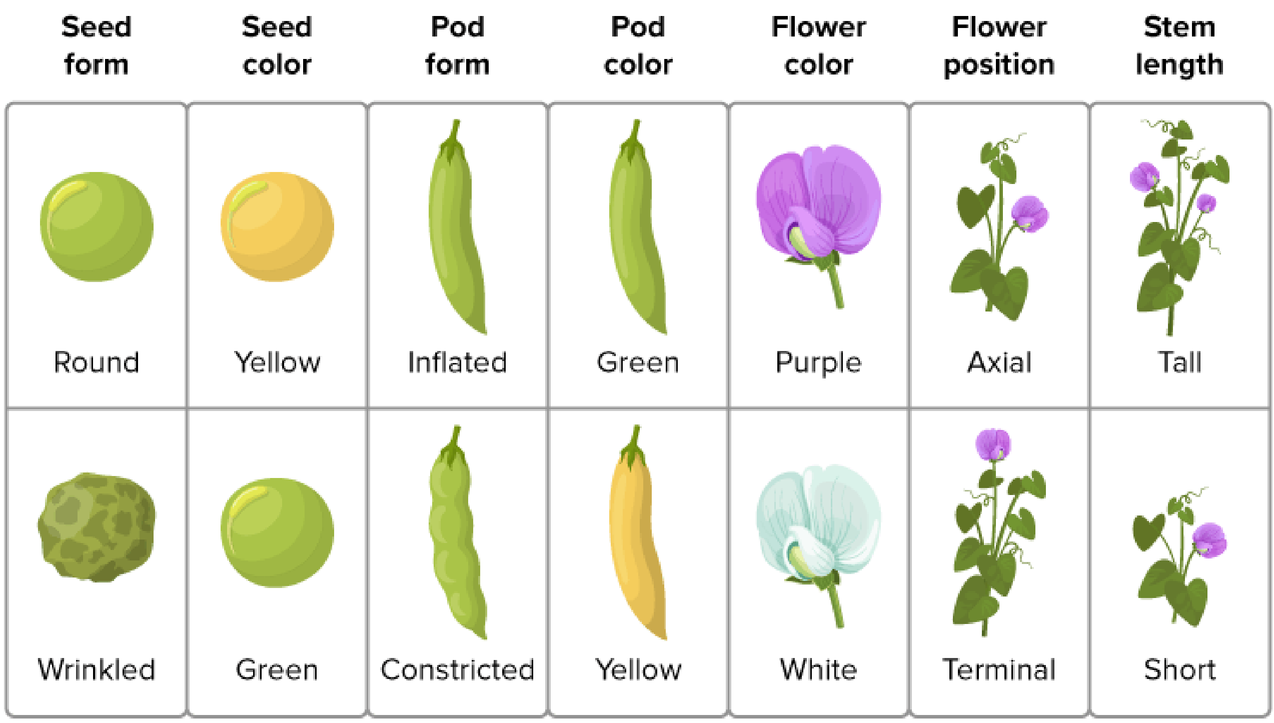
During Mendel's time, the blending theory of inheritance was popular. This is the theory that offspring have a blend, or mix, of the characteristics of their parents. Mendel noticed plants in his own garden that weren't a blend of the parents. For example, a tall plant and a short plant had offspring that were either tall or short but not medium in height. observation such as these led Mendel to question the blending theory. He wondered if there was a different underlying principle that could explain how characteristics are inherited. He decided to experiment with pea plants to find out. In fact, Mendel experimented with almost 30,000 pea plants over the next several years!

DID YOU KNOW?

Mendel studied natural science and mathematics at the University of Vienna. His professors encouraged him to learn science through experimentation and to use mathematics to help explain observations of natural events, which he did. In fact, it was the use of math in his analysis that made his conclusions much more convincing.

Why Study Pea Plants?

Why did Mendel choose common, garden-variety pea plants for his experiments? Pea plants are a good choice because they are fast-growing and easy to raise. They also have several visible characteristics that may vary. These characteristics, which are shown in the **Figure** below, include seed form and color, flower color, pod form and color, placement of pods and flowers on stem, and stem length. Each characteristic has two common values. For example, seed form may be round or wrinkled, and flower color may be white or purple (violet).

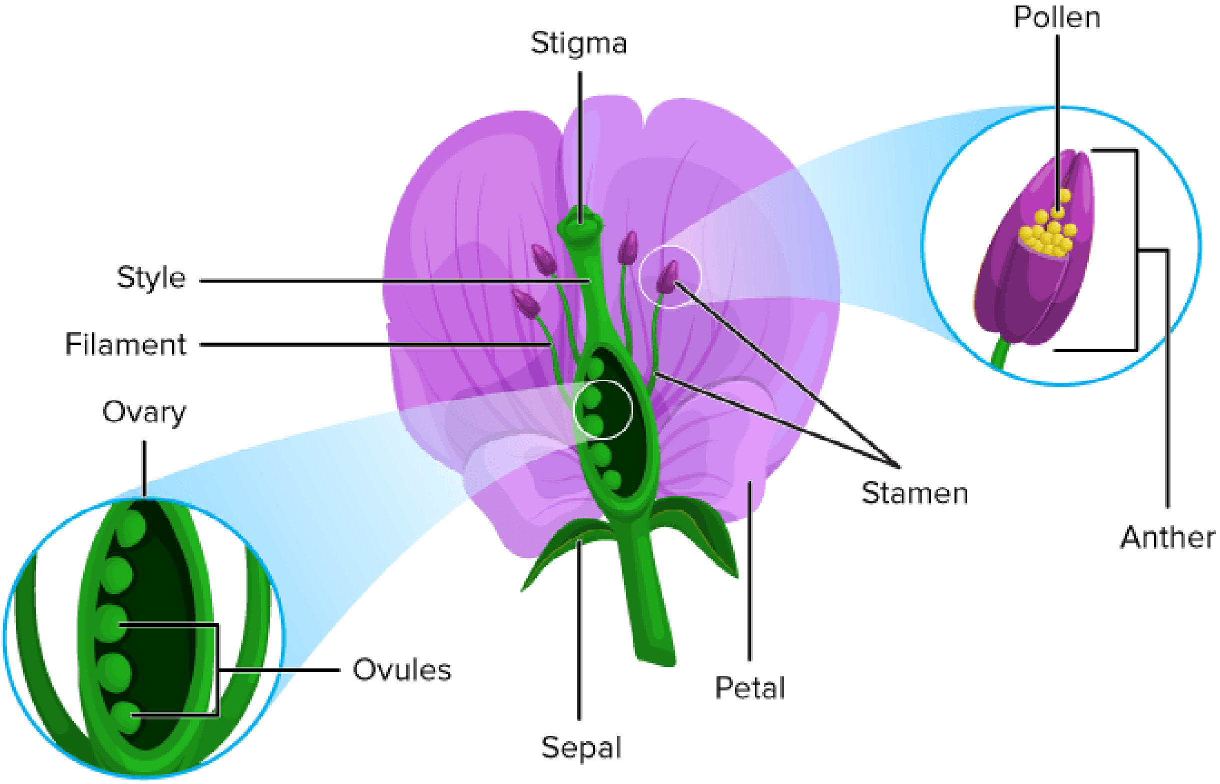


[Figure 3]

Mendel investigated seven different characteristics in pea plants.

Controlling Pollination

To research how characteristics are passed from parents to offspring, Mendel needed to control pollination. **Pollination** is the fertilization step in the sexual reproduction of plants. **pollen** consists of tiny grains that are the male gamete of plants. They are produced by a male flower part called the **anther** (see the **Figure** below). Pollination occurs when pollen is transferred from the anther to the **stigma** of the same or another flower. The **stigma** is a female part of a flower. It passes the pollen grains to female gametes in the ovary.



[Figure 4]

Flowers are the reproductive organs of plants. Each pea plant flower has both male and female parts. The anther is part of the stamen, the male structure that produces male gametes (pollen). The stigma is part of the pistil, the female structure that produces female gametes and guides the pollen grains to them. The stigma receives the pollen grains and passes them to the ovary, which contains female gametes.

Pea plants are naturally self-pollinating. In **self-pollination**, pollen grains from anthers on one plant are transferred to stigmas of flowers on the same plant. Mendel was interested in the offspring of two different parent plants, so he had to prevent self-pollination. He removed the anthers from the flowers of some of the plants in his experiments. Then he pollinated them by hand with pollen from other parent plants of his choice. When pollen from one plant fertilizes another plant of the same species, it is called **cross-pollination**. The offspring that result from such a cross are called **hybrids.**

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Summary

- Gregor Mendel experimented with pea plants to learn how characteristics are passed from parents to offspring.
- Mendel controlled pollination in pea plants in order to research how characteristics are passed from parents to offspring.
- Mendel's discoveries formed the basis of genetics, the science of heredity.
- Cross-pollination produces hybrids.

Review

1. What is the blending theory of inheritance? Why did Mendel question this theory?
2. List the seven characteristics that Mendel investigated in pea plants.
3. How did Mendel control pollination in pea plants?
4. What are hybrids?

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3.2 Mendel's First Experiment

FlexBooks 2.0 > Biology For High School Diploma > Mendel's First Experiment

Last Modified: Jan 25, 2022

What you will learn

- Mendel's first experiment with pea plants
- What were the results of F1 and F2 generations
- Mendel's first law of inheritance: the **law of segregation**

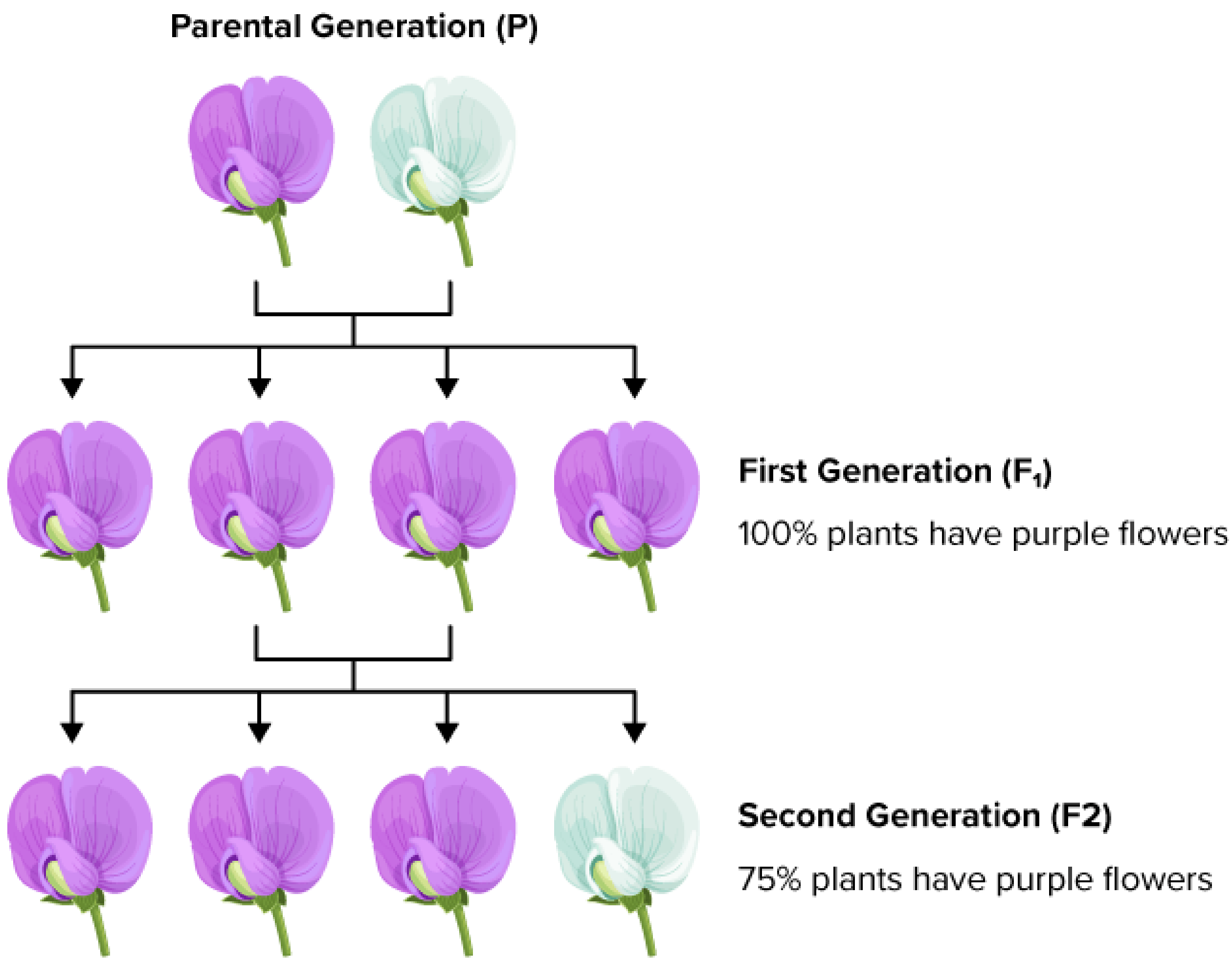
[Figure 1]

Peas. Some round and some wrinkled. *Why?*

That's what Mendel asked. He noticed peas were always round or wrinkled, but never anything else. seed shape was one of the traits Mendel studied in his first set of experiments.

Mendel's First Set of Experiments

Mendel first experimented with just one characteristic of a pea plant at a time. He began with flower color. As shown in the **Figure** below, Mendel cross-pollinated purple- and white-flowered parent plants. The parent plants in the experiments are referred to as the **P** (for parent) **generation**.



[Figure 2]

This diagram shows Mendel's first experiment with pea plants. The F1 generation results from cross-pollination of two parent (P) plants, and contained all purple flowers. The F2 generation results from self-pollination of F1 plants, and contained 75% purple flowers and 25% white flowers. This type of experiment is known as a monohybrid cross.

F1 and F2 Generations

The offspring of the **P generation** are called the **F1** (for filial, or "offspring") **generation**. As you can see from the **Figure** above, all of the plants in the F1 generation had purple flowers. None of them had white flowers. Mendel wondered what had happened to the white-flower characteristic. He assumed some type of inherited factor produces white flowers and some other inherited factor produces purple flowers. Did the white-flower factor just disappear in the F1 generation? If so, then the offspring of the F1 generation—called the **F2 generation**—should all have purple flowers like their parents.

To test this prediction, Mendel allowed the F1 generation plants to self-pollinate. He was surprised by the results. Some of the F2 generation plants had white flowers. He studied hundreds of F2 generation plants, and for every three purple-flowered plants, there was an average of one white-flowered plant.

Law of Segregation

Mendel did the same experiment for all seven pea plant characteristics. In each case, one value of the characteristic disappeared in the F1 plants and then showed up again in the F2 plants. And in each case, 75 percent of F2 plants had one value of the characteristic and 25 percent had the other value. Based on these observation, Mendel formulated his first law of inheritance. This law is called the **law of segregation**. It states that there are two factors controlling a given characteristic, one of which dominates the other, and these factors separate and go to different gamete when a parent reproduces.

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Summary

- Mendel first researched one characteristic at a time. This led to his law of segregation. This law states that each characteristic is controlled by two factors, which separate and go to different gametes when an organism reproduces.

Review

1. Describe in general terms Mendel's first set of experiments.
2. State Mendel's first law.

3. Assume you are investigating the inheritance of stem length in pea plants. You cross-pollinate a short-stemmed plant with a long-stemmed plant. All of the offspring have long stems. Then, you let the offspring self-pollinate. Describe the stem lengths you would expect to find in the second generation of offspring.

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3.3 Mendel's Second Experiment

FlexBooks 2.0 > Biology For High School Diploma > Mendel's Second Experiment

Last Modified: Apr 25, 2022

What you will learn

- What Mendel observed in his second set of experiment
- How the results of these experiments led to the **law of independent assortment**

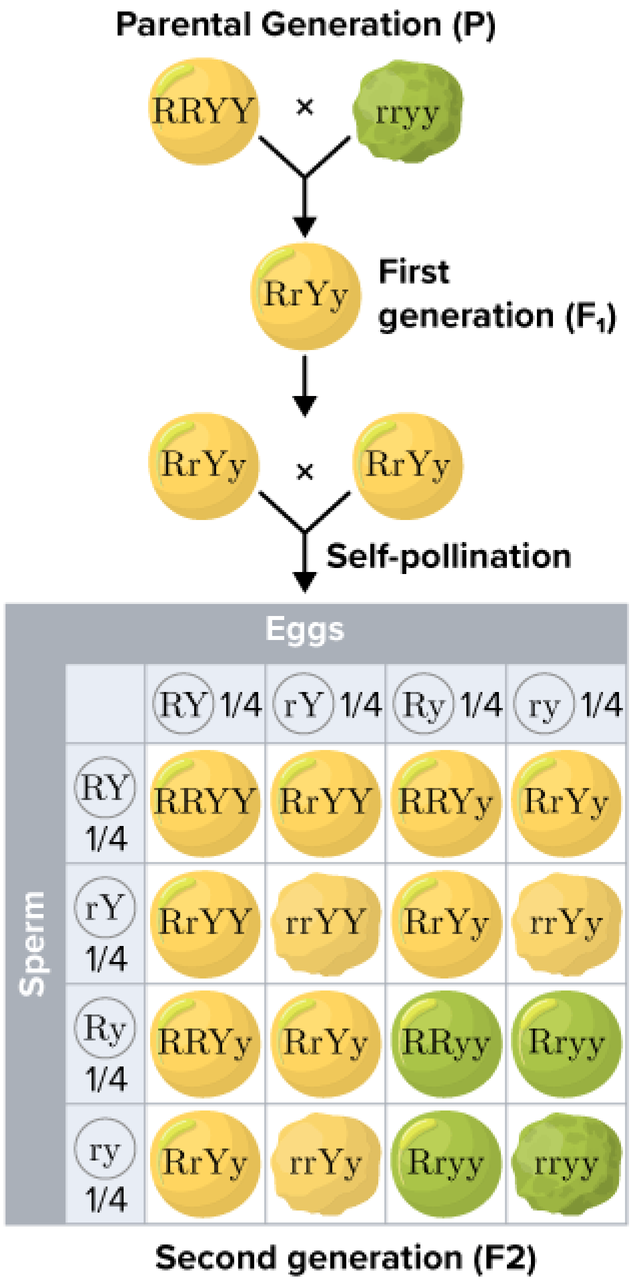
[Figure 1]

Round and green, round and yellow, wrinkled and green, or wrinkled and yellow?

Can two traits be inherited together? Or are all traits inherited separately? Mendel asked these questions after his first round of experiments.

Mendel's Second Set of Experiments

After observing the results of his first set of experiments, Mendel wondered whether different characteristics are inherited together. For example, are purple flower and tall stem always inherited together? Or do these two characteristics show up in different combinations in offspring? To answer these questions, Mendel next investigated two characteristics at a time. For example, he crossed plants with yellow round seed and plants with green wrinkled seeds. The results of this cross, which is a **dihybrid cross**, are shown in the **Figure** below.



[Figure 2]

This chart represents Mendel's second set of experiments. It shows the outcome of a cross between plants that differ in seed color (yellow or green) and seed form (shown here with a smooth round appearance or wrinkled appearance). The letters R, r, Y, and y represent genes for the characteristics Mendel was studying. Mendel didn't know about genes, however. Genes would not be discovered until several decades later. This experiment demonstrates that in the F2 generation, 9/16 were round yellow seeds, 3/16 were wrinkled yellow seeds, 3/16 were round green seeds, and 1/16 were wrinkled green seeds.

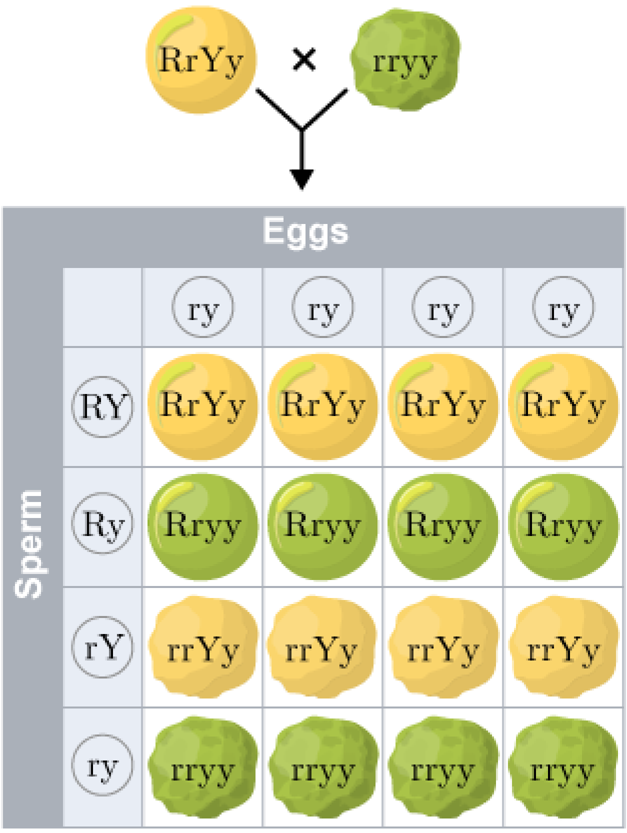
F1 and F2 Generations

In this set of experiments, Mendel observed that plants in the F1 generation were all alike. All of them had yellow and round seeds like one of the two parents. When the F1 generation plants were self-pollinated, however, their offspring—the F2 generation—showed all possible combinations of the two characteristics. Some had green round seeds, for example, and some had yellow wrinkled seeds. These combinations of characteristics were not present in the F1 or P generations.

Law of Independent Assortment

Mendel repeated this experiment with other combinations of characteristics, such as flower color and stem length. Each time, the results were the same as those in the **Figure** above. The results of Mendel's second set of experiments led to his second law. This is the **law of independent assortment**. It states that factors controlling different characteristics are inherited independently of each other.

What are the missing combinations of genes in the cross below?



Summary

- After his first set of experiments, Mendel researched two characteristics at a time. This led to his law of independent assortment. This law states that the factors controlling different characteristics are inherited independently of each other.

Review

1. What was Mendel investigating with his second set of experiments? What was the outcome?
2. State Mendel's second law.
3. If a purple-flowered, short-stemmed plant is crossed with a white-flowered, long-stemmed plant, would all of the purple-flowered offspring also have short stems? Why or why not?

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3.4 Mendel's Laws

FlexBooks 2.0 > Biology For High School Diploma > Mendel's Laws

Last Modified: Jan 25, 2022

What you will learn

- The rediscovery of Mendel's work in the 1900s
- What are the differences between **locus** and allele, **genotype** and **phenotype**, **heterozygote** and **homozygote**, and a **dominant allele** and **recessive allele**

[Figure 1]

Do you look like your parents?

You probably have some characteristics or traits in common with each of your parents. Mendel's work provided the basis to understand the passing of traits from one generation to the next.

Mendel's Laws and Genetics

You might think that Mendel's discoveries would have made a big impact on science as soon as he made them. But you would be wrong. Why? Because Mendel's work was largely ignored. Mendel was far ahead of his time and working from a remote monastery. He had no reputation among the scientific community and no previously published work.

Mendel's work, titled *experiment in Plant Hybridization*, was published in 1866, and sent to prominent libraries in several countries, as well as 133 natural science associations. Mendel himself even sent carefully marked experiment kits to Karl von Nageli, the leading botanist of the day. The result - it was almost completely ignored. Von Nageli instead sent hawkweed seed to Mendel, which he thought was a better plant for studying **heredity**. Unfortunately hawkweed reproduces asexually, resulting in genetically identical clones of the parent.

Charles Darwin published his landmark book on evolution in 1869, not long after Mendel had discovered his laws. Unfortunately, Darwin knew nothing of Mendel's discoveries and didn't understand heredity. This made his arguments about evolution less convincing to many people. This example demonstrates the importance for scientists to communicate the results of their investigations.

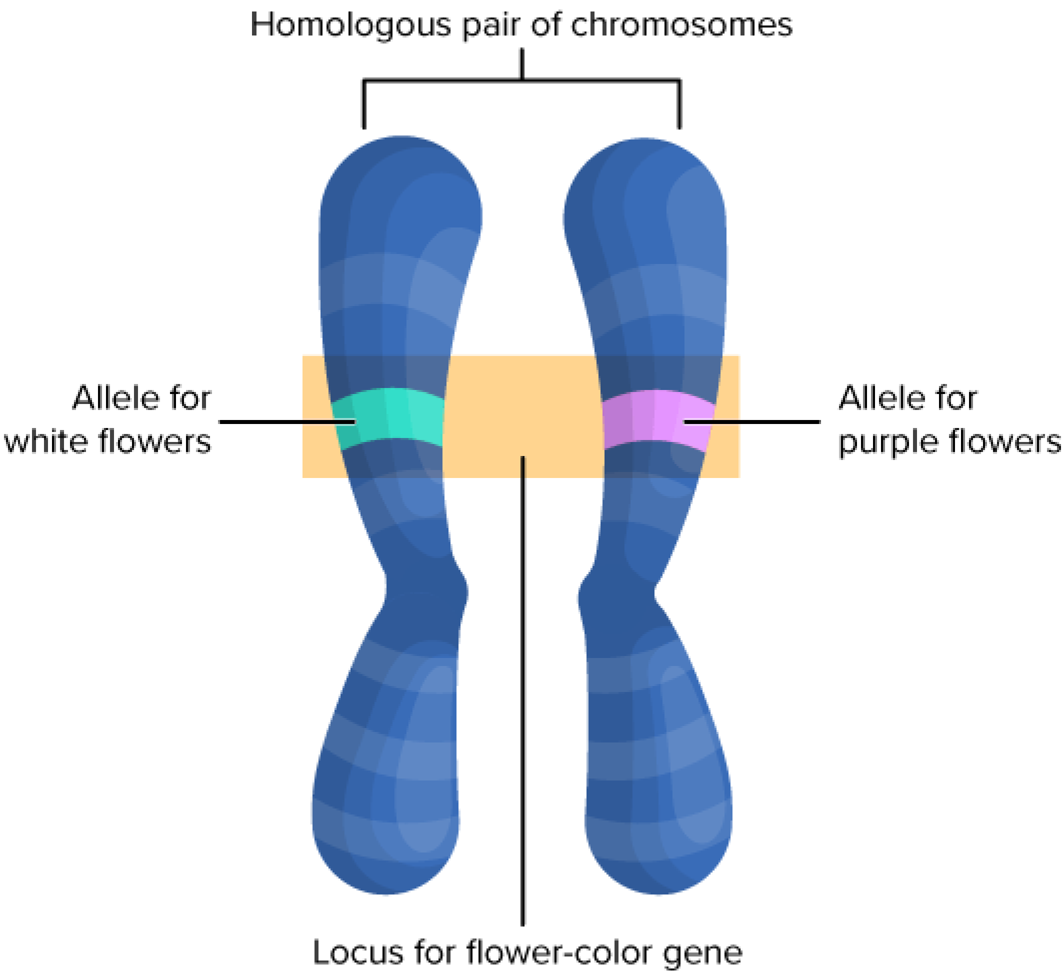
Rediscovering Mendel's Work

Mendel's work was virtually unknown until 1900. In that year, three different European scientists — named Hugo De Vries, Carl Correns, and Erich Von Tschermak-Seysenegg — independently arrived at Mendel's laws. All three had done experiments similar to Mendel's. They came to the same conclusions that he had drawn almost half a century earlier. Only then was Mendel's actual work rediscovered.

As scientists learned more about **heredity** - the passing of traits from parents to offspring - over the next few decades, they were able to describe Mendel's ideas about inheritance in terms of gene. In this way, the field of genetics was born.

Genetics of Inheritance

Today, we know that characteristics of organism are controlled by genes on chromosome (see the **Figure** below). The position of a gene on a chromosome is called its **locus**. In sexually reproducing organisms, each individual has two copies of the same gene, as there are two versions of the same chromosome (**homologous chromosomes**). One copy comes from each parent. The gene for a characteristic may have different versions, but the different versions are always at the same locus. The different versions are called **alleles**. For example, in pea plants, there is a purple-flower allele (*P*) and a white-flower allele (*p*). Different alleles account for much of the variation in the characteristics of organisms.



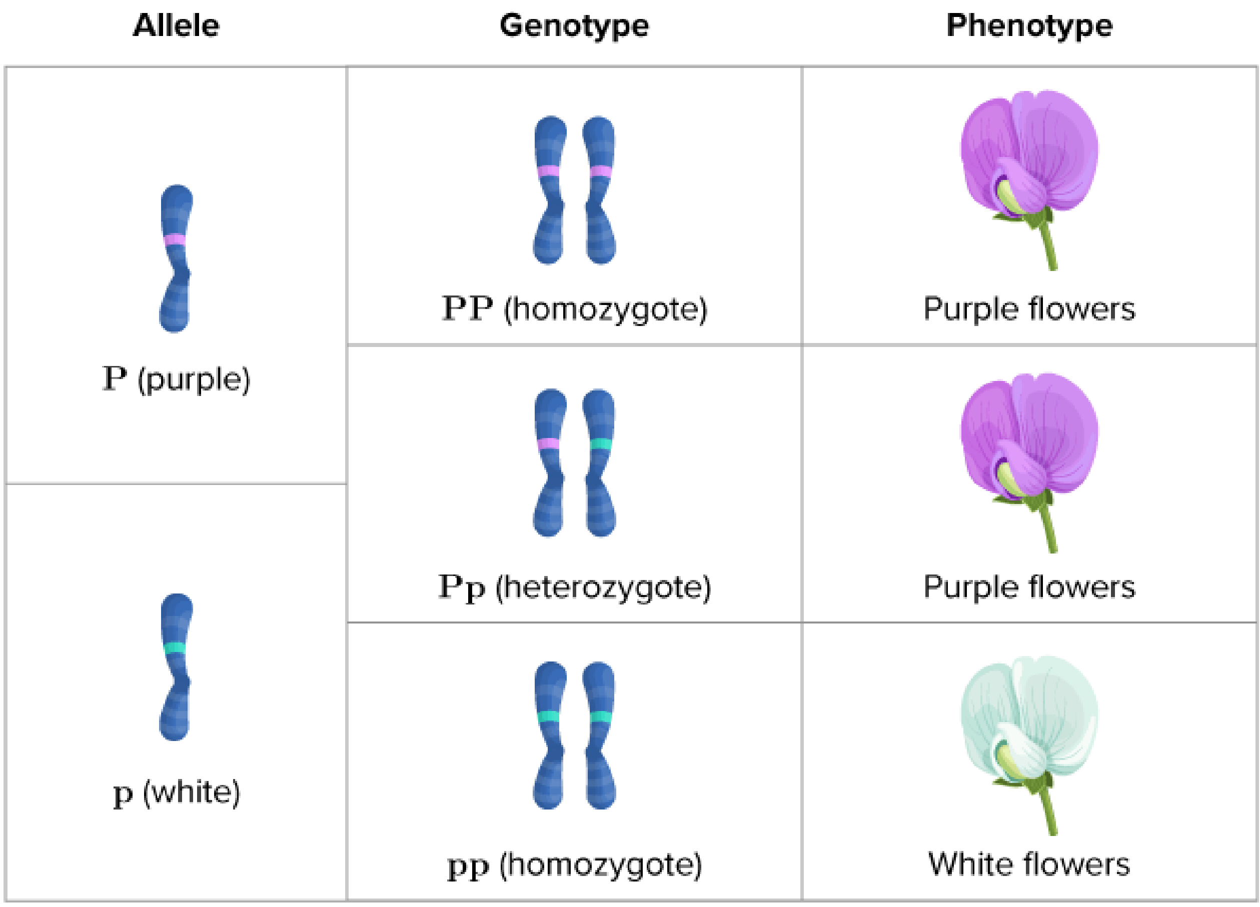
[Figure 2]

Chromosome, Gene, Locus, and Allele. This diagram shows how the concepts of chromosome, gene, locus, and allele are related. What is the difference between a gene and a locus? Between a gene and an allele?

During meiosis, homologous chromosomes separate and go to different gamete. Thus, the two alleles for each gene also go to different gametes. At the same time, different chromosomes assort independently. As a result, alleles for different genes assort independently as well. In these ways, alleles are shuffled and recombined in each parent's gametes.

Genotype and Phenotype

When gametes unite during fertilization, the resulting zygote inherits two alleles for each gene. One allele comes from each parent. The alleles an individual inherits make up the individual's **genotype**. The two alleles may be the same or different. As shown in the **Figure** below, an organism with two alleles of the same type (*PP* or *pp*) is called a **homozygote**. An organism with two different alleles (*Pp*) is called a **heterozygote**. This results in three possible genotypes.



[Figure 3]

Relationship between allele, genotype, and phenotype.

The expression of an organism's genotype produces its **phenotype**. The phenotype refers to the organism's characteristics, such as purple or white flowers. As you can see from the **Figure** above, different genotypes may produce the same phenotype. For example, *PP* and *Pp* genotypes both produce plants with purple flowers. Why does this happen? In a *Pp* heterozygote, only the *P* allele is expressed, so the *p* allele doesn't influence the phenotype. In general, when only one of two alleles is expressed in the phenotype, the expressed allele is called the **dominant** allele. The allele that isn't expressed is called the **recessive** allele.

How Mendel Worked Backward to Get Ahead

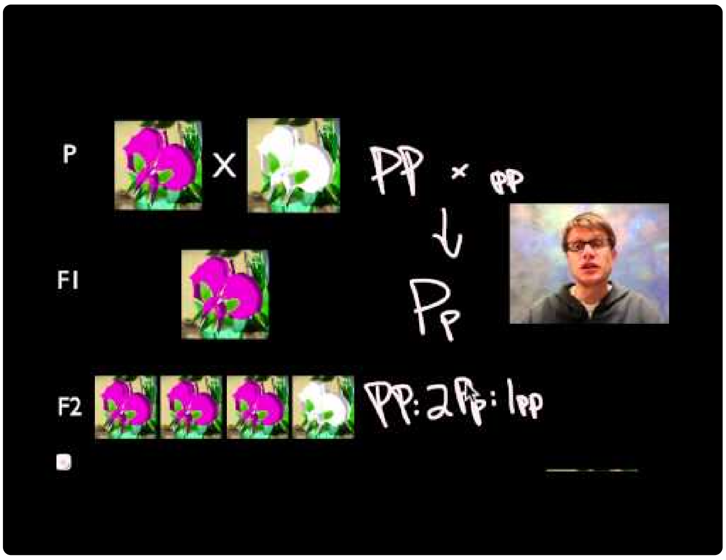
Mendel used hundreds or even thousands of pea plants in each experiment he did. Therefore, his results were very close to those you would expect based on the rules of probability. For example, in one of his first experiments with flower color, there were 929 plants in the F2 generation. Of these, 705 (76 percent) had purple flowers and 224 (24 percent) had white flowers. Thus, Mendel's results were very close to the 75 percent purple and 25 percent white you would expect by the laws of probability for this type of cross.

Of course, Mendel had only phenotypes to work with. He knew nothing about genes and genotypes. Instead, he had to work backward from phenotypes and their percents in offspring to understand inheritance. From the results of his first set of experiments, Mendel realized that there must be two factors controlling each of the characteristics he studied, with one of the factors being dominant to the other. He also realized that the two factors separate and go to different gametes and later recombine in the offspring. This is an example of Mendel's good luck. All of the characteristics he studied happened to be inherited in this way.

Mendel also was lucky when he did his second set of experiments. He happened to pick characteristics that are inherited independently of one another. We now know that these characteristics are controlled by genes on nonhomologous chromosomes. What if Mendel had studied characteristics controlled by genes on homologous chromosomes? Would they be inherited together? If so, how do you think this would have affected Mendel's conclusions? Would he have been able to develop his second law of inheritance?

DID YOU KNOW?

Genes that exhibit incomplete dominance, codominance, or linkage do not follow Mendel's laws of inheritance.



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Summary

- Mendel's work was rediscovered in 1900. Soon after that, genes and alleles were discovered. This allowed Mendel's laws to be stated in terms of the inheritance of alleles.
- The gene for a characteristic may have different versions. These different versions of a gene are known as alleles.
- Alleles for different genes assort independently during meiosis.
- The alleles an individual inherits make up the individual's genotype. The individual may be homozygous (two of the same alleles) or heterozygous (two different alleles).
- The expression of an organism's genotype produces its phenotype.
- When only one of two alleles is expressed, the expressed allele is the dominant allele, and the allele that isn't expressed is the recessive allele.
- Mendel used the percentage of phenotypes in offspring to understand how characteristics are inherited.

Review

1. If Darwin knew of Mendel's work, how might it have influenced his theory of evolution? Do you think this would have affected how well Darwin's work was accepted?
2. Explain Mendel's laws in genetic terms, that is, in terms of chromosomes, genes, and alleles.
3. Explain the relationship between genotype and phenotype. How can one phenotype result from more than one genotype?

Report Content Errors

3.5 Probability

FlexBooks 2.0 > Biology For High School Diploma > Probability

Last Modified: Jan 25, 2022

What you will learn

- What is probability
- How rules of probability are applied to determine the phenotype and **genotype** of offspring

[Figure 1]

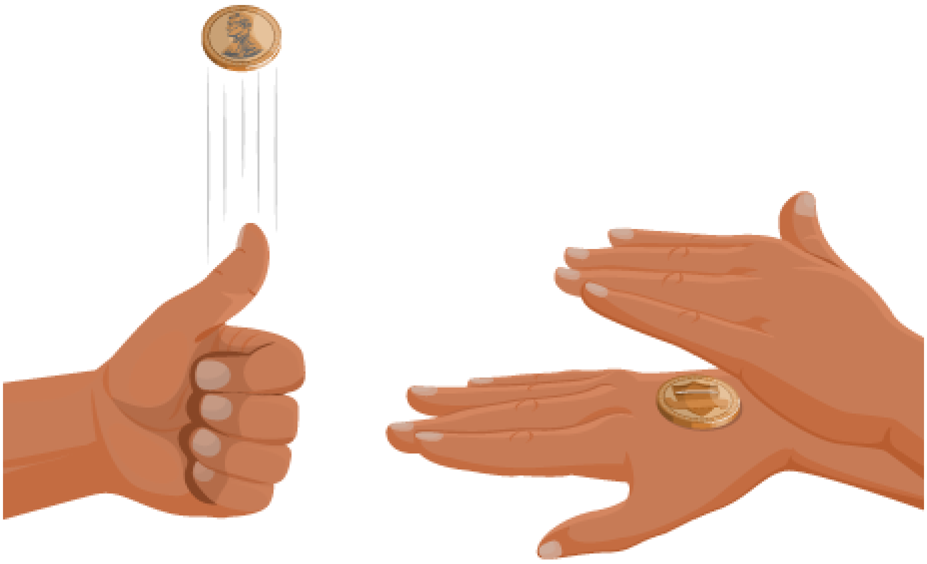
What are the odds of landing on 23 again?

Not as high as inheriting an allele from a parent. Probability plays a big role in determining the chance of inheriting an allele from a parent. It is similar to tossing a coin. What's the chance of the coin landing on heads?

Probability

Assume you are a plant breeder trying to develop a new variety of plant that is more useful to humans. You plan to cross-pollinate an insect-resistant plant with a plant that grows rapidly. Your goal is to produce a variety of plant that is both insect resistant and fast growing. What percentage of the offspring would you expect to have both characteristics? Mendel's laws can be used to find out. However, to understand how Mendel's laws can be used in this way, you first need to know about probability.

Probability is the likelihood, or chance, that a certain event will occur. The easiest way to understand probability is with coin tosses (see the **Figure** below). When you toss a coin, the chance of a head turning up is 50 percent. This is because a coin has only two sides, so there is an equal chance of a head or tail turning up on any given toss.



[Figure 2]

Tossing a Coin. Competitions often begin with the toss of a coin. Why is this a fair way to decide who goes first? If you choose heads, what is the chance that the toss will go your way?

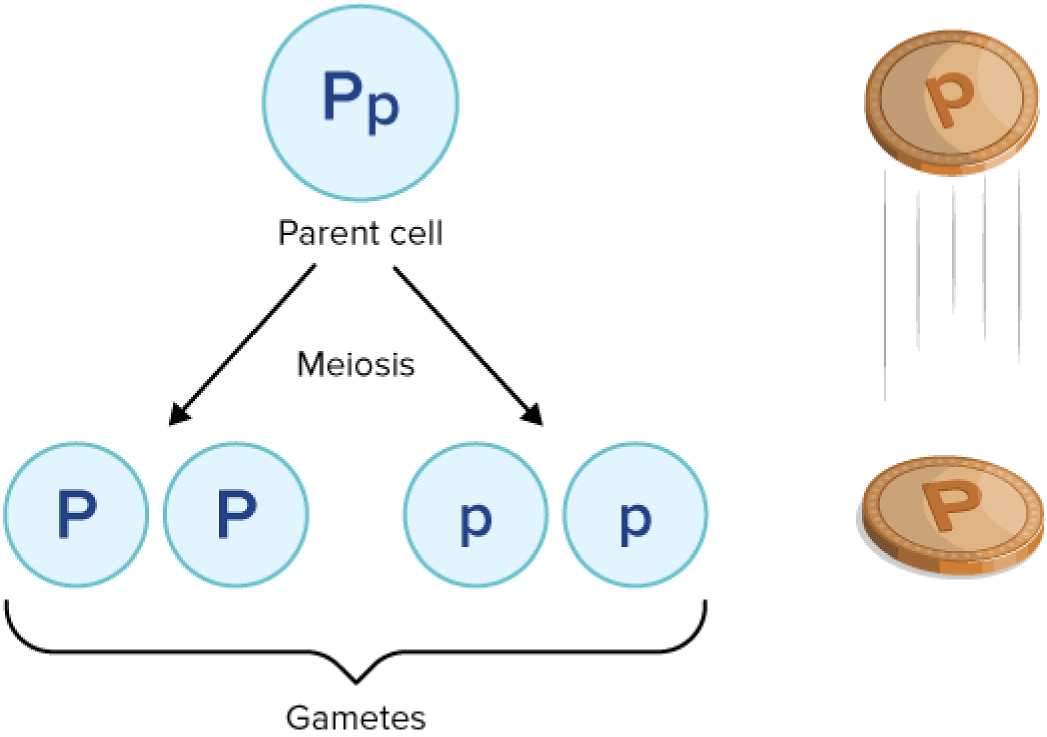
If you toss a coin twice, you might expect to get one head and one tail. But each time you toss the coin, the chance of a head is still 50 percent. Therefore, it's quite likely that you will get two or even several heads (or tails) in a row. What if you tossed a coin ten times? You would probably get more or less than the expected five heads. For example, you might get seven heads (70 percent) and three tails (30 percent). The more times you toss the coin, however, the closer you will get to 50 percent heads. For example, if you tossed a coin 1000 times, you might get 510 heads and 490 tails.

Probability and Inheritance

The same rules of probability in coin tossing apply to the main events that determine the **genotypes** of offspring. These events are the formation of **gamete** during **meiosis** and the union of **gametes** during fertilization.

Probability and Gamete Formation

How is gamete formation like tossing a coin? Consider Mendel's purple-flowered pea plants again. Assume that a plant is heterozygous for the flower-color allele, so it has the genotype *Pp* (see the **Figure** below). During meiosis, homologous chromosomes, and the alleles they carry, segregate and go to different gametes. Therefore, when the *Pp* pea plant forms gametes, the *P* and *p* alleles segregate and go to different gametes. As a result, half the gametes produced by the *Pp* parent will have the *P* allele and half will have the *p* allele. Based on the rules of probability, any given gamete of this parent has a 50 percent chance of having the *P* allele and a 50 percent chance of having the *p* allele.



[Figure 3]

Formation of gametes by meiosis. Paired alleles always separate and go to different gametes during meiosis.

Probability and Fertilization

Which of these gametes joins in fertilization with the gamete of another parent plant? This is a matter of chance, like tossing a coin. Thus, we can assume that either type of gamete—one with the *P* allele or one with the *p* allele—has an equal chance of uniting with any of the gametes produced by the other parent. Now assume that the other parent is also *Pp*. If gametes of two *Pp* parents unite, what is the chance of the offspring having one of each allele like the parents (*Pp*)? What is the chance of them having a different combination of alleles than the parents (either *PP* or *pp*)? To answer these questions, geneticists use a simple tool called a Punnett square, which is the focus of the next concept.

DID YOU KNOW?

The use of probability in genetics helps to understand the likelihood of inheriting traits. An English geneticist, Reginald Punnett, devised a simple graphical way to calculate the mathematical probability of inheriting a trait.

Summary

- Probability is the chance that a certain event will occur. For example, the probability of a head turning up on any given coin toss is 50 percent.
- Probability can be used to predict the chance of gametes and offspring having certain alleles.

Review

1. Define probability. Apply the term to a coin toss.
2. How is gamete formation like tossing a coin?
3. With a *PP* homozygote, what is the chance of a gamete having the *P* allele? The *p* allele?

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3.6 Punnett Squares

FlexBooks 2.0 > Biology For High School Diploma > Punnett Squares

Last Modified: Jan 25, 2022

What will you learn

- What are Punnett squares
- How the **genotype** and **phenotype** of offspring are predicted using Punnett squares
- How Punnett squares help in determining missing genotypes
- Punnet squares for two characteristics

[Figure 1]

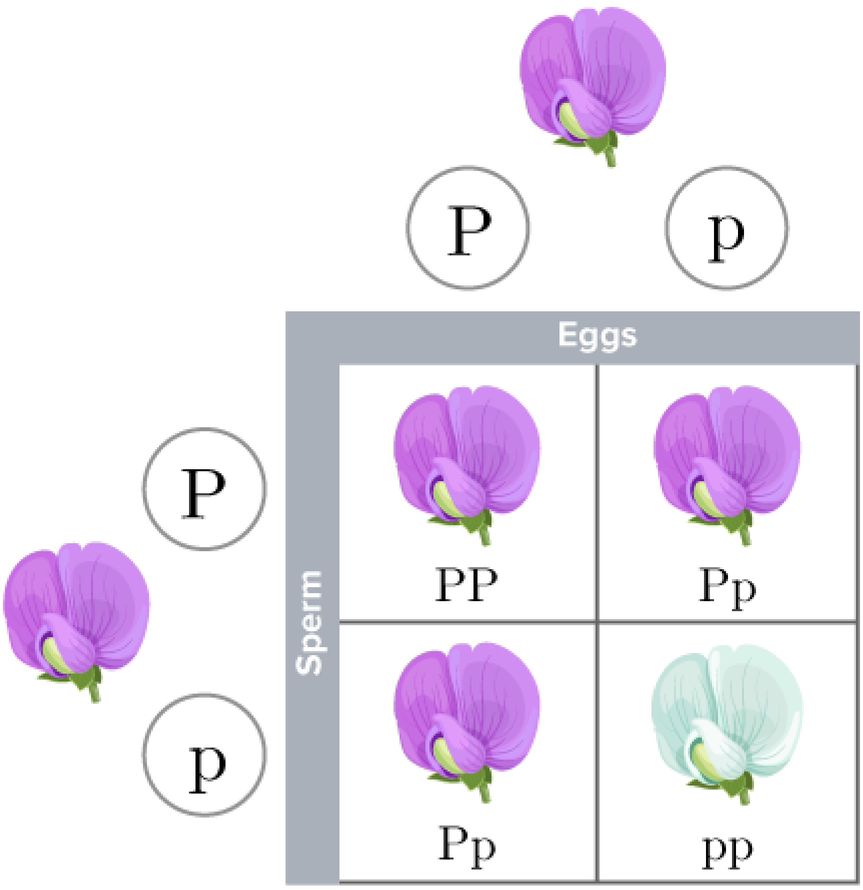
Can the appearance of freckles be predicted?

Yes! Freckles are pigmented patches that appear under the skin of some people, upon exposure to the sun. Having freckles is an inherited trait resulting from the presence of a dominant gene for that trait. Predicting the possible genotypes and phenotypes is often aided by a **Punnett square**.

Punnett Squares

A **Punnett square** is a chart that allows you to easily determine the expected percentage of different genotypes in the offspring of two parents. An example of a Punnett square for pea plants is shown below. In this example, both parents are heterozygous for flower color (*Pp*).

The **gamete** produced by the female parent are at the top of the chart, and the gametes produced by the male parent are along the side. The different possible combinations of **allele** in their offspring are determined by filling in the cell of the Punnett square with the correct letters (alleles).



Predicting Offspring Genotypes

In the cross shown above, you can see that one out of four offspring (25 percent) has the **genotype** *PP*, one out of four (25 percent) has the genotype *pp*, and two out of four (50 percent) have the genotype *Pp*. These percentages of genotypes are what you would expect in any cross between two heterozygous parents. Of course, when just four offspring are produced, the actual percentages of genotypes may vary by chance from the expected percentages. However, if you considered hundreds of such crosses and thousands of offspring, you would get very close to the expected results, just like tossing a coin.

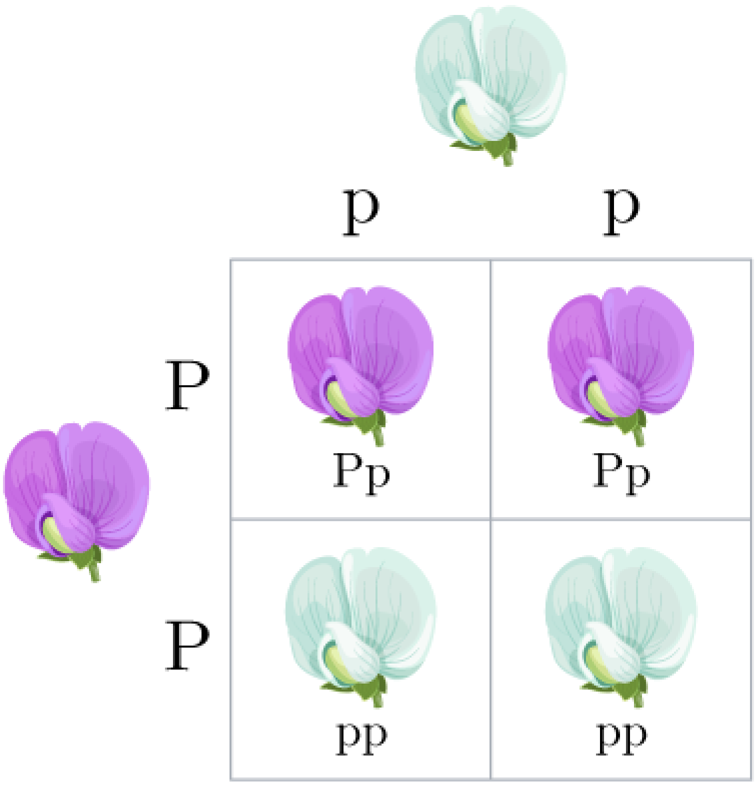
Predicting Offspring Phenotypes

You can predict the percentages of **phenotypes** in the offspring of this cross from their genotypes. *P* is dominant to *p*, so offspring with either the *PP* or *Pp* genotype will have the purple-flower phenotype. Only offspring with the *pp* genotype will have the white-flower phenotype. Therefore, in this cross, you would expect three out of four (75 percent) of the offspring to have purple flowers and one out of four (25 percent) to have white flowers. These are the same percentages that Mendel got in his first experiment.

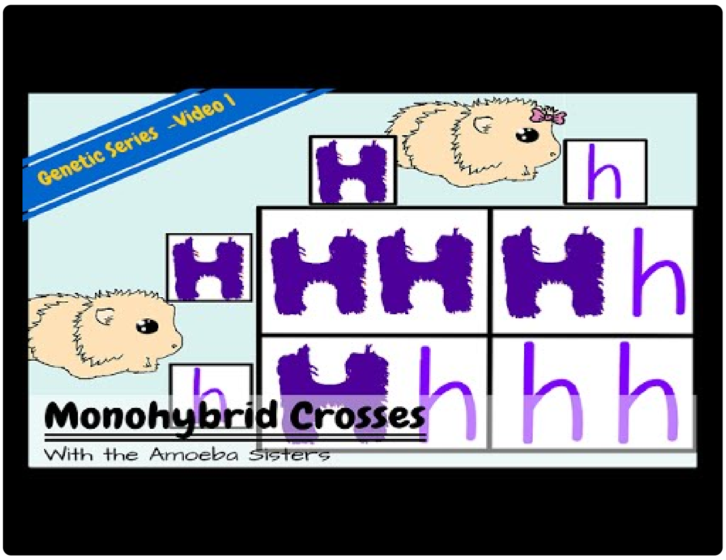
Determining Missing Genotypes

A Punnett square can also be used to determine a missing genotype based on the other genotypes involved in a cross. Suppose you have a parent plant with purple flowers and a parent plant with white flowers. Because the *p* allele is recessive, you know that the white-flowered parent must have the genotype *pp*. The purple-flowered parent, on the other hand, could have either the *PP* or the *Pp* genotype. The Punnett square below shows this cross. The question marks (?) in the chart could be either *P* or *p* alleles.

Can you fill in the missing alleles based on the given phenotypes of the flowers?



Note that two of the four offspring in the above cross have white flowers. Now you know that the offspring in the second row must have the *pp* genotype. One of their *p* alleles obviously comes from the white-flowered (*pp*) parent, because that's the only allele this parent has. The other *p* allele must come from the purple-flowered parent. Therefore, the parent with purple flowers must have the genotype *Pp*.



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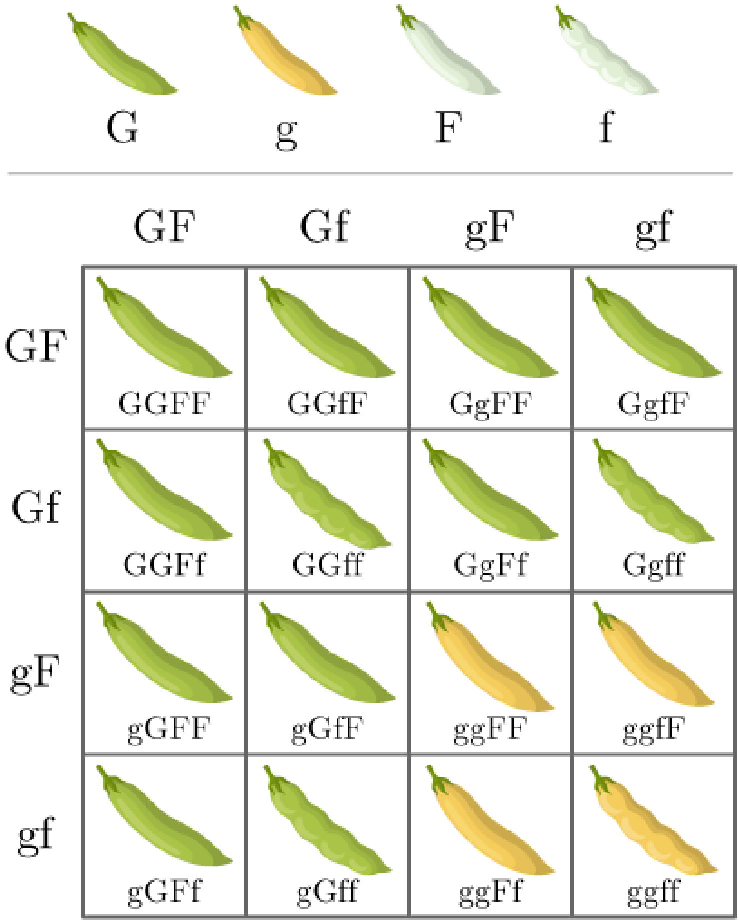
Punnett Square for Two Characteristics

When you consider more than one characteristic at a time, using a Punnett square is more complicated. This is because many more combinations of alleles are possible. For example, with two genes each having two alleles, an individual has four alleles, and these four alleles can occur in 16 different combinations.

In the Punnett square for two characteristics (shown below), G represents the dominant allele for green pod color, and g represents the recessive allele for yellow pod color. F represents the dominant allele for full pod form, and f represents the recessive allele for constricted pod form. In this cross, known as a dihybrid cross, both parents are heterozygous for pod color (*Gg*) and pod form (*Ff*). Test your understanding by answering the questions based on the given cross with the help of the Punnett square.

PROGRESS 0 / 3

1.



How many offsprings in the above cross are homozygous for green pod color?

a 8

b 12

c 4

Check It

Hint

Attribution

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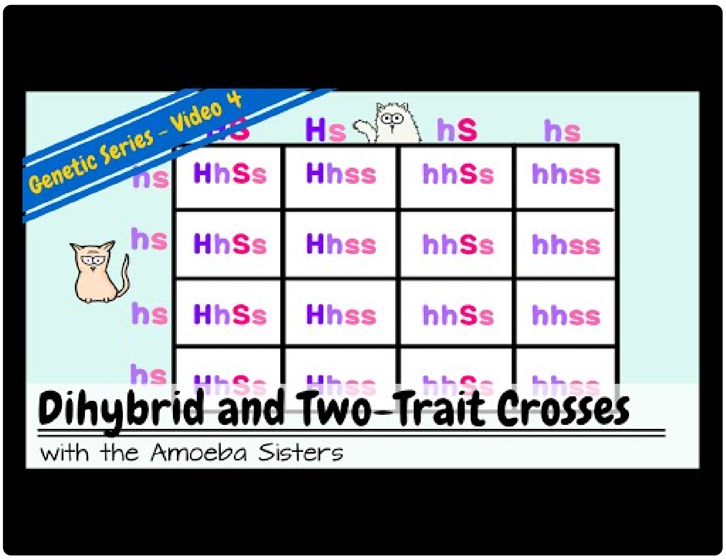
DID YOU KNOW?

Although Punnett squares are pretty accurate, they cannot predict the genotypes and phenotypes of offspring for traits controlled by many genes, like hair color, skin color, or height in humans.



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Summary

- A Punnett square is a chart that allows you to determine the expected percentages of different genotypes in the offspring of two parents.
- A Punnett square allows the prediction of the percentages of phenotypes in the offspring of a cross from known genotypes.
- A Punnett square can be used to determine a missing genotype based on the other genotypes involved in a cross.

Review

1. What is a Punnett square? How is it used?

2. Draw a Punnett square of an *Ss* x *ss* cross. The *S* allele codes for long stems in pea plants and the *s* allele codes for short stems. If *S* is dominant to *s*, what percentage of the offspring would you expect to have each phenotype?

3. What letter should replace the question marks (?) in this Punnett square? Explain how you know.

	A	A
?	A?	Aa
?	Aa	A?

4. How do the Punnett squares for a monohybrid cross and a dihybrid cross differ?

5. What are the genotypes of gametes of a AaBb self-pollination?

6. Mendel carried out a dihybrid cross to examine the inheritance of the characteristics for seed color and seed shape. The dominant allele for yellow seed color is *Y*, and the recessive allele for green color is *y*. The dominant allele for round seeds is *R*, and the recessive allele for a wrinkled shape is *r*. The two plants that were crossed were F1 dihybrids *RrYy*. Identify the ratios of traits that Mendel observed in the F2 generation. Create a Punnett square to help you answer the question.

Report Content Errors

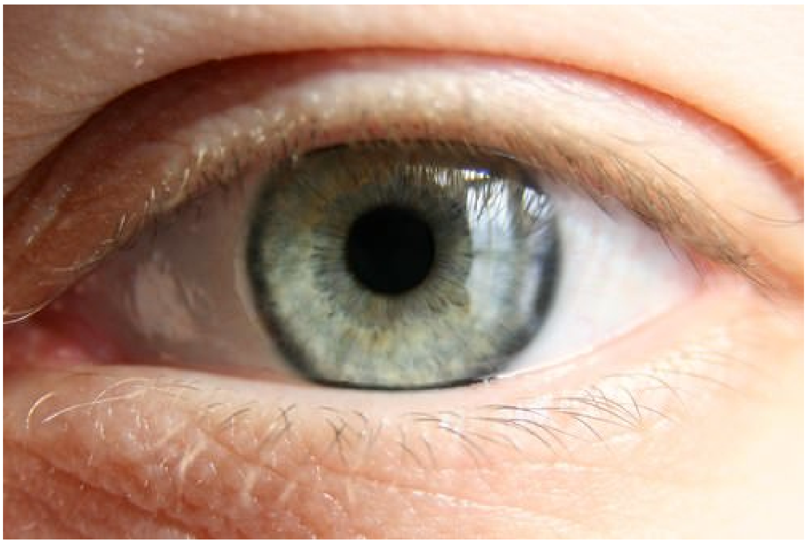
3.7 Non-Mendelian Inheritance

FlexBooks 2.0 > Biology For High School Diploma > Non-Mendelian Inheritance

Last Modified: Jan 25, 2022

What you will learn

- Complex patterns of inheritance other than those studied by Mendel
- The types of Non-Mendelian inheritance: **codominance**, **incomplete dominance**, multiple allele, and **polygenic trait**
- How environment affects the phenotype of an individual



[Figure 1]

Green, blue, brown, black, hazel, violet, or grey. What color are your eyes?

Of course, human eyes do not come in multi-color, but they do come in many colors. How do eyes come in so many colors? That brings us to complex inheritance patterns, known as non-Mendelian inheritance. Many times inheritance is more complicated than the simple patterns observed by Mendel.

Non-Mendelian Inheritance

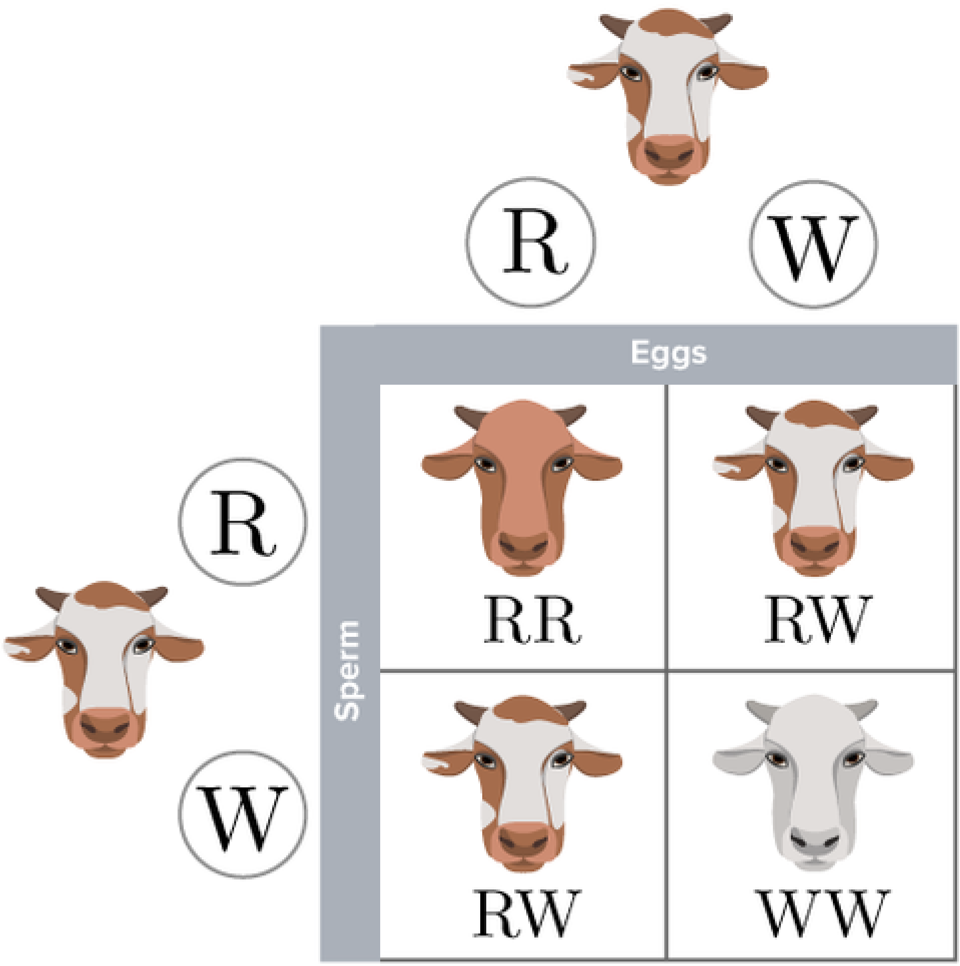
The inheritance of characteristics is not always as simple as it is for the characteristics that Mendel studied in pea plants. Each characteristic Mendel investigated was controlled by one gene that had two possible alleles, one of which was completely dominant to the other. This resulted in just two possible phenotypes for each characteristic. Each characteristic Mendel studied was also controlled by a gene on a different (nonhomologous) chromosome.

As a result, each characteristic was inherited independently of the other characteristics. Geneticists now know that inheritance is often more complex than this.

A characteristic may be controlled by one gene with two alleles, but the two alleles may have a different relationship than the simple dominant-recessive relationship that you have read about so far. For example, the two alleles may have a codominant or incompletely dominant relationship.

Codominance

Codominance occurs when both alleles are expressed equally in the phenotype of the heterozygote. The reddish-brown and white coat color in the example below has codominant alleles for reddish-brown coat color and white coat color in cows.



[Figure 2]

Codominance of alleles for reddish-brown (R) and white coat color (W) in cows.

Incomplete Dominance

Incomplete dominance occurs when the phenotype of a heterozygote offspring is somewhere in between the phenotypes of both homozygous parents; a completely dominant allele does not occur. For example, when red snapdragons (RR) are crossed with white snapdragons (WW), the F_1 hybrids are all pink heterozygotes for flower color (RW). The pink color is an intermediate between the two parent colors. When two F_1 (RW) hybrids are crossed they will produce red, pink, and white flowers. The genotype of an organism with incomplete dominance can be determined from its phenotype.

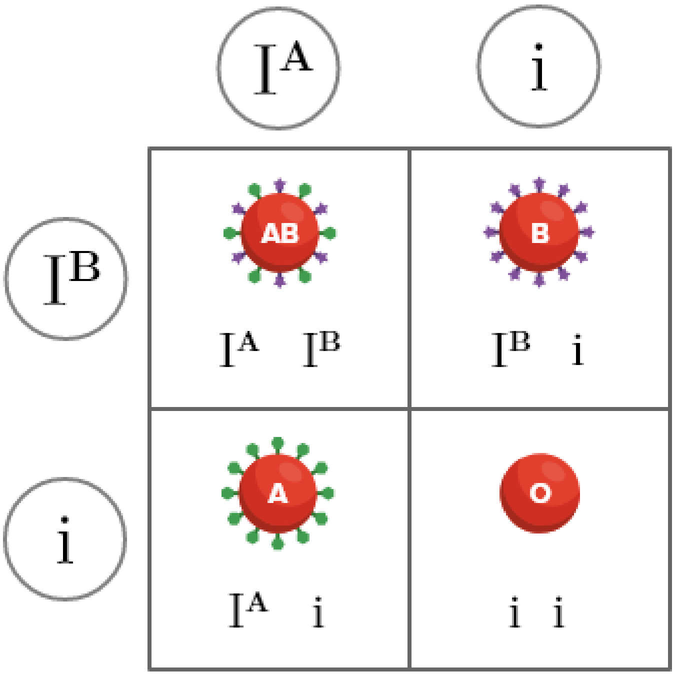
What are the missing genotypes in the cross below?

Multiple Alleles

Many genes have multiple (more than two) alleles. An example is ABO blood type in humans. There are three common alleles for the gene that controls this characteristic. The alleles I^A and I^B are dominant over i. A person who is homozygous recessive ii has type O blood. Homozygous dominant I^AI^A or heterozygous dominant I^Ai have type A blood, and homozygous dominant I^BI^B or heterozygous dominant I^Bi have type B blood. I^AI^B people have type AB blood, because the A and B alleles are codominant. Type A and type B parents can have a type AB child. Type A and type B parents can also have a child with Type O blood, if they are both heterozygous (I^Bi, I^Ai).

- Type A blood: I^AI^A, I^Ai
- Type B blood: $I^B I^B$, $I^B i$
- Type AB blood: I^AI^B
- Type O blood: ii

What are the missing genotypes in the cross below?

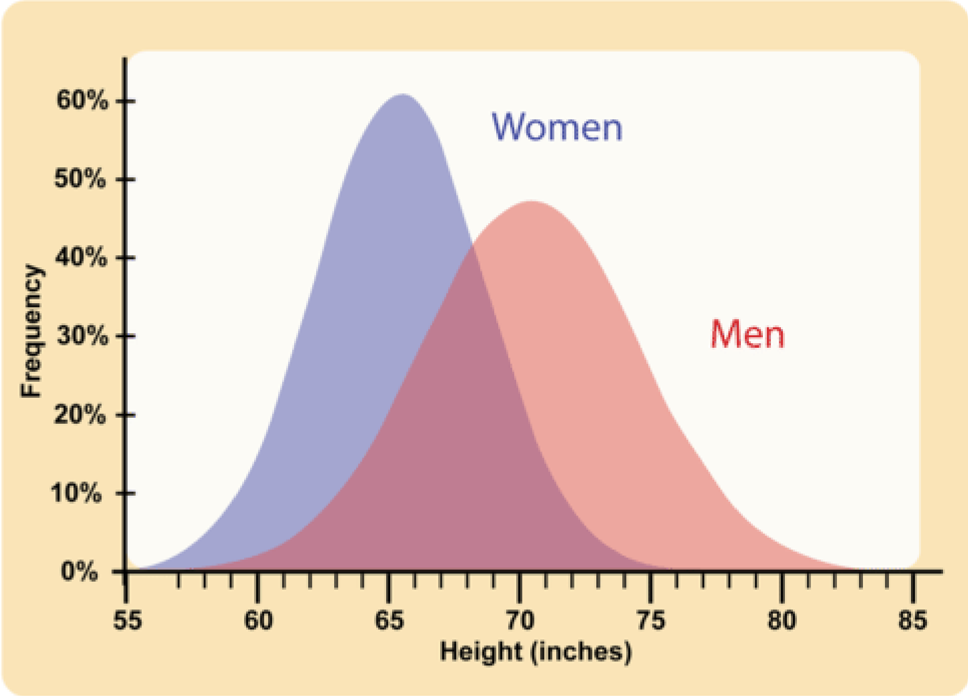


Polygenic Traits

Polygenic traits are controlled by more than one gene, and each gene may have two or more alleles. The genes may be on the same chromosome or on nonhomologous chromosomes.

- If the genes are located close together on the same chromosome, they are likely to be inherited together. However, it is possible that they will be separated by crossing over during meiosis, in which case they may be inherited independently of one another.
- If the genes are on nonhomologous chromosomes, they may be recombined in various ways because of independent assortment.

For these reasons, the inheritance of polygenic traits is very complicated. Such characteristics may have many possible phenotypes. Skin color, eye color, and adult height are examples of polygenic traits in humans. Do you have any idea how many phenotypes each characteristic has?



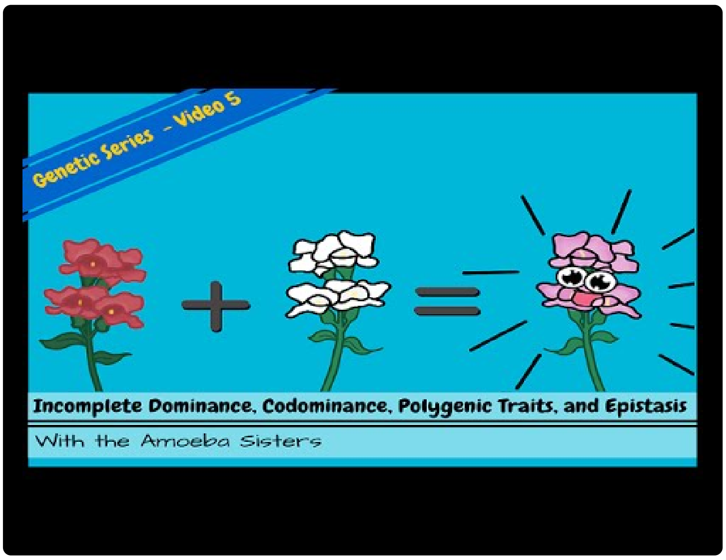
[Figure 3]

Human Adult Height. Like many other polygenic traits, adult height has a bell-shaped distribution.

Effects of Environment on Phenotype

Genes play an important role in determining an organism's characteristics. However, for many characteristics, the individual's phenotype is influenced by other factors as well. Environmental factors, such as sunlight and food availability, can affect how genes are expressed in the phenotype of individuals. Here are just two examples:

- Genes play an important part in determining our adult height. However, factors such as poor nutrition can prevent us from achieving our full genetic potential.
- Genes are a major determinant of human skin color. However, exposure to ultraviolet radiation can increase the amount of pigment in the skin and make it appear darker.



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Check your understanding!

PROGRESS 0 / 3

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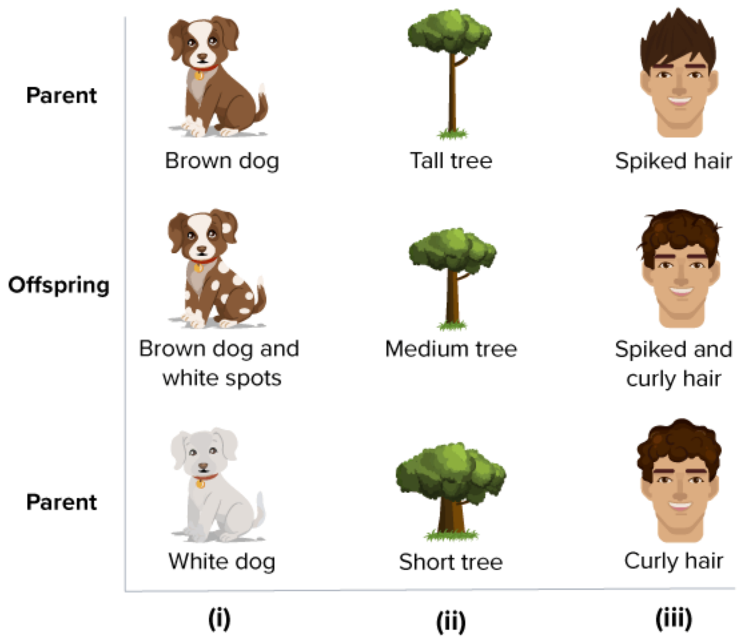

In the figure above, what is the type of inheritance in each case?

a
(i) codominance
(ii) incomplete dominance
(iii) incomplete dominance

b
(i) incomplete dominance
(ii) codominance
(iii) incomplete dominance

(i) codominance

C (ii) incomplete dominance

(iii) codominance

Check It

Hint

Attribution

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Summary

- Many characteristics have more complex inheritance patterns than those studied by Mendel. They are complicated by factors such as codominance, incomplete dominance, multiple alleles, and environmental influences.

Review

1. A classmate tells you that a person can have type AO blood. Do you agree? Explain.
2. Mendelian inheritance does not apply to the inheritance of alleles that result in incomplete dominance and codominance. Explain why this is so.
3. Describe the relationship between environment and phenotype.
4. Mendel investigated stem length, or height, in pea plants. What if he had investigated human height instead? Why would his results have been harder to interpret?

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3.8 Human Genome

FlexBooks 2.0 > Biology For High School Diploma > Human Genome

Last Modified: Feb 08, 2022

What you will learn

- How many **gene** are present in the human genome
- What are the various components of the human genome
- The goals and findings of ENCODE: Encyclopedia of DNA element

[Figure 1]

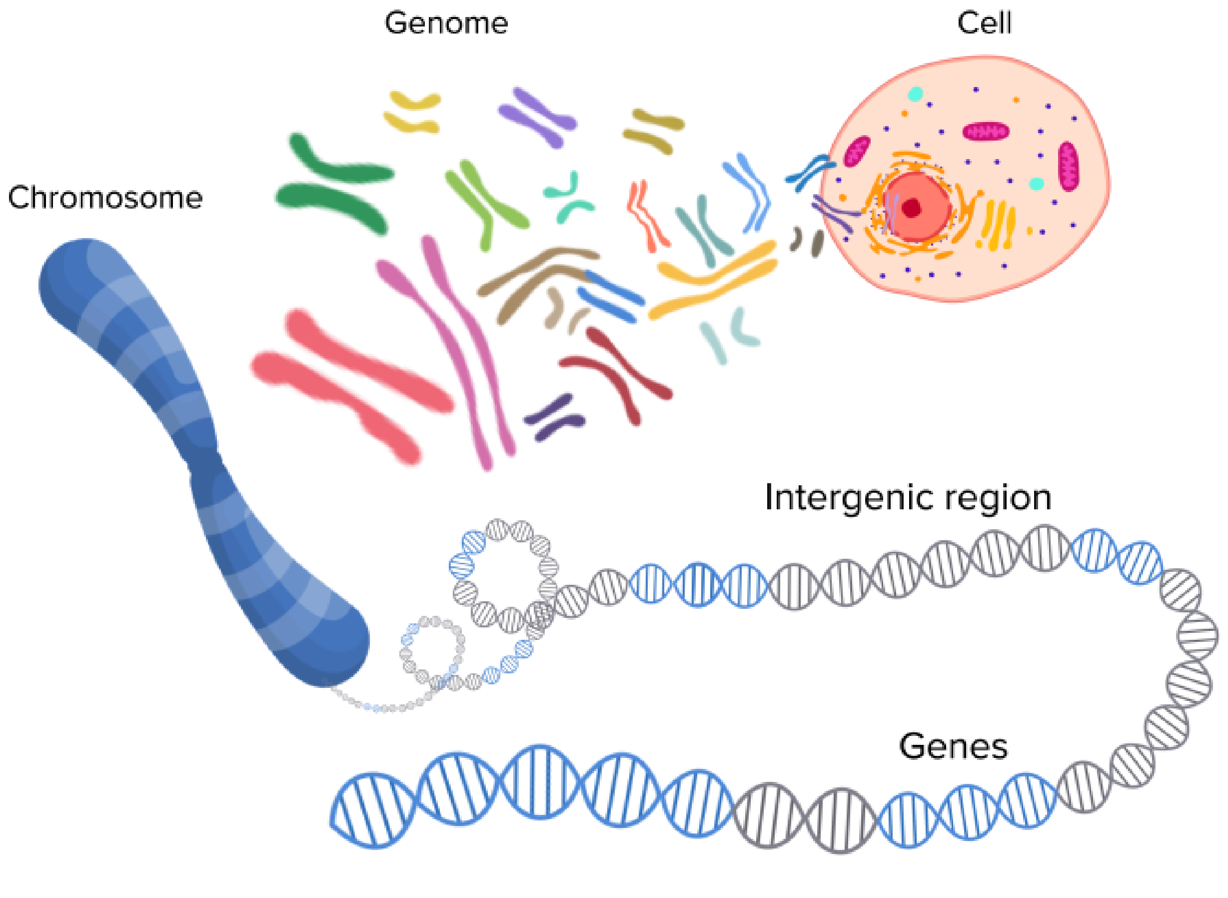
All these ACGTs. What are they?

Over three billion of them from a human form the human genome - the human genetic material - all the information needed to encode a human being. It would take about 9.5 years to read out loud - without stopping - the more than three billion pairs of bases in one person's **genome**.

The Human Genome

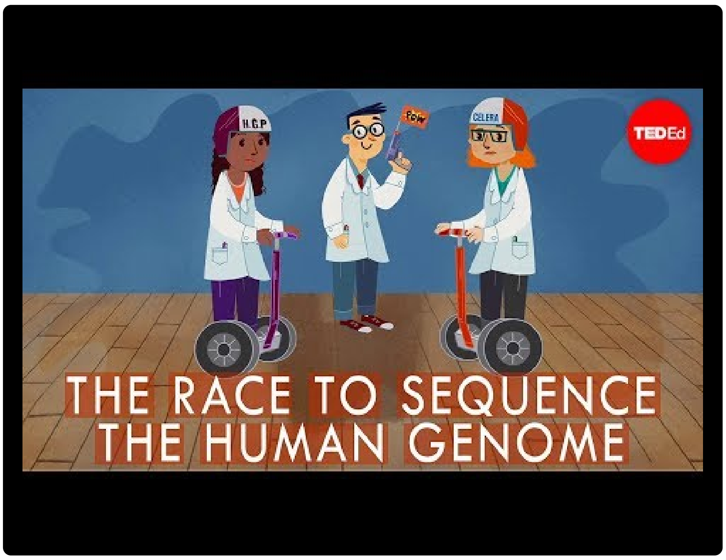
What makes each one of us unique? You could argue that the environment plays a role, and it does to some extent. But most would agree that your parents have something to do with your uniqueness. In fact, it is our **genes** that make each one of us unique – or at least genetically unique. We all have the genes that make us human: the genes for skin and bone, eyes and ears, fingers and toes, and so on. However, we all have different skin colors, different bone sizes, different eye colors and different ear shapes. In fact, even though we have the same genes, the products of these genes work a little differently in most of us. And that is what makes us unique.

The **human genome** is the **genome** - all the DNA - of *Homo sapiens*. Humans have about 3 billion bases of information, divided into roughly 20,000 to 22,000 genes, which are spread among non-coding sequences and distributed among 24 distinct chromosome (22 **autosome** plus the X and Y **sex chromosome**). The genome is all of the hereditary information encoded in the DNA, including the genes and non-coding sequences.



Human Genome, Chromosomes, and Genes. Each chromosome of the human genome contains many genes as well as noncoding intergenic (between genes) regions. Each pair of chromosomes is shown here in a different color.

Thanks to the **Human Genome Project**, scientists now know the DNA sequence of the entire human genome. The Human Genome Project is an international project that includes scientists from around the world. It began in 1990, and by 2003, scientists had sequenced all 3 billion base pairs of human DNA. Now they are trying to identify all the genes in the sequence. The Human Genome Project has produced a reference sequence of the human genome. The human genome consists of protein-coding **exon**, associated **intron** and regulatory sequences, genes that encode other RNA molecules, and other DNA sequences (sometimes referred to as "junk" DNA), which are regions in which no function as yet been identified.



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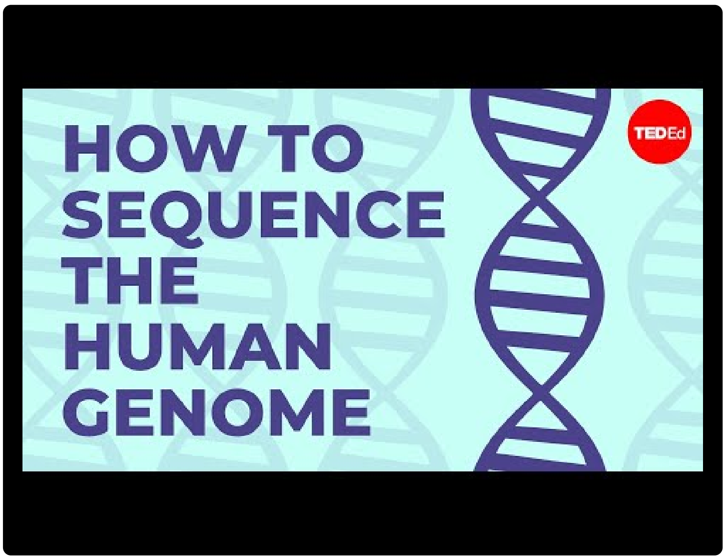
ENCODE: The Encyclopedia of DNA Elements

In September 2012, ENCODE, The **Enc**yclopedia **o**f **D**NA **E**lements, was announced. ENCODE was a colossal project, involving over 440 scientists in 32 labs the world-over, whose goal was to understand the human genome. It had been thought that about 80% of the human genome was "junk" DNA. ENCODE has established that this is not true. Now it is thought that about 80% of the genome is active. In fact, much of the human genome is regulatory sequences, on/off switches that tell our genes what to do and when to do it. Dr. Eric Green, director of the National Human Genome Research Institute of the National Institutes of Health which organized this project, states, "It's this incredible choreography going on, of a modest number of genes and an immense number of ... switches that are choreographing how those genes are used."

It is now thought that at least three-quarters of the genome is involved in making RNA, and most of this RNA appears to help regulate gene activity. Scientists have also identified about 4 million sites where protein bind to DNA and act in a regulatory capacity. These new findings demonstrate that the human genome has remarkable and precise, and complex, controls over the expression of genetic information within a cell.



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DID YOU KNOW?

A proteome is the set of proteins expressed by an organism's genome. A Proteome does not remain constant for an organism, varies from cell to cell, and can change over time.

Summary

- The human genome consists of about 3 billion base pairs of DNA.
- In 2003, the Human Genome Project finished sequencing all 3 billion base pairs.
- In September 2012, ENCODE, The Encyclopedia of DNA Elements, was announced, whose goal was to understand the human genome.

Review

1. Describe the human genome.
2. What has the Human Genome Project achieved?
3. Describe the makeup of the human genome.

Report Content Errors

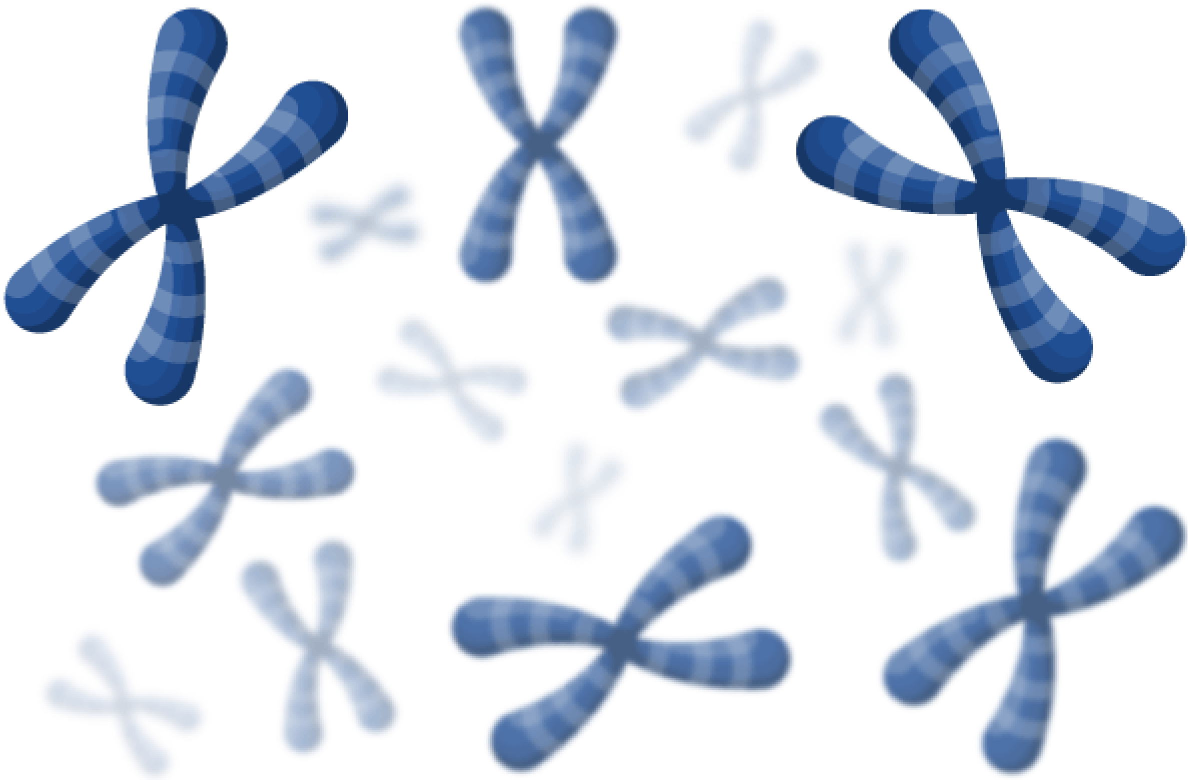
3.9 Human Chromosomes

FlexBooks 2.0 > Biology For High School Diploma > Human Chromosomes

Last Modified: Feb 08, 2022

What you will learn

- What are **chromosome** and how many chromosomes are present in human somatic cell
- What are **autosome** and **sex chromosome**
- How many gene are present in the human genome



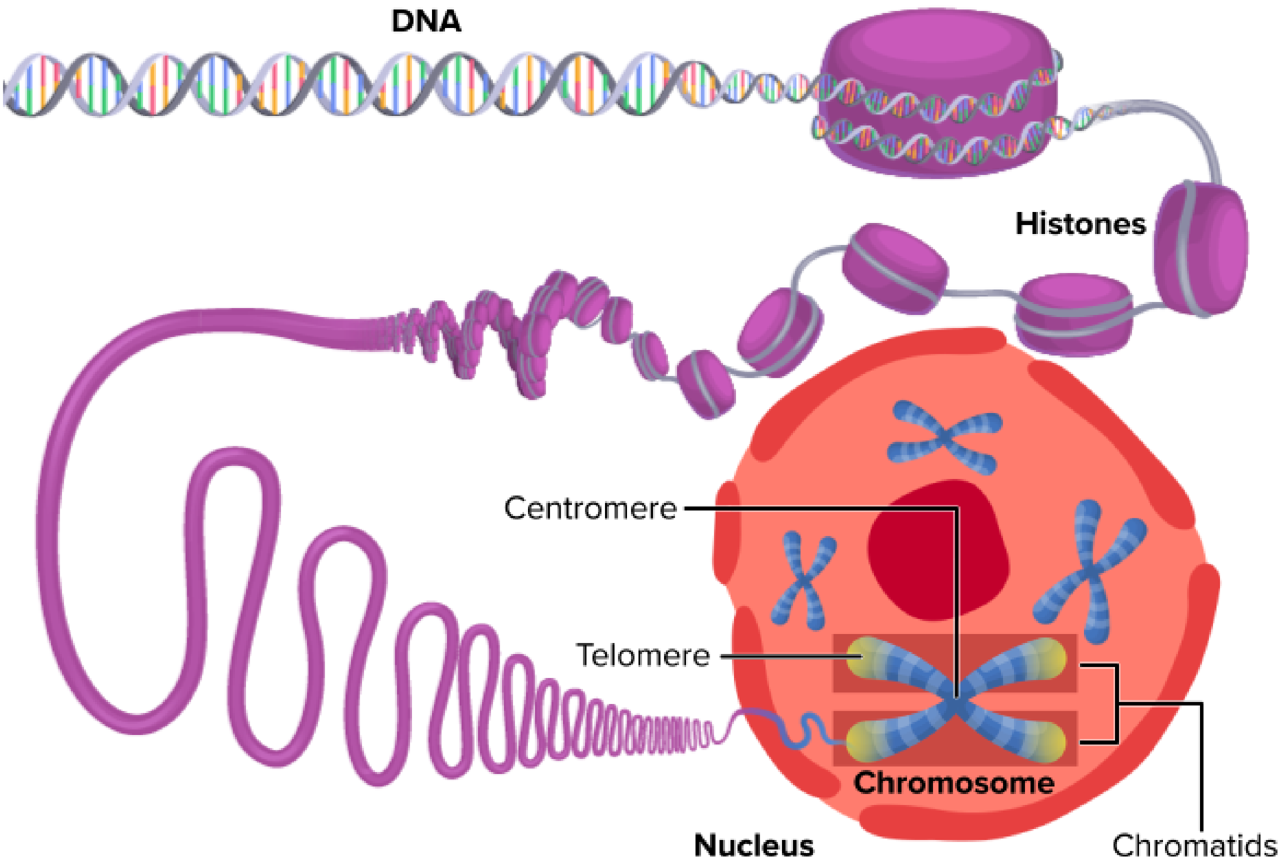
[Figure 1]

Coiled bundles of DNA and proteins, containing hundreds or thousands of genes. What are these things?

Chromosomes. These ensure that each cell receives the proper amount of DNA during cell division. And usually people have 46 of them, 23 from each parent.

Chromosomes and Genes

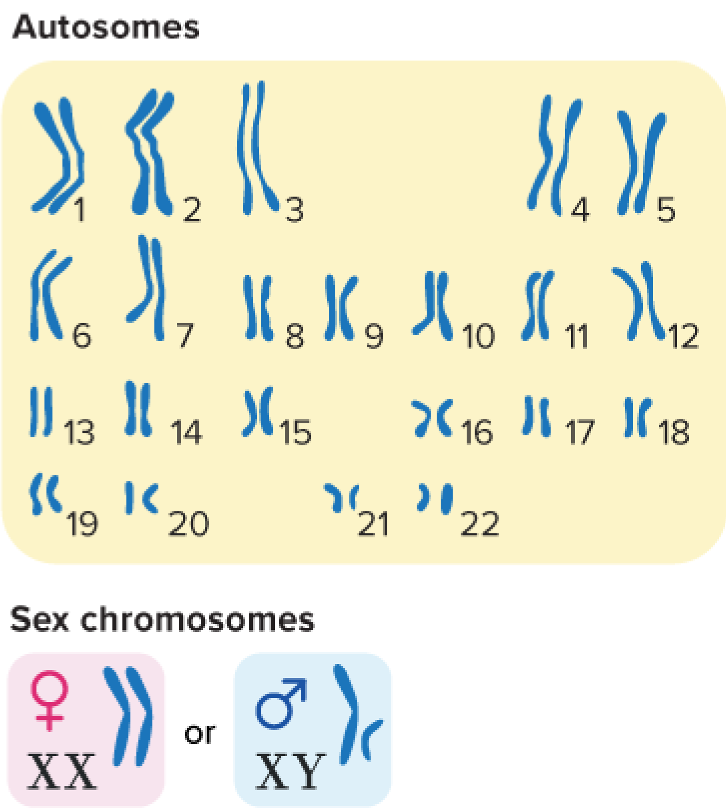
Each species has a characteristic number of chromosomes. **Chromosomes** are coiled structures made of DNA and protein called **histone**. Chromosomes are the form of the genetic material of a cell during cell division.



The human species is characterized by 23 pairs of chromosomes.

Autosomes

Of the 23 pairs of human chromosomes, 22 pairs are autosomes (numbers 1–22) and the 23rd pair consists of sex chromosomes, X and Y. **Autosomes** are chromosomes that contain genes for characteristics that are unrelated to sex. These chromosomes are the same in males and females. The great majority of human genes are located on autosomes.



Sex Chromosomes

The remaining pair of human chromosomes consists of the **sex chromosomes**, X and Y. Females have two X chromosomes, and males have one X and one **Y chromosome**. In females, one of the X chromosomes in each cell is inactivated and known as a Barr body. This ensures that females, like males, have only one functioning copy of the **X chromosome** in each cell.

As you can see from the **Figures** above, the X chromosome is much larger than the Y chromosome. The X chromosome has about 2,000 genes, whereas the Y chromosome has fewer than 100, none of which are essential to survival. (For comparison, the smallest autosome, chromosome 22, has over 500 genes.) Virtually all of the X chromosome genes are unrelated to sex. Only the Y chromosome contains genes that determine sex. A single Y chromosome gene, called **SRY** (which stands for sex-determining region Y gene), triggers an embryo to develop into a male. Without a Y chromosome, an individual develops into a female, so you can think of female as the default sex of the human species. Can you think of a reason why the Y chromosome is so much smaller than the X chromosome?

DID YOU KNOW?

Bees, wasps, and ants do not have sex chromosomes. In these organism, sex is determined by fertilization. Fertilized egg develop into females, and unfertilized eggs hatch into males.

Human Genes

Humans have an estimated 20,000 to 22,000 genes. This may sound like a lot, but it really isn't. Far simpler species have almost as many genes as humans. However, human cells use splicing and other processes to make multiple proteins from the instructions encoded in a single gene. Of the 3 billion base pairs in the human genome, only about 25 percent make up genes and their regulatory element. The functions of many of the other base pairs are still unclear.

The majority of human genes have two or more possible **allele**, which are alternative forms of a gene. Differences in alleles account for the considerable genetic variation among people. In fact, most human genetic variation is the result of differences in individual DNA bases within alleles.

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Summary

- Humans have 23 pairs of chromosomes. Of these, 22 pairs are autosomes.

- The X and Y chromosomes are the sex chromosomes. Females have two X chromosomes, and males have one X and one Y.
- Human chromosomes contain a total of 20,000 to 22,000 genes, the majority of which have two or more alleles.

Review

1. Describe human chromosomes.
2. Compare and contrast human autosomes and sex chromosomes.
3. What is SRY?
4. Why are females the "default sex" of the human species?

3.10 Genetic Linkage

FlexBooks 2.0 > Biology For High School Diploma > Genetic Linkage

Last Modified: Feb 08, 2022

What you will learn

- **linked genes** and how they are inherited
- How the frequency of **crossing over** can help construct a genetic map

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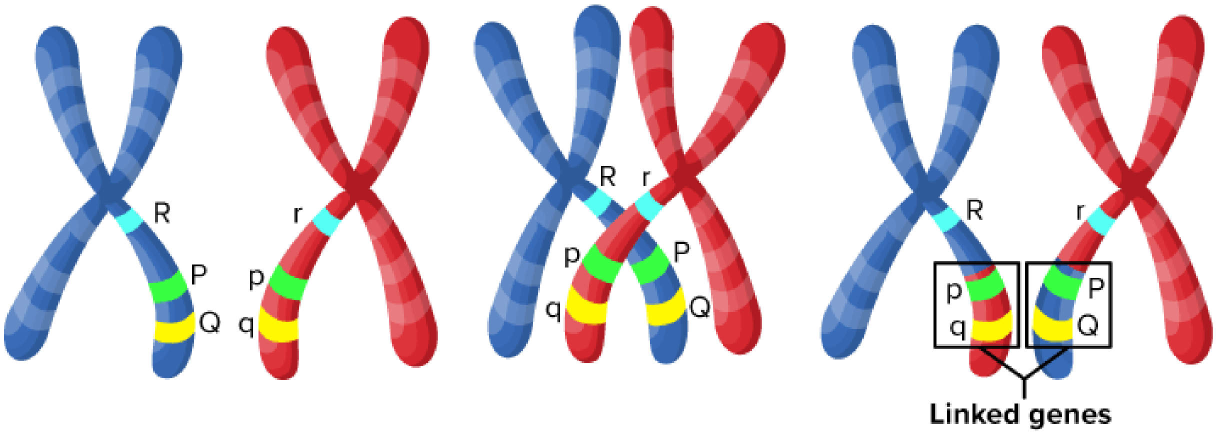
[Figure 1]

What does it mean to be linked?

For a chain, the above image may suggest a certain type of linkage. For gene, it might suggest that they are very hard to separate. If this is the case, what does this mean in terms of human traits? Can you think of any human traits that tend to be inherited together?

Linkage

Genes that are located on the same chromosome are called **linked genes**. allele for these genes tend to segregate together during meiosis unless they are separated by crossing over. **Crossing over** occurs when two homologous chromosomes exchange genetic material during meiosis I. The closer together two genes are on a chromosome, the less likely their alleles will be separated by crossing over as shown in the **Figure** below.



[Figure 2]

Linked genes are inherited together as their alleles are located close to each other and are less likely to be separated by crossing over.

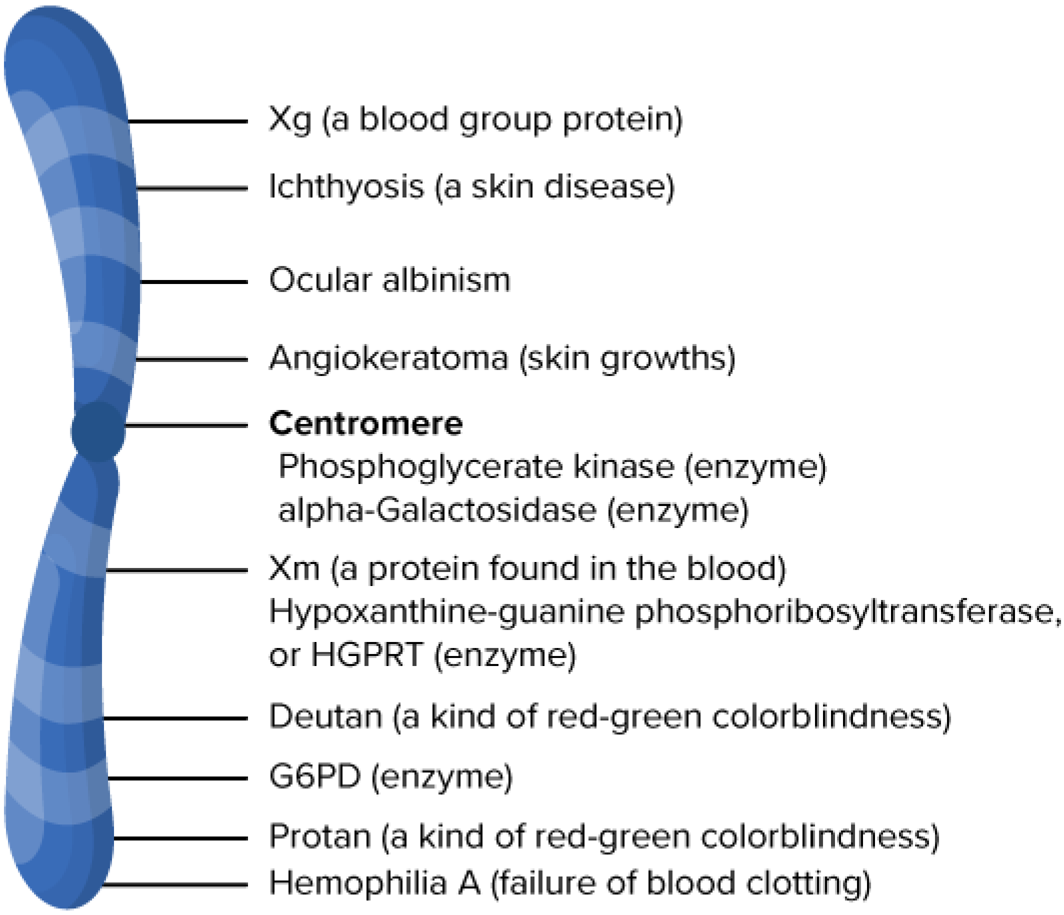
Linkage explains why certain characteristics are frequently inherited together. For example, genes for hair color and eye color are linked, so certain hair and eye colors tend to be inherited together, such as blonde hair with blue eyes and brown hair with brown eyes. What other human traits seem to occur together? Do you think they might be controlled by linked genes?

Sex-Linked Genes

Genes located on the sex chromosome are called **sex-linked gene**. Most sex-linked genes are on the X chromosome because the Y chromosome has relatively few genes. Strictly speaking, genes on the X chromosome are **X-linked gene**, but the term sex-linked is often used to refer to them.

Mapping Linkage

Linkage can be assessed by determining how often crossing over occurs between two genes on the same chromosome. Genes on different (nonhomologous) chromosomes are not linked. They assort independently during meiosis, so they have a 50 percent chance of ending up in different gamete. If genes show up in different gametes less than 50 percent of the time (that is, they tend to be inherited together), they are assumed to be on the same (homologous) chromosome. They may be separated by crossing over, but this is likely to occur less than 50 percent of the time. The lower the frequency of crossing over, the closer together on the same chromosome the genes are presumed to be. Frequencies of crossing over can be used to construct a **linkage map** like the one in the **Figure** below. A **linkage map** shows the locations of genes on a chromosome.

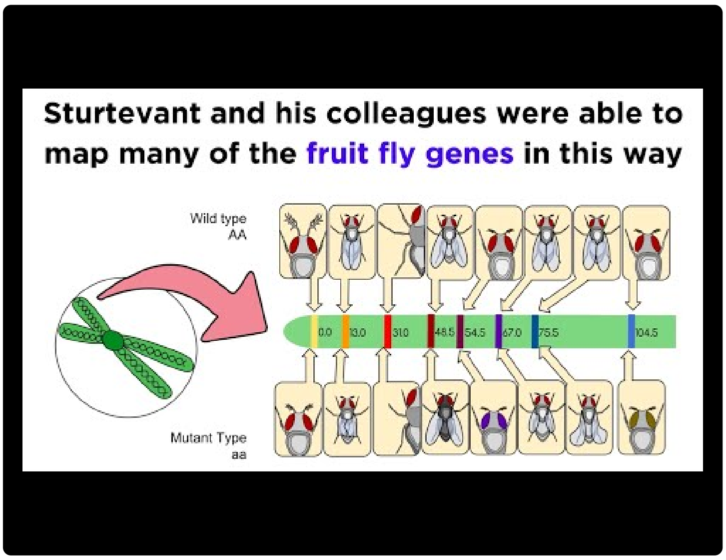


[Figure 3]

Linkage Map for the Human X Chromosome. This linkage map shows the locations of several genes on the X chromosome. Some of the genes code for normal proteins. Others code for proteins that are associated with genetic disorders. Which pair of genes would you expect to have a lower frequency of crossing over: the genes that code for hemophilia A and G6PD deficiency, or the genes that code for Protan and Xm?

DID YOU KNOW?

Alfred Henry Sturtevant, an American geneticist, constructed the first genetic map of a chromosome in 1913. He was the first to propose that genes are arranged on a chromosome in an order that can be mapped by observing the frequency of crossing over. His genetic mapping method is still used today, among other modern techniques.



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Summary

- Linked genes are located on the same chromosome.
- Sex-linked genes are located on a sex chromosome, and X-linked genes are located on the X chromosome.
- The frequency of crossing over between genes is used to construct linkage maps that show the locations of genes on chromosomes.

Review

1. What are linked genes?
2. Explain how you would construct a linkage map for a human chromosome. What data would you need?
3. People with red hair usually have very light skin. What might be a genetic explanation for this observation?
4. How often does crossing over occur between non-linked genes? Explain your answer.

Report Content Errors

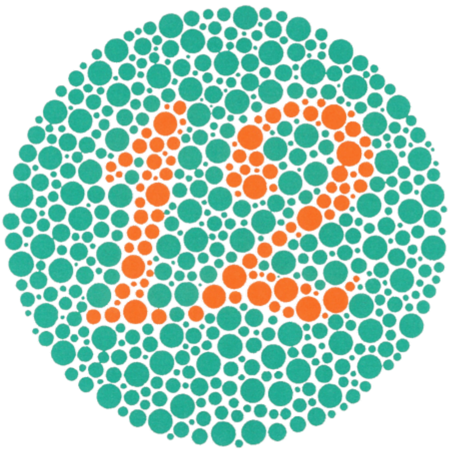
3.11 Mendelian Inheritance

FlexBooks 2.0 > Biology For High School Diploma > Mendelian Inheritance

Last Modified: Feb 08, 2022

What you will learn

- Traits in humans that have Mendelian patterns of inheritance
- Single-gene autosomal traits and their inheritance
- What are **pedigree** charts and how they are used in studying inheritance patterns
- **sex-linked trait** and their inheritance in humans



[Figure 1]

What number can you see?

red-green color blindness is a common inherited trait in humans. About 1 in 10 men have some form of color blindness, however, very few women are color blind. Why?

Mendelian Inheritance in Humans

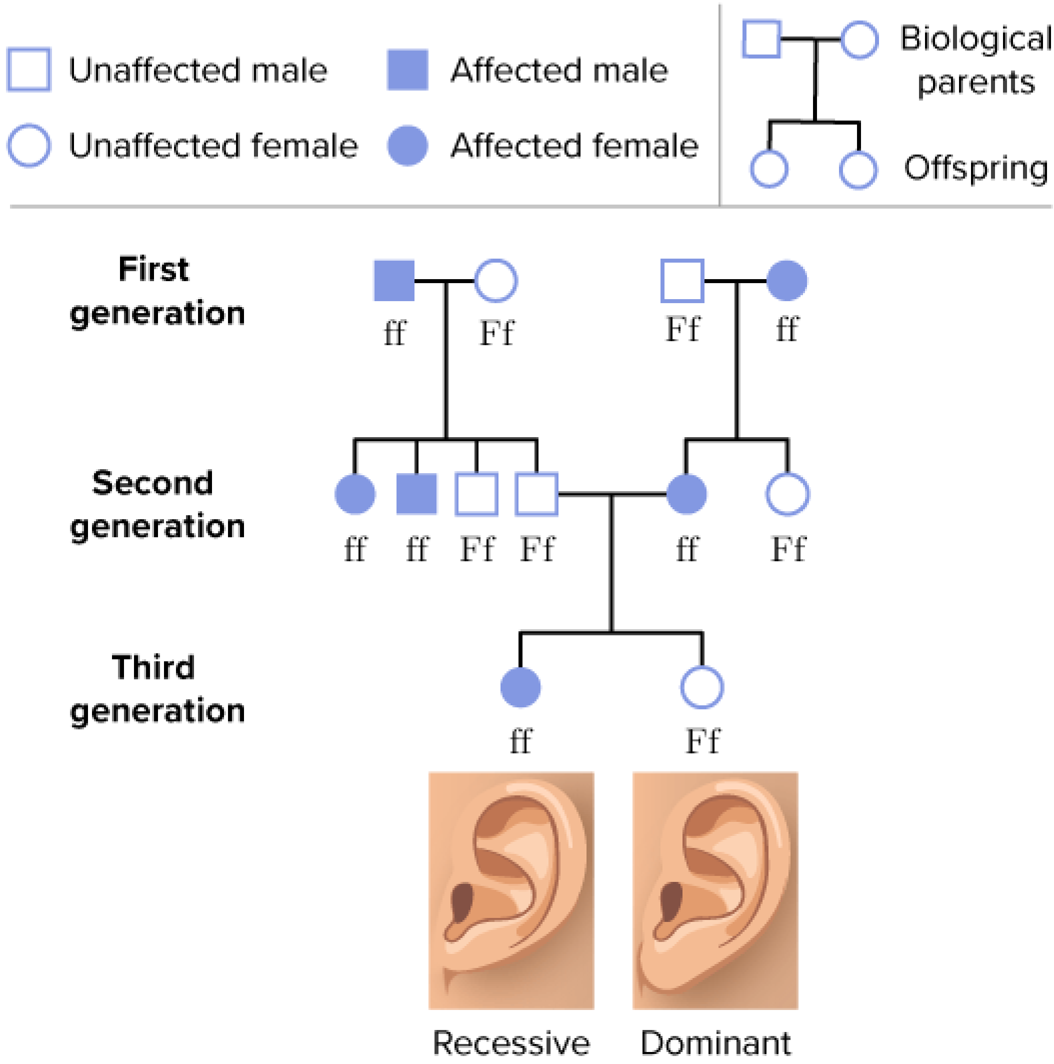
Characteristics that are encoded in DNA are called **genetic traits**. Different types of human traits are inherited in different ways. Some human traits have simple inheritance patterns like the traits that Gregor Mendel studied in pea plants. Other human traits have more complex inheritance patterns.

Mendelian inheritance refers to the inheritance of traits controlled by a single gene with two allele, one of which may be dominant to the other. Not many human traits are controlled by a single gene with two alleles, but they are a good starting point for understanding human heredity. How Mendelian traits are inherited depends on whether the traits are controlled by genes on autosome or the X chromosome.

Autosomal Traits

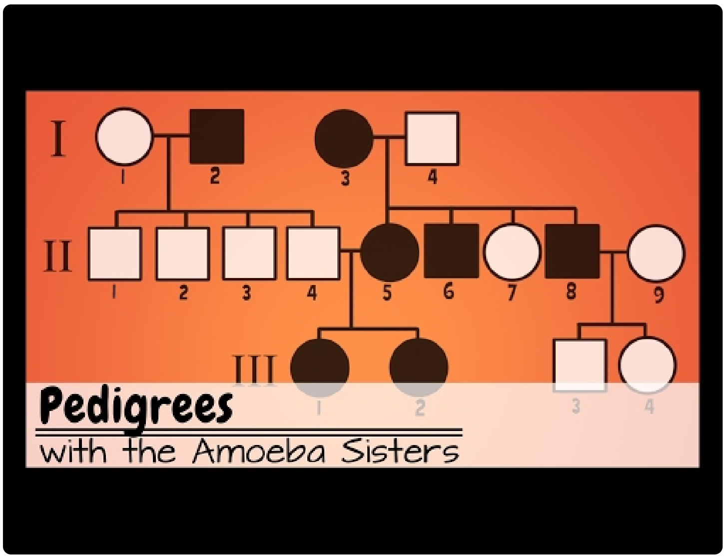
Autosomal traits are controlled by genes on one of the 22 human autosomes. Consider earlobe attachment. A single autosomal gene with two alleles determines whether you have attached earlobes or free-hanging earlobes. The allele for free-hanging earlobes (*F*) is dominant to the allele for attached earlobes (*f*).

The chart in the **Figure** below is called a **pedigree**. It shows how the earlobe trait was passed from generation to generation within a family. Pedigrees are useful tools for studying inheritance patterns.



[Figure 2]

Having free-hanging earlobes is an autosomal dominant trait. This figure shows the trait and how it was inherited in a family over three generations. Shading indicates people who have the recessive form of the trait. Look at (or feel) your own earlobes. Which form of the trait do you have? Can you tell which genotype you have?



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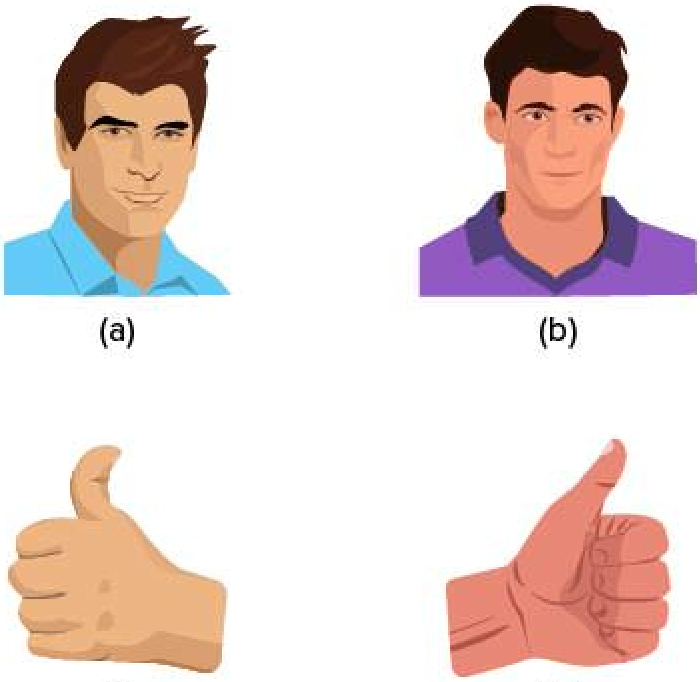
Other single-gene autosomal traits include widow's peak and hitchhiker's thumb. The dominant and recessive forms of these traits are shown in the **Figure** below. Which form of these traits do you have? What are your possible genotype for the traits?



(a) (b)

(c) (d)

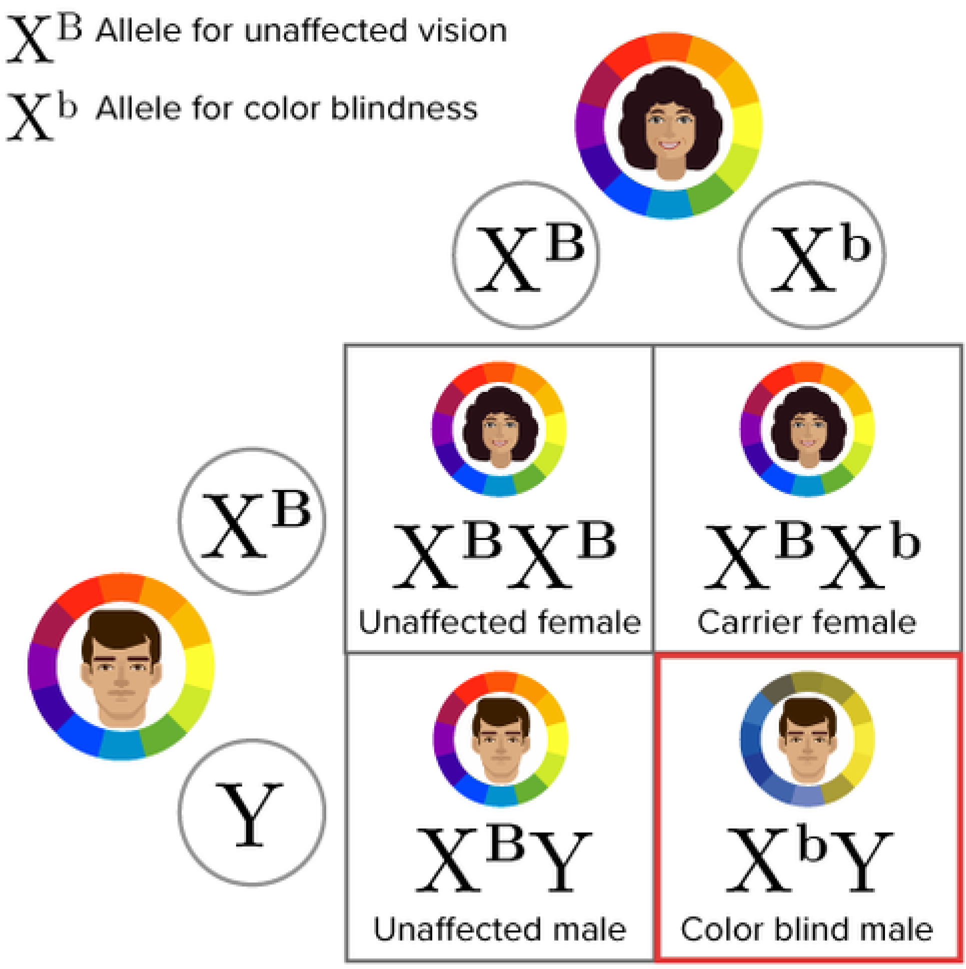
[Figure 3]

Widow's peak and hitchhiker's thumb are dominant traits controlled by a single autosomal gene. (a) widow's peak, (b) no widow's peak, (c) hitchhiker's thumb, (d) no hitchhiker's thumb.

Sex-Linked Traits

Traits controlled by genes on the sex chromosome are called **sex-linked traits**, or **X-linked trait** in the case of the X chromosome. Single-gene X-linked traits have a different pattern of inheritance than single-gene autosomal traits. Do you know why? It's because males have just one X chromosome. In addition, they always inherit their X chromosome from their female parent, and they pass it on to all their female offspring but none of their male offspring.

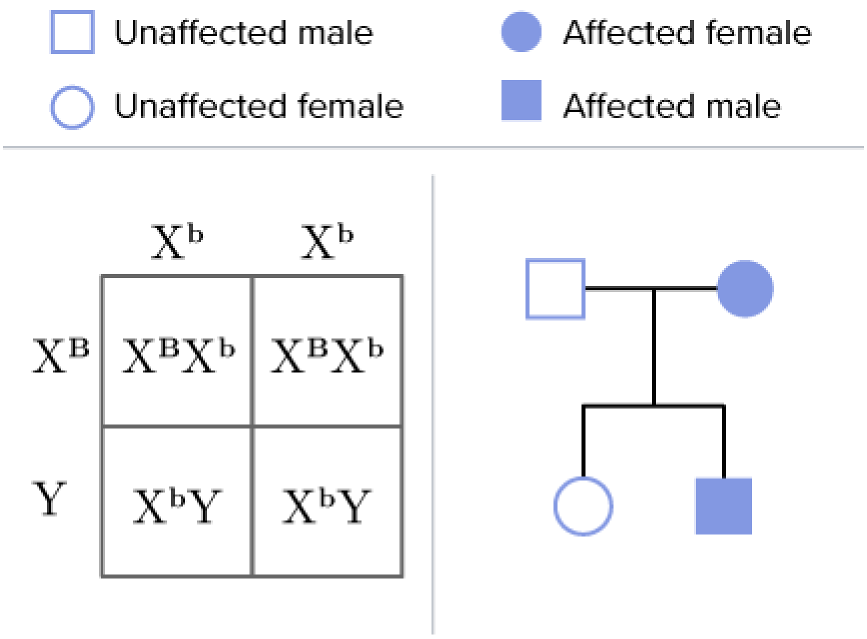
Because males have just one X chromosome, they have only one allele for any . Therefore, a recessive X-linked allele is always expressed in males. Because females have two X chromosome, they have two alleles for any X-linked trait. Therefore, they must inherit two copies of the recessive allele to express the recessive trait. This explains why X-linked recessive traits are less common in females than males. An example of a recessive X-linked trait is **red-green color blindness**. People with this trait cannot distinguish between the colors red and green. More than one recessive gene on the X chromosome codes for this trait, which is fairly common in males but relatively rare in females (**Figure** below).

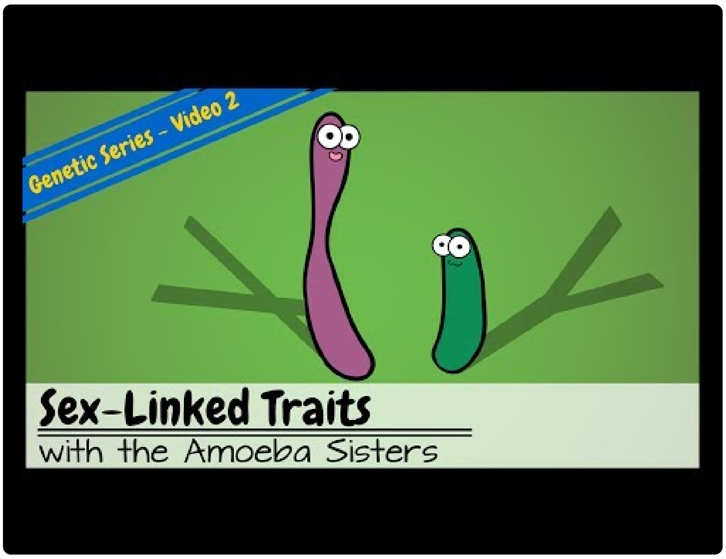


[Figure 4]

Inheritance of Sex Chromosomes. Female parents pass only X chromosomes to their offspring. Male parents always pass their X chromosome to their female offspring and their Y chromosome to their male offspring. Color blindness is an X-linked recessive trait. Female parents pass the recessive allele for the trait to their male offspring, who pass it to their female offspring.

Shown below is a pedigree chart of the inheritance of color blindness in a family. Can you predict the missing phenotype in the chart with the help of the given Punnett square?





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Summary

- A minority of human traits are controlled by single genes with two alleles.
- They have different inheritance patterns depending on whether they are controlled by autosomal or X-linked genes.

Review

1. Describe the inheritance pattern for a single-gene autosomal dominant trait, such as free-hanging earlobes.
2. Draw a pedigree for hitchhiker's thumb. Your pedigree should cover at least two generations and include both dominant and recessive forms of the trait. Label the pedigree with genotypes, using the letter *H* to represent the dominant allele for the trait and the letter *h* to represent the recessive allele.
3. Why is a recessive X-linked allele always expressed in males?
4. What is necessary for a recessive X-linked allele to be expressed in females?
5. What is an example of a recessive X-linked trait?

3.12 Genetic Disorders

FlexBooks 2.0 > Biology For High School Diploma > Genetic Disorders

Last Modified: Mar 04, 2022

What you will learn

- Common genetic disorders in humans and how they are caused
- Chromosomal disorders and their modes of inheritance
- How genetic disorders are diagnosed and treated

[Figure 1]

Is being short-statured inherited?

It can be. Achondroplasia is the most common form of dwarfism in humans, which can also be observed in other animal such as horses. In humans, it is caused by a dominant mutation. The mutation can be passed from one generation to the next.

Genetic Disorders

Many **genetic disorders** are caused by mutations in one or a few gene. Other genetic disorders are caused by abnormal numbers of chromosome.

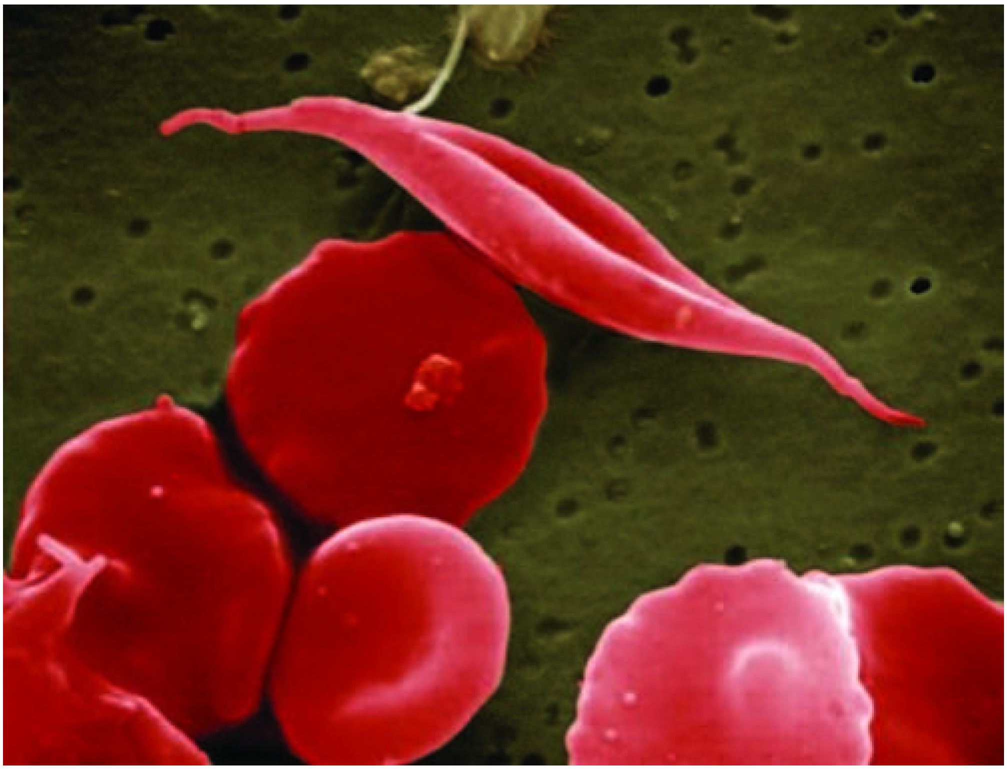
Genetic Disorders Caused by Mutations

The **Table** below lists several genetic disorders caused by mutations in just one gene. Some of the disorders are caused by mutations in autosomal genes, others by mutations in X-linked gene. Which disorder would you expect to be more common in males than females?

Genetic Disorder	Direct Effect of Mutation	Signs and Symptoms of the Disorder	Mode of Inheritance
Marfan syndrome	defective protein in connective tissue	heart and bone defects and unusually long, slender limbs and fingers	autosomal dominant
Sickle cell anemia	abnormal hemoglobin protein in red blood cell	sickle-shaped red blood cells that clog tiny blood vessel, causing pain and damaging organ and joint	autosomal recessive
vitamin D-resistant rickets	lack of a substance needed for bones to absorb mineral	soft bones that easily become deformed, leading to bowed legs and other skeletal deformities	X-linked dominant
Hemophilia A	reduced activity of a protein needed for blood clotting	internal and external bleeding that occurs easily and is difficult to control	X-linked recessive

Few genetic disorders are controlled by dominant allele. A mutant dominant allele is expressed in every individual who inherits even one copy of it. If it causes a serious disorder, affected people may die young and fail to reproduce. Therefore, the mutant dominant allele is likely to die out of the population.

A mutant recessive allele, such as the allele that causes sickle cell anemia (see the **Figure** below), is not expressed in people who inherit just one copy of it. These people are called **carriers**. They do not have the disorder themselves, but they carry the mutant allele and can pass it to their offspring. Thus, the allele is likely to pass on to the next generation rather than die out.



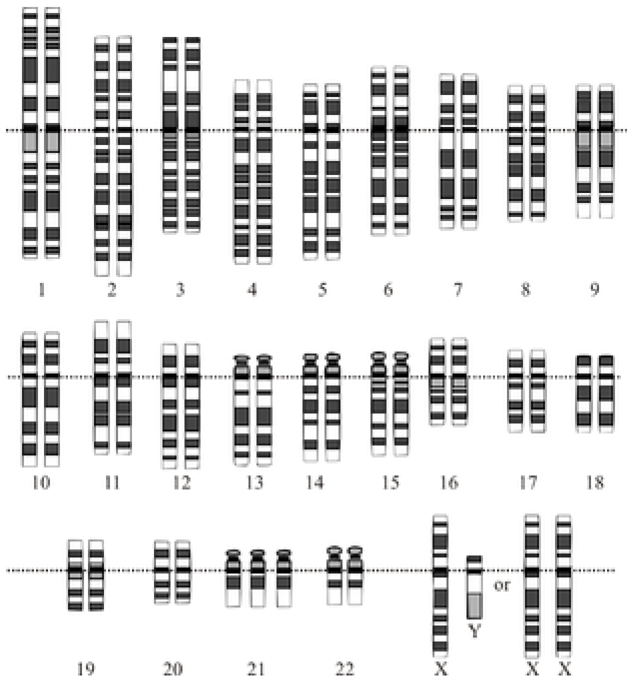
[Figure 2]

Sickle-Shaped and Normal Red Blood Cells. Sickle cell anemia is an autosomal recessive disorder. The mutation that causes the disorder affects just one amino acid in a single protein, but it has serious consequences for the affected person. This photo shows the sickle shape of red blood cells in people with sickle cell anemia.

Chromosomal Disorders

Mistakes may occur during meiosis that result in **nondisjunction**. This is the failure of replicated chromosomes to separate during meiosis. Some of the resulting gamete will be missing a chromosome, while others will have an extra copy of the chromosome. If such gametes are fertilized and form zygote, they usually do not survive. If they do survive, the individuals are likely to have serious genetic disorders. The **Table** below lists several genetic disorders that are caused by abnormal numbers of chromosomes. Most chromosomal disorders involve the X chromosome. Look back at the X and Y chromosomes and you will see why. The X and Y chromosomes are very different in size, so nondisjunction of the sex chromosome occurs relatively often.

Genetic Disorder	Genotype	Phenotypic Effects
Down syndrome	extra copy (complete or partial) of chromosome 21 (see the **Figure** below)	developmental delays, distinctive facial appearance, and other abnormalities (see the **Figure** below)
Turner syndrome	one X chromosome but no other sex chromosome (XO)	female with short height and infertility (inability to reproduce)
Triple X syndrome	three X chromosomes (XXX)	female with mild developmental delays and menstrual irregularities
Klinefelter syndrome	one Y chromosome and two or more X chromosomes (XXY, XXXY)	male with problems in sexual development and reduced levels of the hormone testosterone



[Figure 3]

[Figure 4]

(First) Trisomy 21 (Down Syndrome) Karyotype. A karyotype is a picture of a cell's chromosomes. Note the extra chromosome 21. (Second) Child with Down syndrome, exhibiting characteristic facial appearance.

DID YOU KNOW?

Over 6,000 genetic disorders are known, with new ones being added to the list constantly. These disorders are also quite common. For instance, single-gene disorders affect around one in 50 people!

Diagnosing Genetic Disorders

A genetic disorder that is caused by a mutation can be inherited. Therefore, people with a genetic disorder in their family may be concerned about having children with the disorder. Professionals known as **genetic counselor** can help them understand the risks of their children being affected. If they decide to have children, they may be advised to have **prenatal** ("before birth") testing to see if the fetus has any genetic abnormalities. One method of prenatal testing is **amniocentesis**. In this procedure, a few fetal cells are extracted from the fluid surrounding the fetus, and the fetal chromosomes are examined.

Treating Genetic Disorders

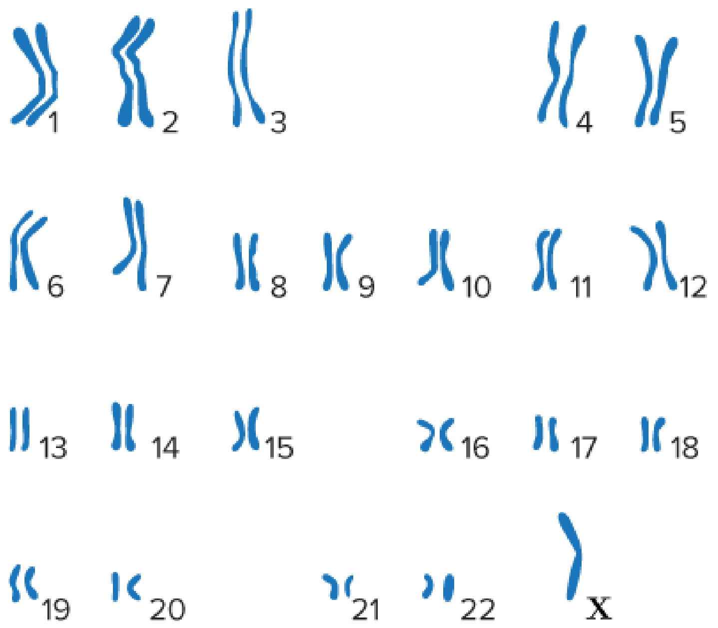
The symptoms of genetic disorders can sometimes be treated, but cures for genetic disorders are still in the early stages of development. One potential cure that has already been used with some success is **gene therapy**. This involves inserting normal genes into cells with mutant genes.

If you could learn your risk of getting cancer or another genetic disease, would you? Though this is a personal decision, it is a possibility. A number of companies now make it easy to order medical genetic tests through the Web.

Check your understanding!

PROGRESS 0 / 3

1.



Which genetic disorder does the above karyotype represent?

a Klinefelter syndrome

b Turner syndrome

c Triple X syndrome

Check It

Hint

Attribution

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Summary

- Many genetic disorders are caused by mutations in one or a few genes.
- Other genetic disorders are caused by abnormal numbers of chromosomes.

Review

1. Describe a genetic disorder caused by a mutation in a single gene.
2. What causes Down syndrome?
3. What is nondisjunction?
4. What is gene therapy?
5. Explain why genetic disorders caused by abnormal numbers of chromosomes most often involve the X chromosome.

Report Content Errors

3.13 Biotechnology

FlexBooks 2.0 > Biology For High School Diploma > Biotechnology

Last Modified: Feb 08, 2022

What you will learn

- The commonly used methods in biotechnology: **gene cloning** and **polymerase chain reaction** (PCR)

[Figure 1]

So how does a scientist work with DNA?

It always starts with the sequence. Once the sequence is known, so much more can be done. Specific regions can be isolated, cloned, amplified, and then used to help us.

Biotechnology Methods

Biotechnology is the use of technology to change the genetic makeup of living things for human purposes. Generally, the purpose of biotechnology is to create organism that are useful to humans or to cure genetic disorder. For example, biotechnology may be used to create crops that resist insect pests or yield more food, or to create new treatments for human diseases.

Biotechnology uses a variety of techniques to achieve its aims. Two commonly used techniques are gene cloning and the polymerase chain reaction.

Gene Cloning

Gene cloning is the process of isolating and making copies of a gene. This is useful for many purposes. For example, gene cloning might be used to isolate and make copies of a normal gene for gene therapy. Gene cloning involves four steps: isolation, ligation, transformation, and selection.

1. In isolation, an enzyme (called a restriction enzyme) is used to break DNA at a specific base sequence. This is done to isolate a gene.
2. During **ligation**, the enzyme **DNA ligase** combines the isolated gene with **plasmid** DNA from bacterium. (A **plasmid** is circular DNA that is not part of a chromosome and can replicate independently.) The DNA that results is called **recombinant DNA**.
3. In **transformation**, the recombinant DNA is inserted into a living cell, usually a bacterial cell. Changing an organism in this way is also called **genetic engineering**.
4. Selection involves growing transformed bacteria to make sure they have the recombinant DNA. This is a necessary step because transformation is not always successful. Only bacteria that contain the recombinant DNA are selected for further use.

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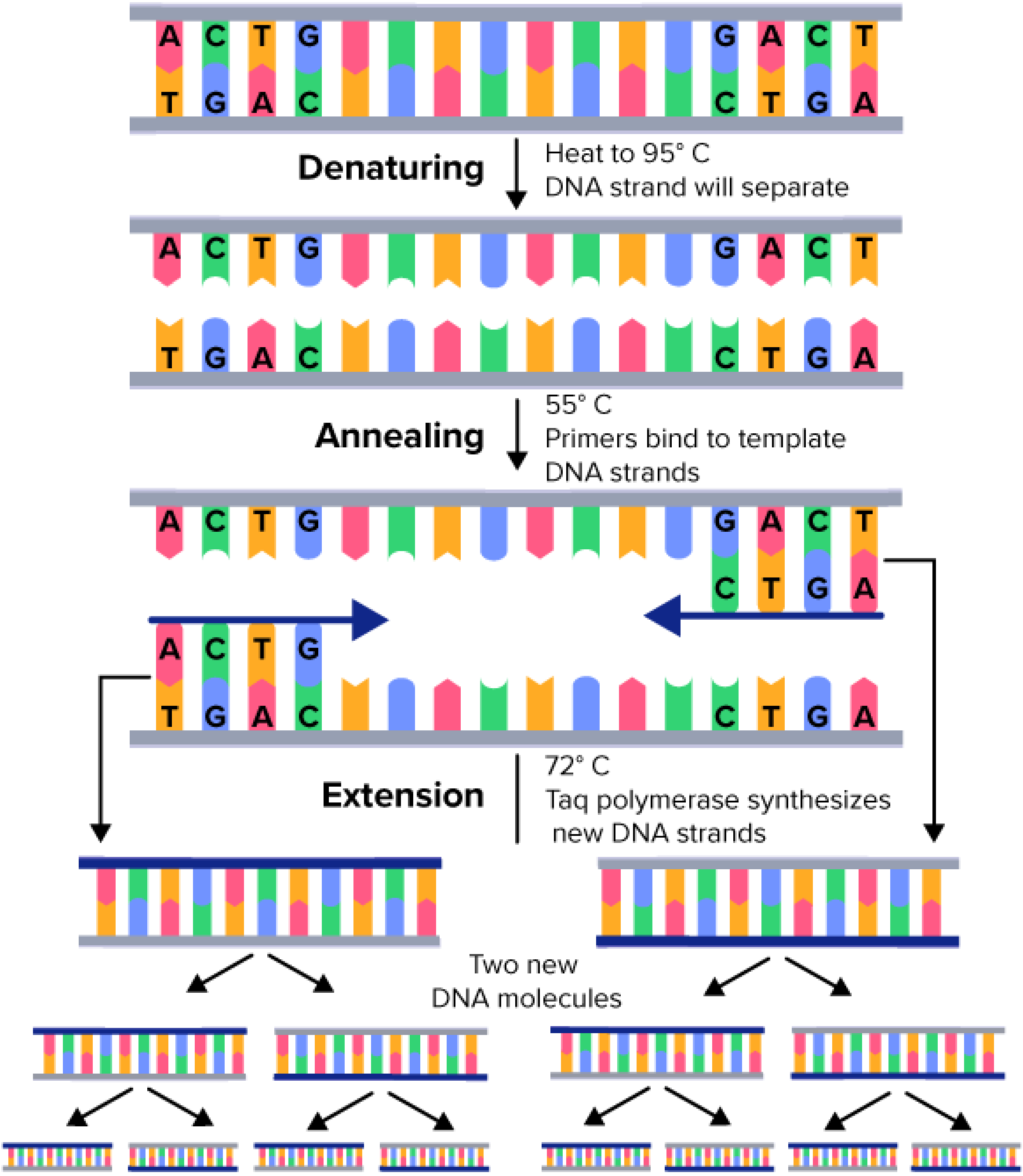
Polymerase Chain Reaction

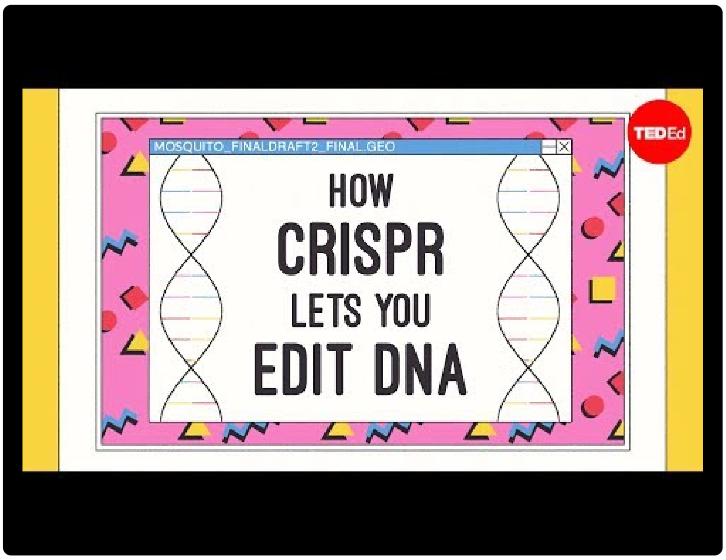
The **polymerase chain reaction (PCR)** makes many copies of a gene or other DNA segment. This might be done in order to make large quantities of a gene for genetic testing. PCR involves three steps: **denaturing**, **annealing**, and **extension**. The three steps are illustrated in the **Figure** below. They are repeated many times in a cycle to make large quantities of the gene.

1. Denaturing involves heating DNA to break the bonds holding together the two DNA strands. This yields two single strands of DNA.
2. Annealing involves cooling the single strands of DNA and mixing them with short DNA segments called **primer**. Primers have base sequences that are complementary to segments of the single DNA strands. As a result, bonds form between the DNA strands and primers.
3. Extension occurs when an enzyme (**Taq polymerase** or Taq DNA polymerase) adds nucleotide to the primers. This produces new DNA molecules, each incorporating one of the original DNA strands.



[Figure 2]

The Polymerase Chain Reaction. The polymerase chain reaction involves three steps. High temperatures are needed for the process to work. The enzyme Taq polymerase is used in step 3 because it can withstand high temperatures.



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DID YOU KNOW?

Cloning is not always successful. Most of the time, this cloning process does not result in a healthy adult animal, and the process has to be repeated many times until it works. The high failure rate of this process is one reason that human cloning is prohibited in many countries.

Summary

- Biotechnology is the use of technology to change the genetic makeup of living things for human purposes.
- Gene cloning is the process of isolating and making copies of a DNA segment such as a gene.
- The polymerase chain reaction makes many copies of a gene or other DNA segment.

Review

1. Define biotechnology.
2. What is recombinant DNA?
3. Identify the steps of gene cloning.
4. What is the purpose of the polymerase chain reaction?
5. Describe the three steps of PCR.

Report Content Errors

3.14 Biotechnology Applications

FlexBooks 2.0 > Biology For High School Diploma > Biotechnology Applications

Last Modified: Feb 08, 2022

What you will learn

- What are the applications of biotechnology in medicine and agriculture

[Figure 1]

Why would anyone grow plants like this?

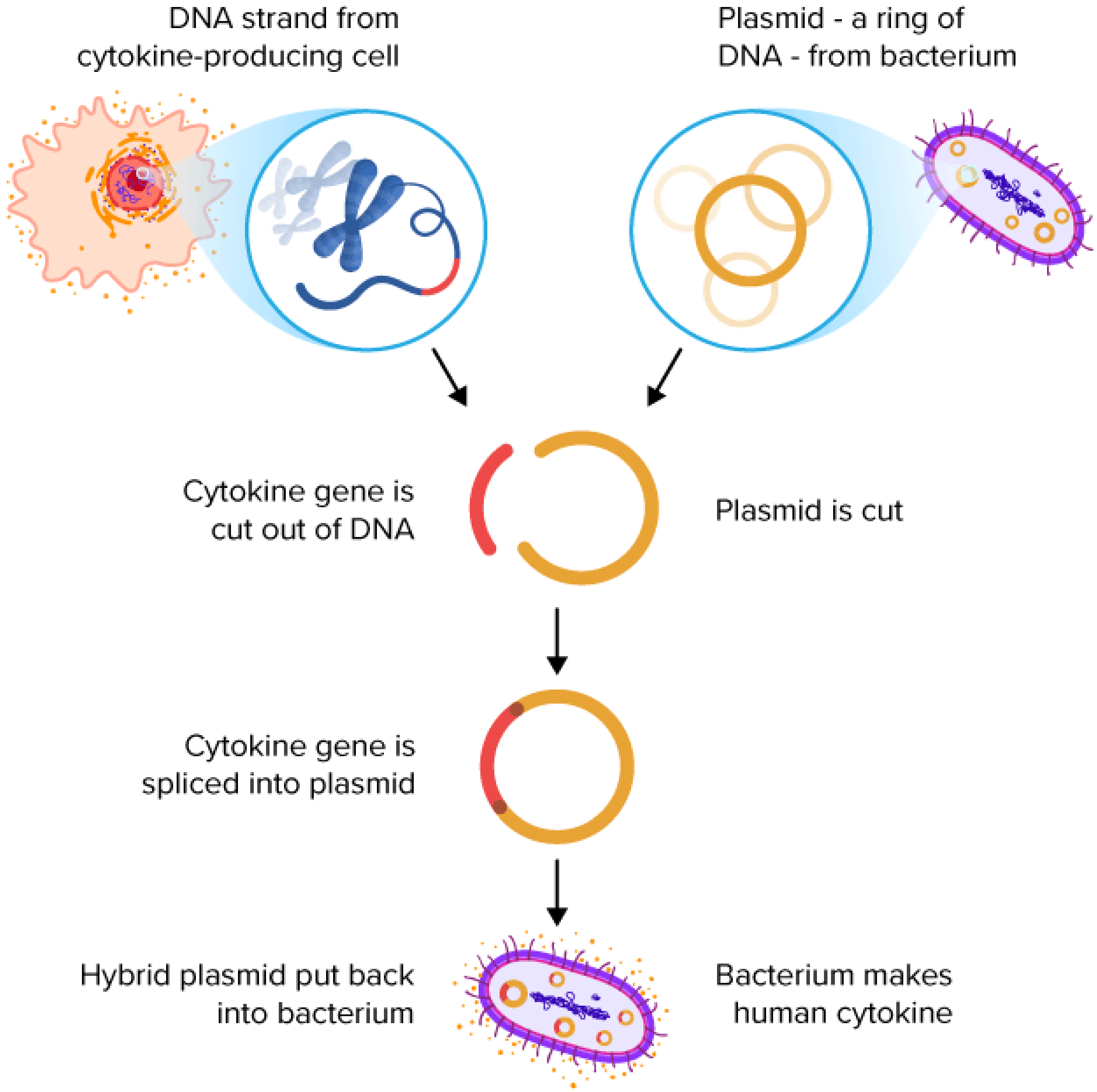
Developing better crops is a significant aspect of biotechnology. Crops that are resistant to damage from insects or droughts must have a significant role in the world's future. And it all starts in the lab.

Applications of Biotechnology

Methods of biotechnology can be used for many practical purposes. They are used widely in both medicine and agriculture.

Applications in Medicine

In addition to gene therapy for genetic disorder, biotechnology can be used to transform bacterium so they are able to make human protein. The **Figure** below shows how this is done to produce a **cytokine**, which is a small protein that helps fight infections. Proteins made by the bacteria are injected into people who cannot produce them because of mutation.



[Figure 2]

Genetically Engineering Bacteria to Produce a Human Protein. Bacteria can be genetically engineered to produce a human protein, such as a cytokine. A cytokine is a small protein that helps fight infections.

insulin was the first human protein to be produced in this way. Insulin helps cell take up glucose from the blood. People with type 1 diabetes have a mutation in the gene that normally codes for insulin. Without insulin, their blood glucose rises to harmfully high levels.

At present, the only treatment for type 1 diabetes is the injection of insulin from outside sources. Until recently, there was no known way to make insulin outside the human body. The problem was solved by gene cloning. The human insulin gene was cloned and used to transform bacterial cells, which could then produce large quantities of human insulin.

Pharmacogenomics

We know that, thanks to our DNA, each of us is a little bit different. Some of those differences are obvious, like eye and hair color. Others are not so obvious, like how our bodies react to medication. Researchers are beginning to look at how to tailor medical treatments to our genetic profiles, in a relatively new field called **pharmacogenomics**. Some of the biggest breakthroughs have been in cancer treatment.

Synthetic Biology

Imagine living cells acting as memory devices, biofuels brewing from yeast, or a light receptor taken from alga that makes photographs on a plate of bacteria. The new field of **synthetic biology** is making biology easier to engineer so that new functions can be derived from living systems.

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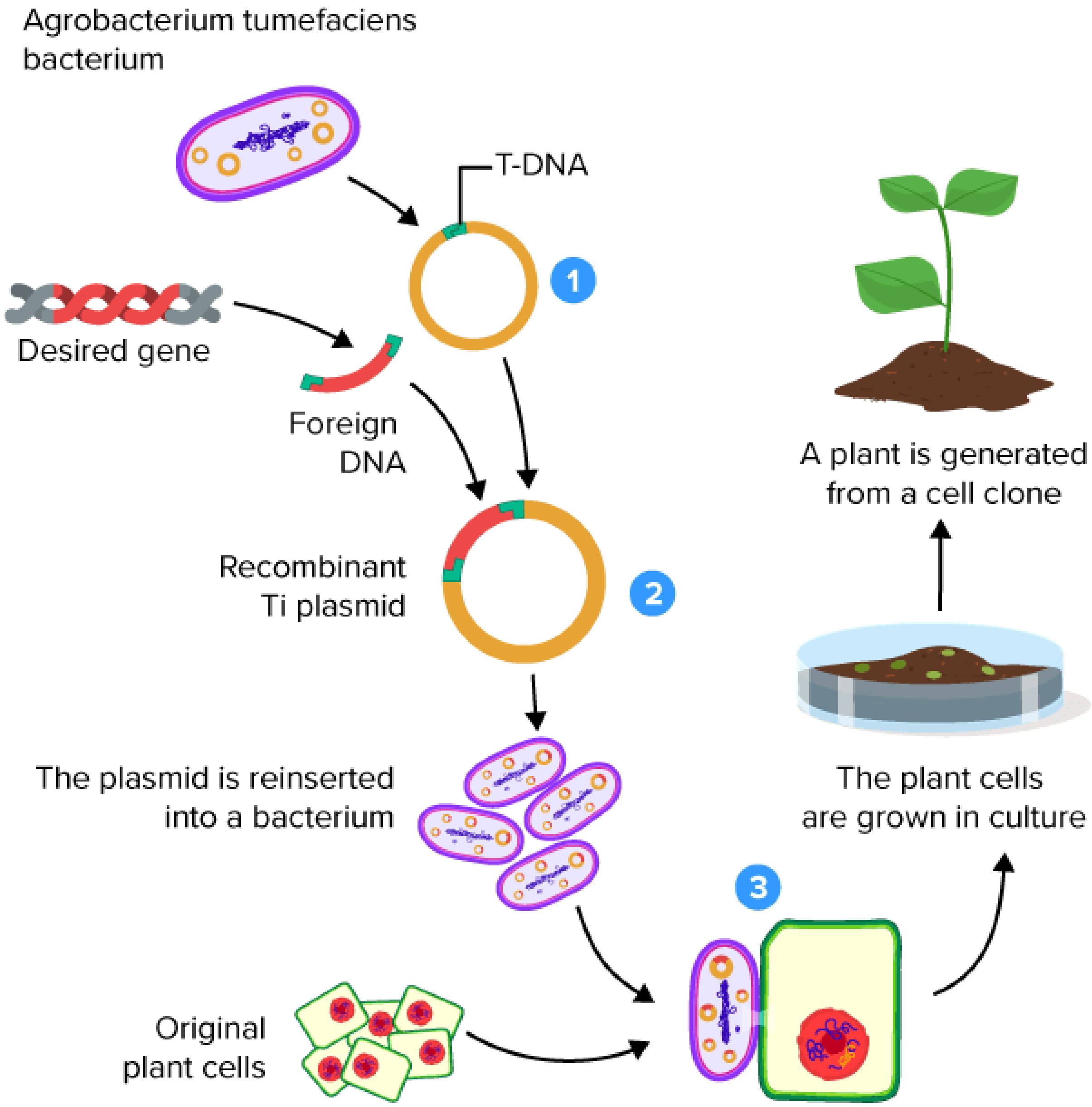
Applications in Agriculture

Biotechnology has been used to create **transgenic crop**. **Transgenic crops** are genetically modified with new genes that code for traits useful to humans. The diagram in the **Figure** below shows how a transgenic crop is created.



[Figure 3]

Creating a Transgenic Crop. (1) T - DNA, a part of tumor inducing plasmid (Ti plasmid) is used to transfer its genetic material to dicotyledon plants. (2) T-DNA is cut by a restriction enzyme to insert the foreign DNA to form a recombinant Ti plasmid. (3) The bacterium transfers the T-DNA fragment with the desired gene (from the recombinant Ti plasmid) into the host plant's nuclear genome. A transgenic plant is generated from genetically modified plant cells.

Transgenic crops have been created with a variety of different traits, such as yielding more food, tasting better, surviving drought, and resisting insect pests. Scientists have even created a transgenic purple tomato that contains a cancer-fighting compound and others that have high levels of antioxidants (see the **Figure** below).

[Figure 4]

[Figure 5]

Transgenic Purple Tomato. A purple tomato is genetically modified to contain a cancer-fighting compound. A gene for the compound was transferred into normal red tomatoes.

DID YOU KNOW?

The first transgenic plant was created in 1982. It was a tobacco plant produced by inserting a bacterial antibiotic resistance gene into its genome.

https://flexbooks.ck12.org/flx/render/embeddedobject/260492

Applications in Forensic Science

Biotechnology has also had tremendous impacts in the forensic sciences.

https://flexbooks.ck12.org/flx/render/embeddedobject/315549

Summary

- Biotechnology can be used to transform bacteria so they are able to make human proteins, such as insulin.
- It can also be used to create transgenic crops, such as crops that yield more food or resist insect pests.
- Researchers are beginning to look at how to tailor medical treatments to our genetic profiles, in a relatively new field called pharmacogenomics.

Review

1. What are transgenic crops?
2. Make a flow chart outlining the steps involved in creating a transgenic crop.
3. Explain how bacteria can be genetically engineered to produce a human protein.

Report Content Errors

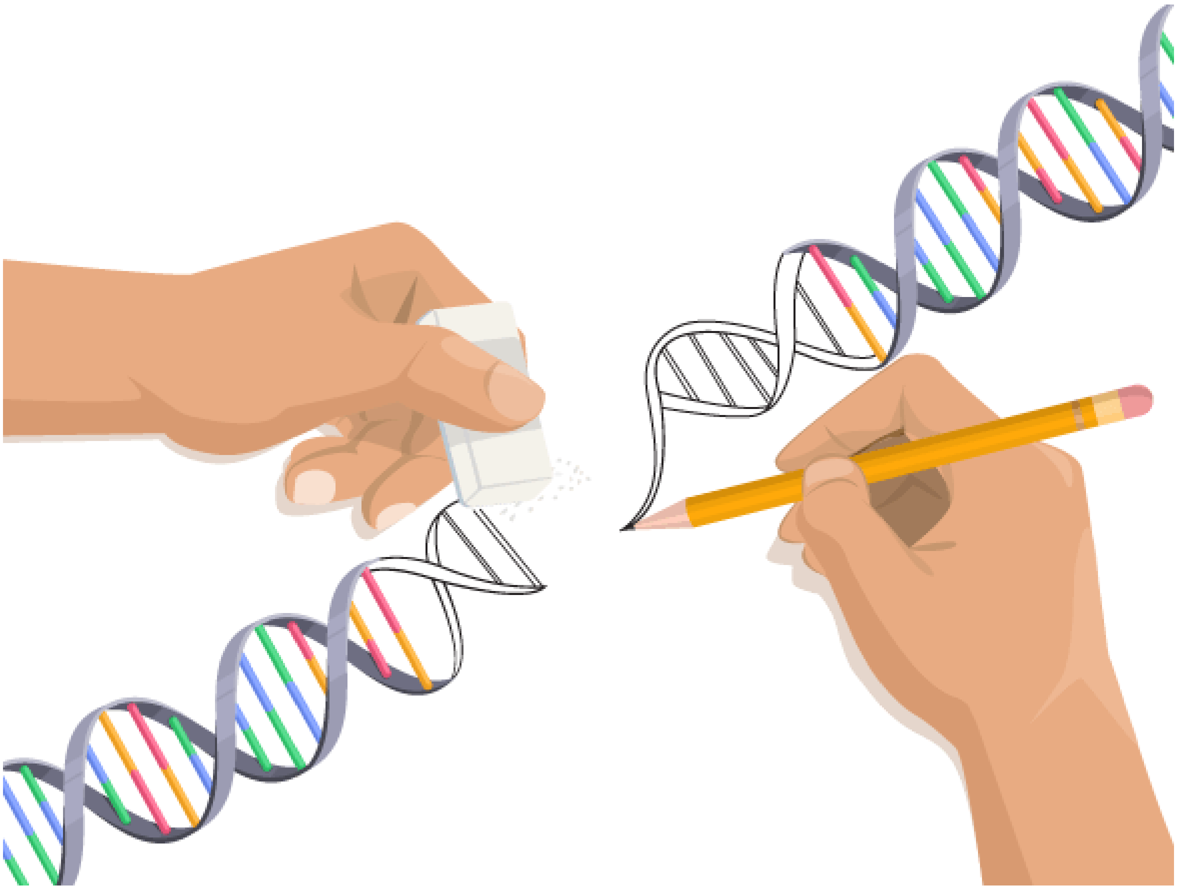
3.15 Ethical, Legal, and Social Issues in Biotechnology (ELSI)

FlexBooks 2.0 > Biology For High School Diploma > Ethical, Legal, and Social Issues in Biotechnology (ELSI)

Last Modified: Feb 08, 2022

What you will learn

- What are the ethical, legal, and social concerns raised due to the advancement of biotechnology



[Figure 1]

Right or wrong? Good or bad? Legal or illegal?

The completion of The Human Genome Project is one of the most important scientific events of the past 50 years. However, is knowing all of our DNA a good thing? The advancement of biotechnology has raised many interesting ethical, legal and social questions.

Ethical, Legal, and Social Issues

Imagine someone analyzes part of your DNA. Who controls that information? What if your health insurance company found out you were predisposed to develop a devastating genetic disease. Might they decide to cancel your insurance? Privacy issues concerning genetic information is an important issue in this day and age.

ELSI stands for Ethical, Legal and Social Issues. It's a term associated with the Human Genome project. This project didn't only have the goal to identify all the gene in the human genome, but also to address the ELSI that might arise from the project. Rapid advances in DNA-based research, human genetics, and their applications have resulted in new and complex ethical and legal issues for society.

Concerns from Biotechnology

The use of biotechnology has raised a number of ethical, legal, and social issues. Here are just a few:

- Who owns genetically modified organism such as bacterium? Can such organisms be patented like inventions?
- Are genetically modified foods safe to eat? Might they have unknown harmful effects on the people who consume them?
- Are genetically engineered crops safe for the environment? Might they harm other organisms or even entire ecosystem?
- Who controls a person's genetic information? What safeguards ensure that the information is kept private?
- How far should we go to ensure that children are free of mutation? Should a pregnancy be ended if the fetus has a mutation for a serious genetic disorder?

DID YOU KNOW?

Currently, the US does not mandate the labeling of genetically modified foods. Corn is the most commonly grown crop in the US and genetically modified corn is a large percentage of this crop.

Summary

- Biotechnology has raised a number of ethical, legal, and social issues. For example, are genetically modified foods safe to eat, and who controls a person's genetic information?

Review

1. Identify three ethical, legal, or social issues raised by biotechnology.
2. State your view on an ELSI issue, and develop a logical argument to support your view.

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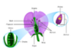	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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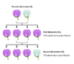	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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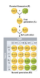	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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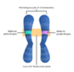
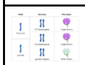
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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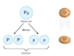	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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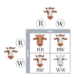
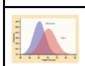
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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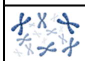	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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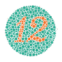	**Credit:** Unknown author **Source:** https://commons.wikimedia.org/wiki/File:Ishihara_1.PNG **License:** Public Domain
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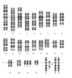	**Credit:** National Human Genome Research Institute **Source:** https://commons.wikimedia.org/wiki/File:Down_Syndrome_karyotype.png **License:** CC BY 4.0
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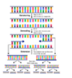	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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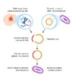
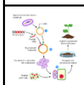
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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CHAPTER 4

Molecular Biology

Chapter Outline

4.1 Central Dogma

FlexBooks 2.0 > Biology For High School Diploma > Central Dogma

Last Modified: Mar 04, 2022

What you will learn

- The **central dogma of molecular biology**: **DNA** to **RNA** to protein

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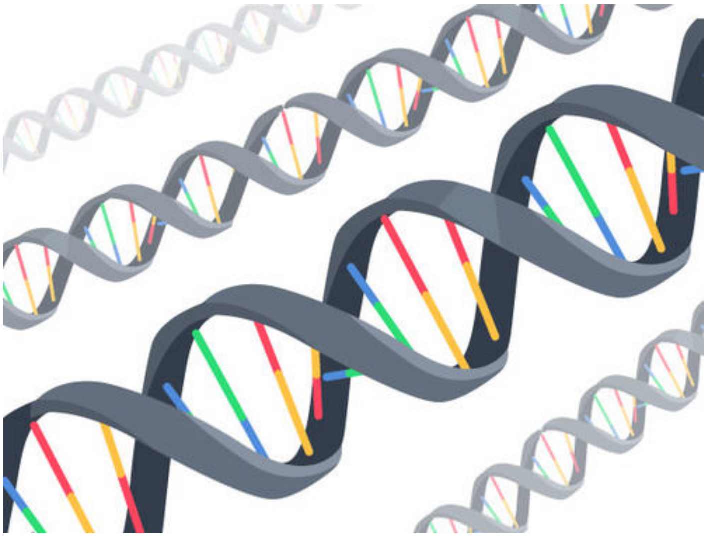


[Figure 1]

Is it always DNA to RNA to proteins?

The central dogma of molecular biology. Coined by Francis Crick. And in his own words, "I called this idea the central dogma, for two reasons, I suspect. I had already used the obvious word hypothesis in the sequence hypothesis, and in addition, I wanted to suggest that this new assumption was more central and more powerful."

Central Dogma of Molecular Biology

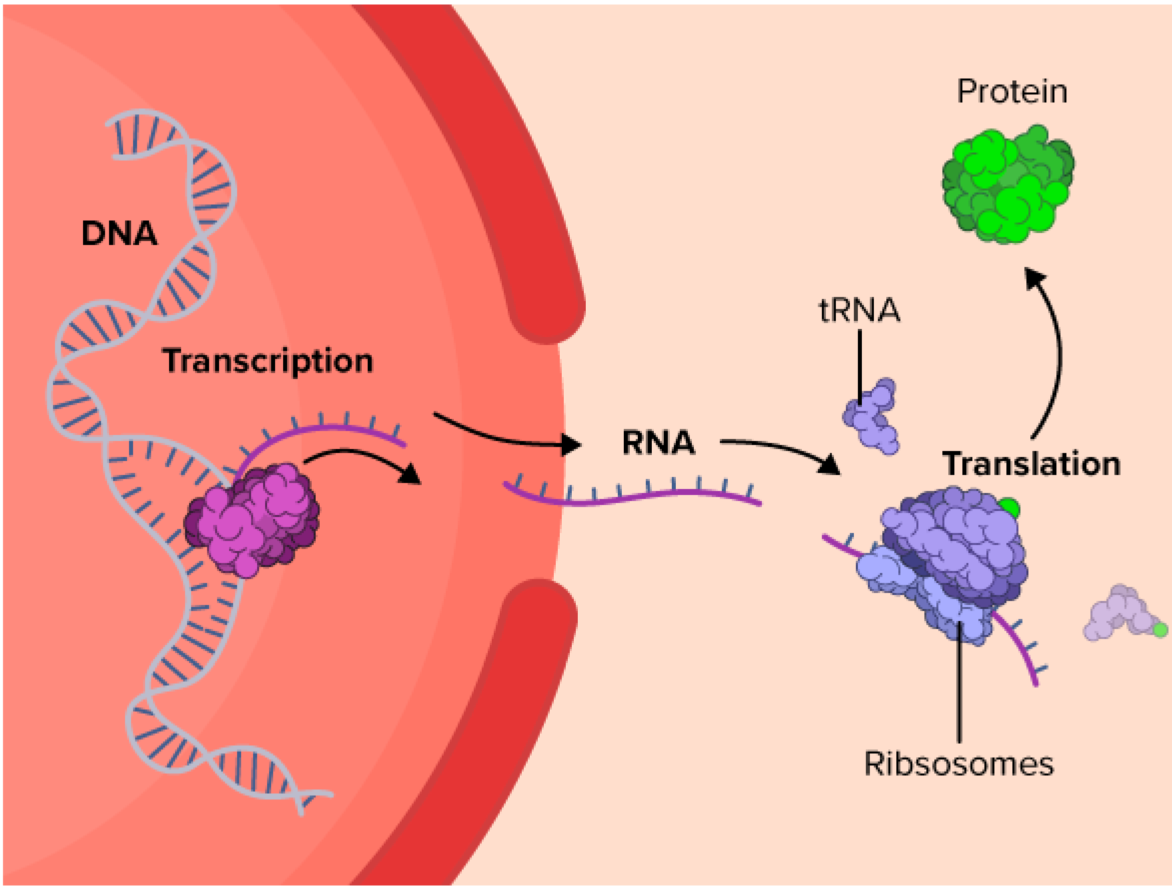
Your **DNA**, or deoxyribonucleic acid, contains the gene that determine who you are. How can this organic molecule control your characteristics? DNA contains instructions for all the proteins your body makes. Proteins, in turn, determine the structure and function of all your cell. What determines a protein's structure? It begins with the sequence of amino acid that make up the protein. Instructions for making proteins with the correct sequence of amino acids are encoded in DNA.

DNA is found in chromosome. In eukaryotic cell, chromosomes always remain in the nucleus, but proteins are made at ribosome in the cytoplasm. How do the instructions in

DNA get to the site of protein synthesis outside the nucleus? Another type of nucleic acid is responsible. This nucleic acid is **RNA** or ribonucleic acid. RNA is a small molecule that can squeeze through pores in the nuclear membrane. It carries the information from DNA in the nucleus to a ribosome in the cytoplasm and then helps assemble the protein. In short:

DNA → RNA → Protein

Discovering this sequence of events was a major milestone in molecular biology. It is called the **central dogma of molecular biology**. The two processes involved in the central dogma are **transcription** and **translation**. In eukaryotic cells, transcription takes place in the nucleus. It uses DNA as a template to make an RNA molecule known as messenger RNA (mRNA). The RNA molecule then leaves the nucleus and goes to a ribosome in the cytoplasm, where translation occurs. Translation reads the genetic code in mRNA and makes a protein.



DID YOU KNOW?

retrovirus are RNA virus that do not obey the central dogma. When they infect a host cell, their genetic material, RNA, is transcribed into DNA by a process known as "reverse transcription.” The human immunodeficiency virus (HIV), which causes AIDS (Acquired Immuno Deficiency Syndrome), is an example of a retrovirus.

Summary

- The central dogma of molecular biology states that DNA contains instructions for making a protein, which are copied by RNA.
- RNA then uses the instructions to make a protein.
- In short: DNA → RNA → Protein, or DNA to RNA to Protein.

Review

1. State the central dogma of molecular biology.
2. What are transcription and translation?
3. Explain the central dogma of molecular biology.

Report Content Errors

4.2 DNA

FlexBooks 2.0 > Biology For High School Diploma > DNA

Last Modified: Sep 09, 2021

What you will learn

- Important experiment conducted by scientists to determine the nature of **genetic material**
- Establishment of DNA as the genetic material
- Timeline of the major discoveries related to DNA structure and its function

[Figure 1]

What type of organic molecule is this?

Here's a hint: molecules like this one determine who you are. They contain genetic information that controls your characteristics. They determine your eye color, facial features, and other physical attributes. What molecule is it?

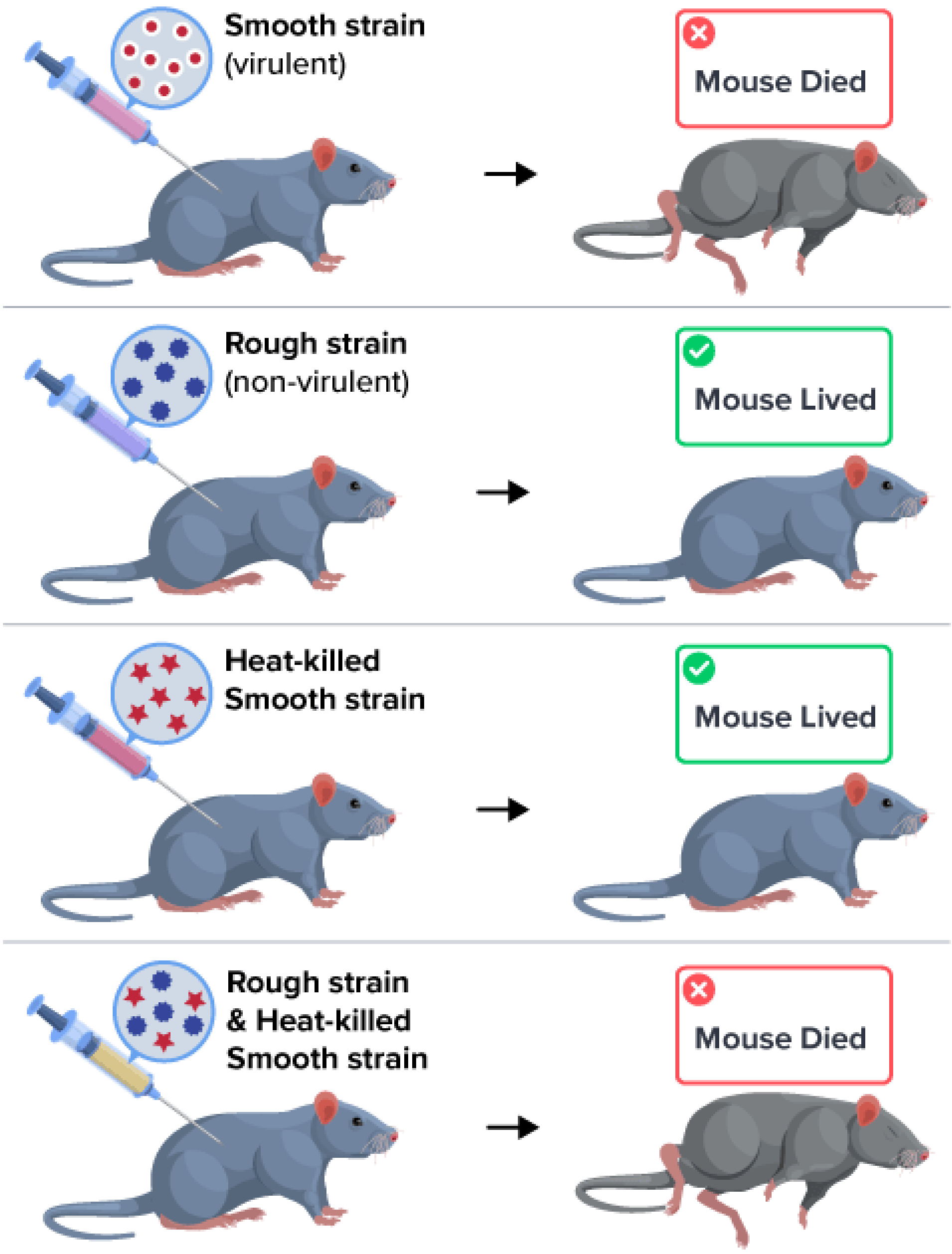
You probably answered "DNA." Today, it is commonly known that DNA is the genetic material. For a long time, scientists knew such molecules existed. They were aware that genetic information was contained within organic molecule. However, they didn't know which type of molecules play this role. In fact, for many decades, scientists thought that protein were the molecules that carry genetic information.

DNA, the Genetic Material

DNA, deoxyribonucleic acid, is the genetic material in your cell. It was passed on to you from your parents and determines your characteristics. The discovery that DNA is the genetic material was another important milestone in molecular biology.

Griffith Searches for the Genetic Material

Many scientists contributed to the identification of DNA as the genetic material. In the 1920s, Frederick Griffith made an important discovery. He was studying two different strains of a bacterium, called R (rough) strain and S (smooth) strain. He injected the two strains into mice. The S strain killed (virulent) the mice, but the R strain did not (non-virulent). Griffith also injected mice with S-strain bacteria that had been killed by heat. As expected, the killed bacteria did not harm the mice. However, when the dead S-strain bacteria were mixed with live R-strain bacteria and injected, the mice died.



[Figure 2]

Griffith's Experiment

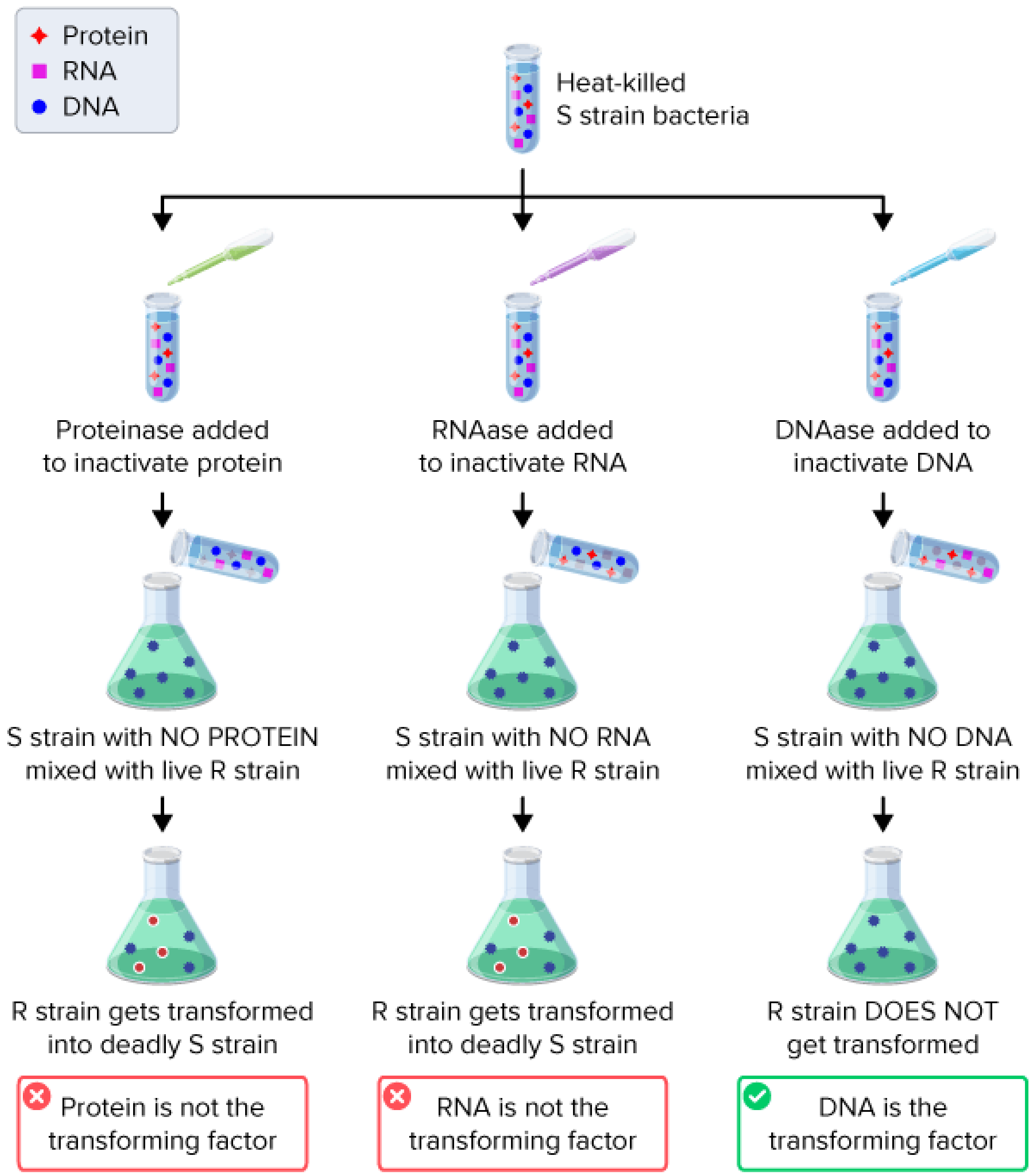
DID YOU KNOW?

Griffith used strains of pneumococcus bacteria for his experiments because he was interested in finding a vaccine against these pathogen. These bacteria caused millions of deaths by causing pneumonia as a secondary infection during the 1918 pandemic.

Based on his observation, Griffith deduced that something in the killed S strain was transferred to the previously harmless R strain, making the R strain deadly. He called this process transformation, as something was "transforming" the bacteria from one strain into another strain. What was that something? What type of substance could change the characteristics of the organism that received it?

Avery's Team Makes a Major Contribution

In the early 1940s, a team of scientists led by Oswald Avery tried to answer the question raised by Griffith's results. Avery, together with his colleagues Colin MacLeod and Maclyn McCarty, inactivated various substances in the heat-killed S-strain bacteria. They then mixed the heat-killed S-strain bacteria with the harmless R-strain bacteria. When proteins and RNA were inactivated, the R-strain still transformed into the deadly S-strain. This ruled out proteins and RNA as the genetic material. Why? Even without the S-strain proteins or RNA, the R-strain was changed or transformed, into the deadly S-strain. However, when the researchers inactivated DNA in the S-strain, the R-strain did not transform. This led to the conclusion that DNA is the substance that controls the characteristics of organisms. In other words, DNA is the genetic material.



[Figure 3]

The Avery-MacLeod-McCarty Experiment

DID YOU KNOW?

Even after Avery and his team's experiments showed that DNA was the genetic material, the scientific community was skeptical. They thought that a molecule of DNA was too simple to carry genetic information while proteins were considered complex enough to be the genetic material.

Hershey and Chase Seal the Deal

The conclusion that DNA is the genetic material was not widely accepted at first. It had to be confirmed by other research. In the 1950s, Alfred Hershey and Martha Chase did experiments with **virus** known as bacteriophage, a virus that infects bacteria, and bacteria. Viruses are not made of cells. Bacteriophages are basically DNA inside a protein coat. To reproduce, a virus must insert its own genetic material into a cell (such as a bacterium). Then it uses the cell's machinery to make more viruses. The researchers used different radioactive element to label the DNA and proteins in viruses. This allowed them to identify which molecule the viruses inserted into bacteria. DNA was the molecule they identified. This confirmed that DNA is the genetic material.

The Hershey and Chase Experiment

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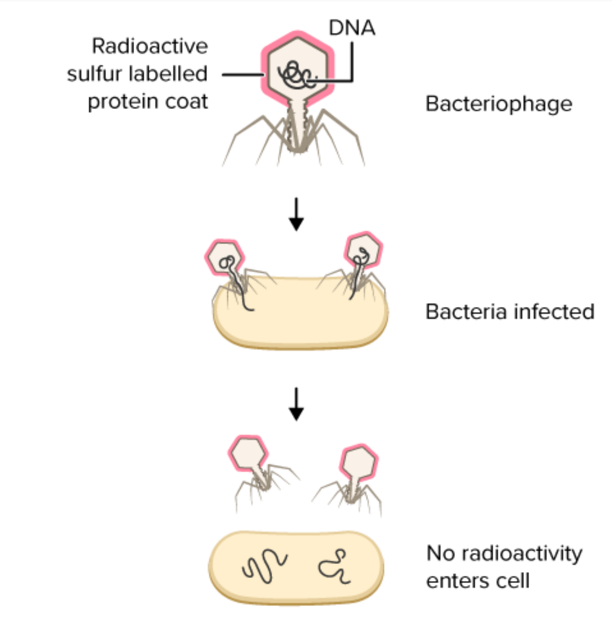

[Figure 4]

Conclusion - Proteins are not the genetic material.
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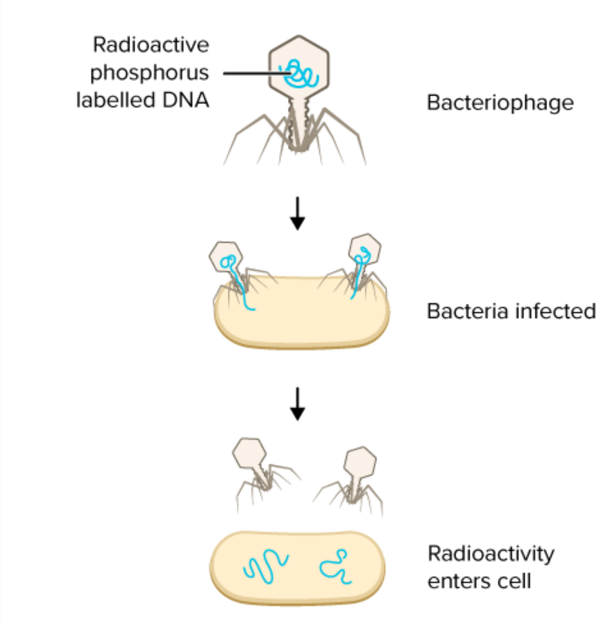

[Figure 5]

Conclusion - DNA is the genetic material.
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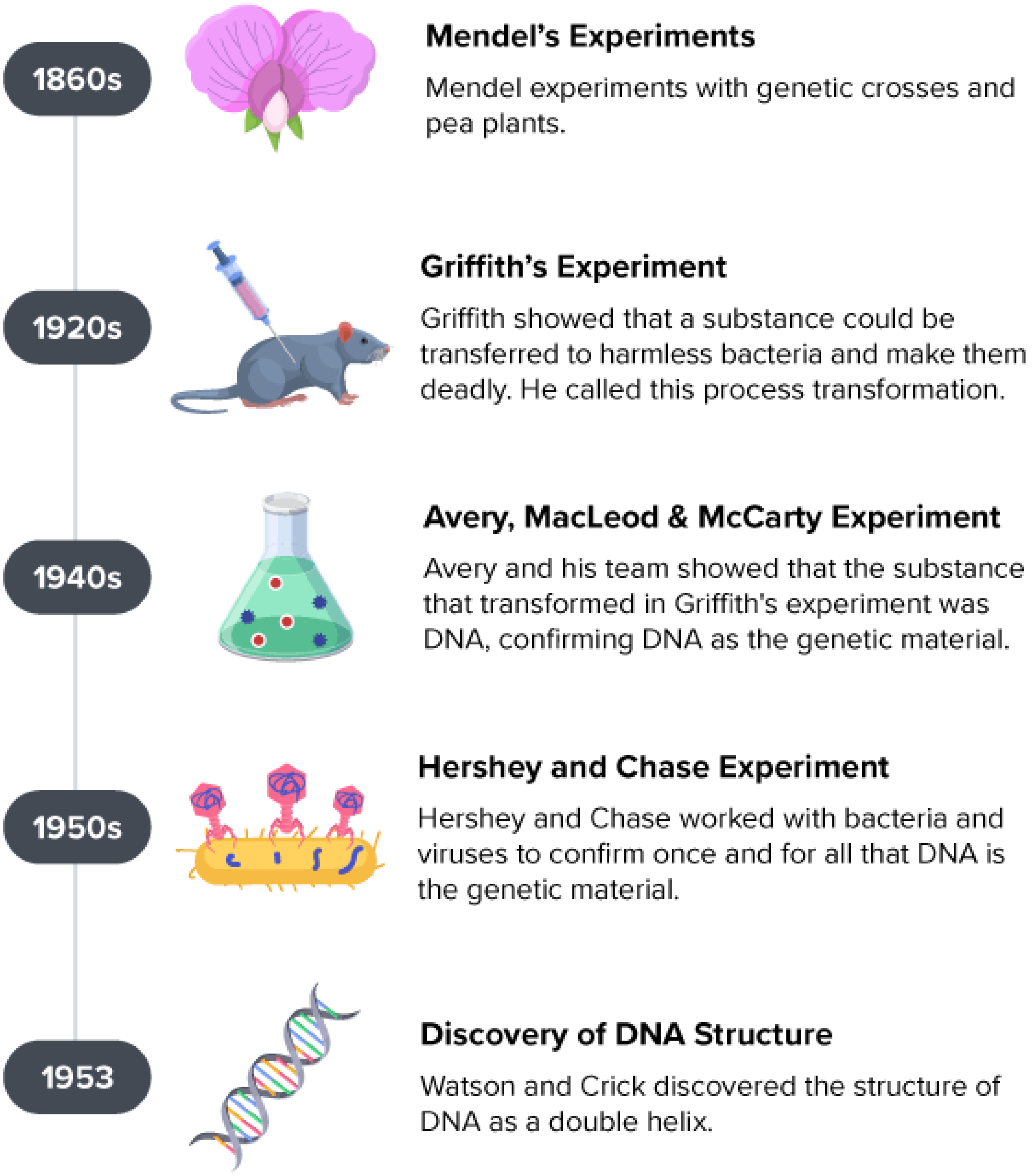
Shown in the **Figure** below is a timeline of the work of several researchers that led to the establishment of DNA as the genetic material followed by the discovery of its structure.

DNA Discovery Timeline



[Figure 6]

Summary

- DNA, deoxyribonucleic acid, is the genetic material in your cells. It was passed on to you from your biological parents and determines your characteristics.
- For many decades, scientists thought that proteins were the molecules that carry genetic information.
- The work of several researchers led to the discovery that DNA is the genetic material.
- Along the way, Griffith discovered the process of transformation.

Review Questions

1. List the research that determined that DNA is the genetic material.
2. What is transformation?
3. What happened to the R-strain bacteria when Avery and his colleagues inactivated DNA in the S strain bacteria?

Report Content Errors

4.3 DNA Structure and Replication

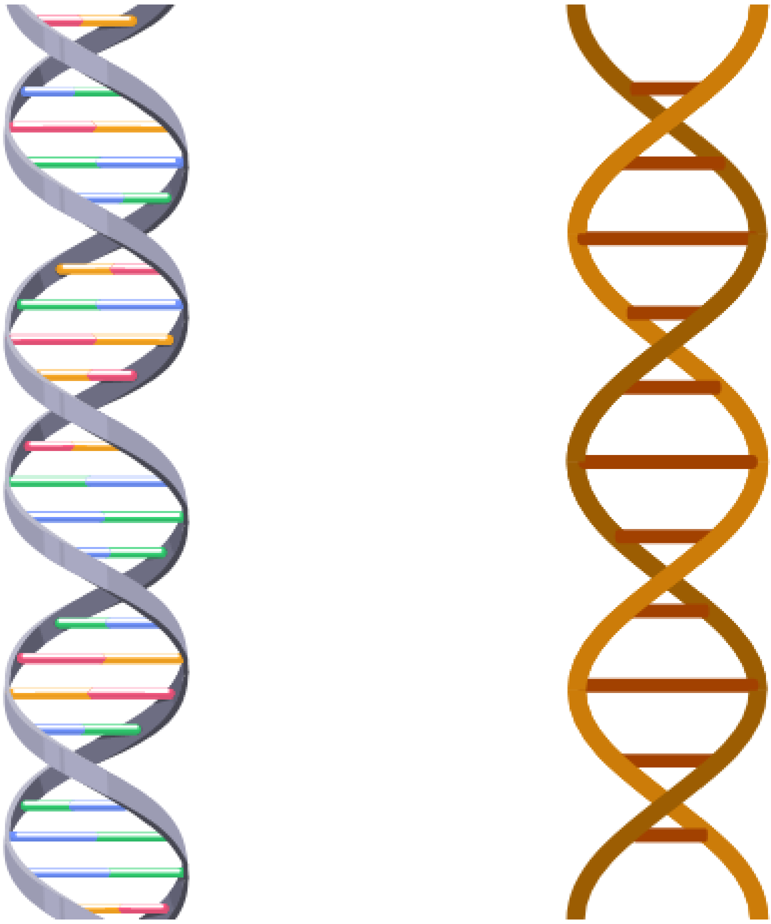
FlexBooks 2.0 > Biology For High School Diploma > DNA Structure and Replication

Last Modified: Mar 04, 2022

What you will learn

- Structure and function of DNA
- Chargaff's rule
- **DNA replication** and the role of DNA polymerase

What does DNA look like?

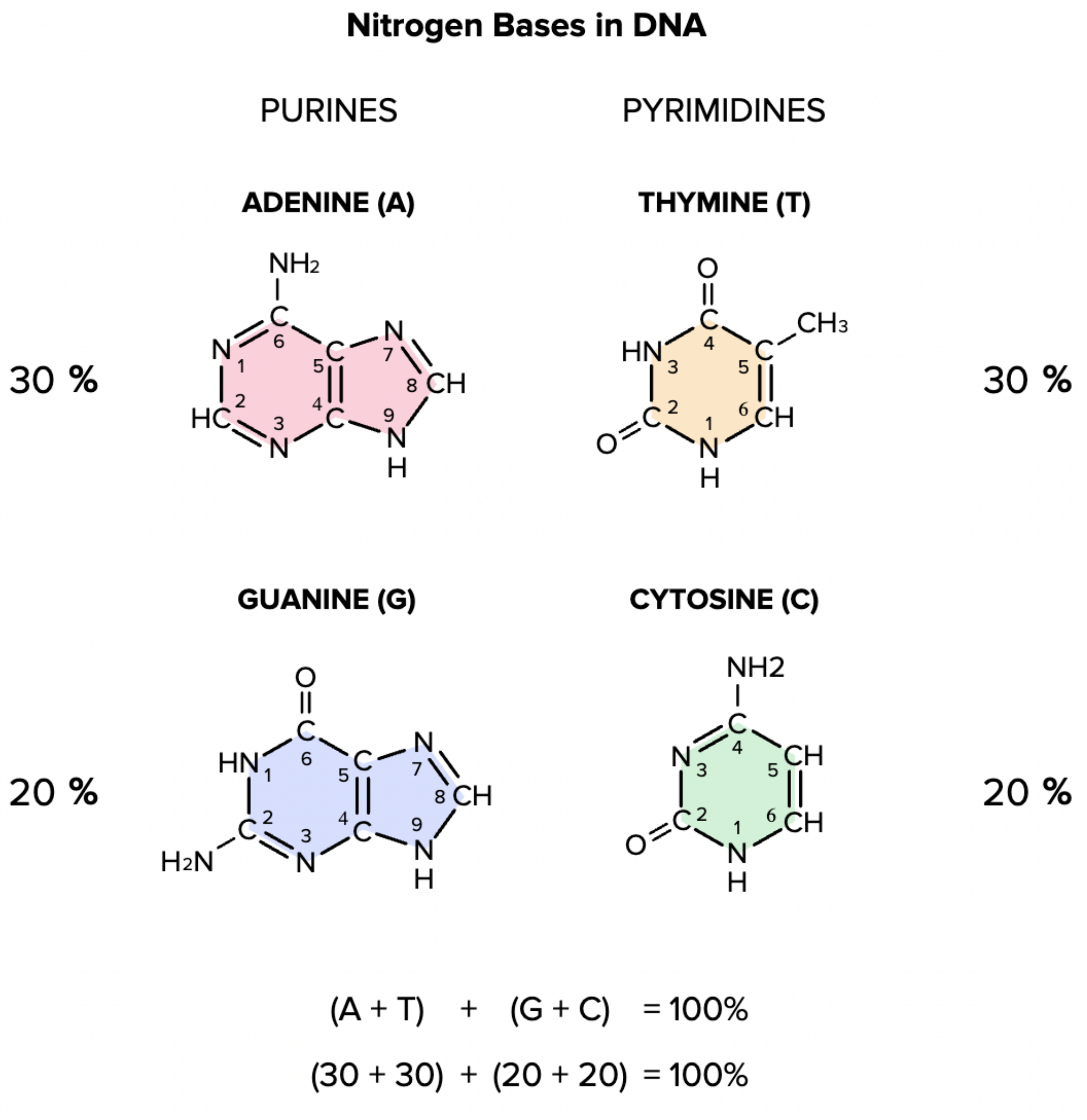


Have you ever seen a ladder? Imagine being able to twist the ladder. The basic shape of DNA is sometimes described as a twisted ladder. Do you see the resemblance? Which parts of the DNA molecule are like the steps of the ladder? What about the railings? There are other ways you can represent or model the structure of DNA in order to better understand its function. The discovery of DNA's structure actually involved modeling. A model is a very useful tool in science. Models provide a way to explore things that might be too complex or small to investigate directly. So how might you create a model of DNA?

DNA Structure

Chargaff's Rules

Other important discoveries about DNA were made in the mid-1900s by Erwin Chargaff. He studied DNA from many different species. He was especially interested in the four different nitrogen bases of DNA: adenine (A), guanine (G), cytosine (C), and thymine (T) .



Chargaff found that concentrations of the four bases differed from one species to another. However, within each species, the concentration of adenine was always about the same as the concentration of thymine. The same was true of the concentrations of guanine and cytosine. These observation came to be known as **Chargaff's rules**. The significance of the rules would not be revealed until the structure of DNA was discovered.

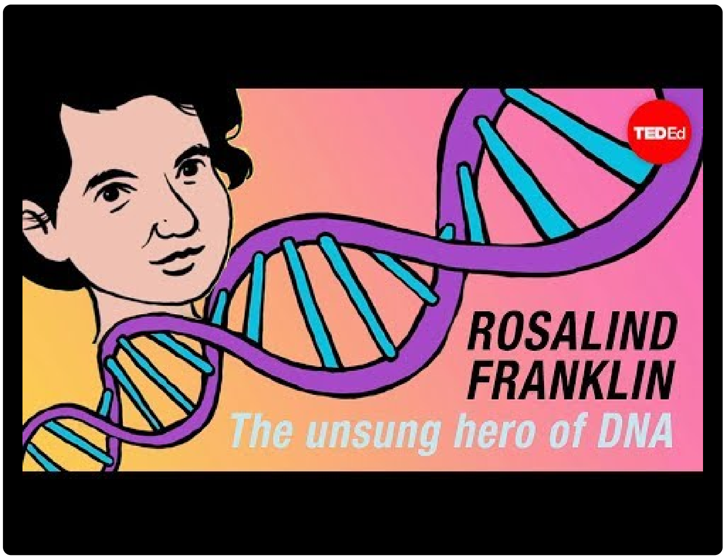
DID YOU KNOW?

The same nitrogen base adenine present in DNA is also found in adenosine triphosphate (ATP), an energy-carrying molecule that cell use to power their cellular and metabolic processes.

The Double Helix

After DNA was found to be the genetic material, scientists wanted to learn more about it. James Watson and Francis Crick are usually given credit for discovering that DNA has a **double helix** shape, like a twisted ladder.

The discovery was based on the prior work of Rosalind Franklin and other scientists, who had used X-rays to learn more about DNA's structure. Franklin and these other scientists have not always been given credit for their contributions. With the help of prior work from other scientists, Watson and Crick developed a model of the DNA double helix structure that correctly matched what was observed in Franklin's X-ray crystallography photos.



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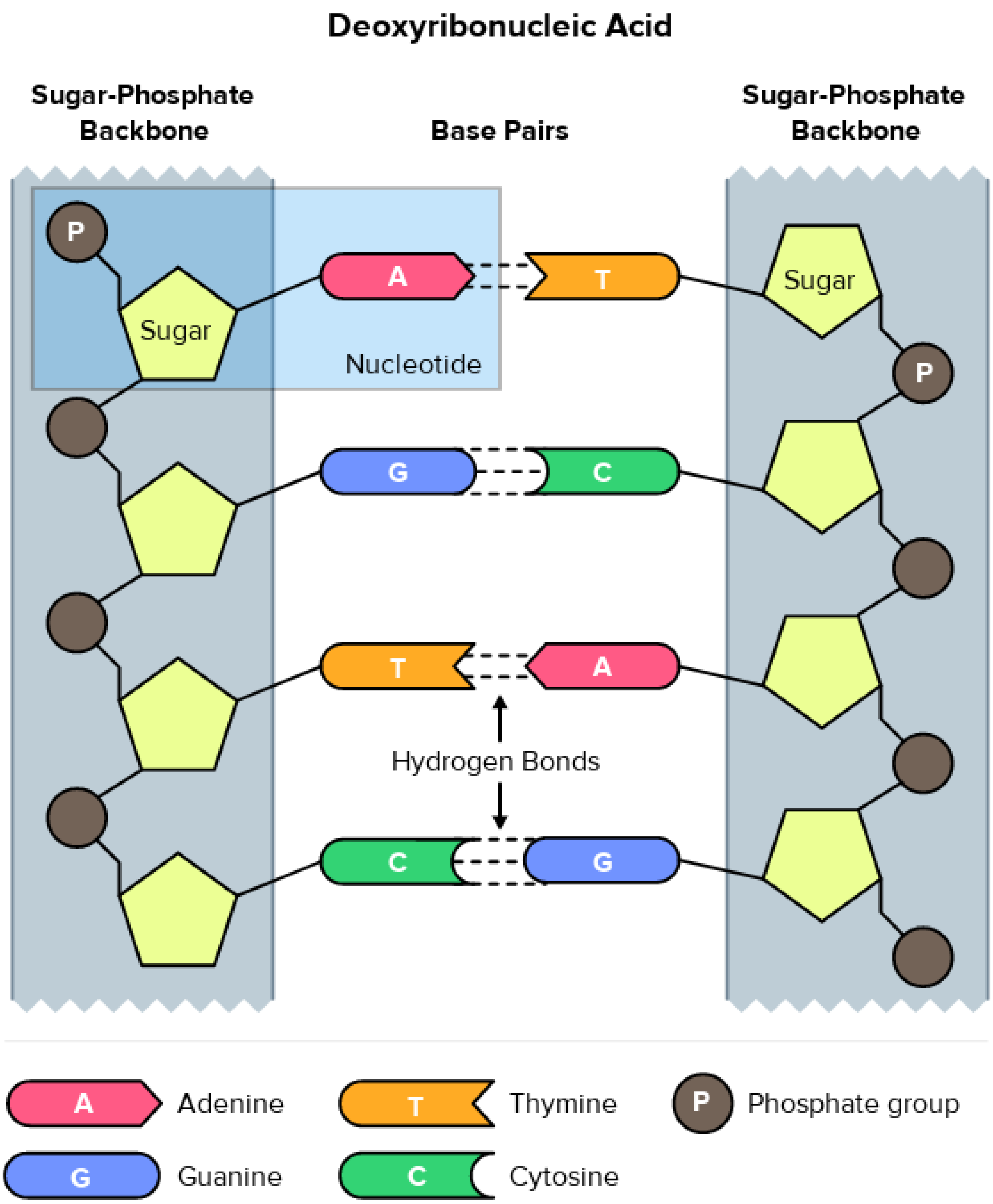
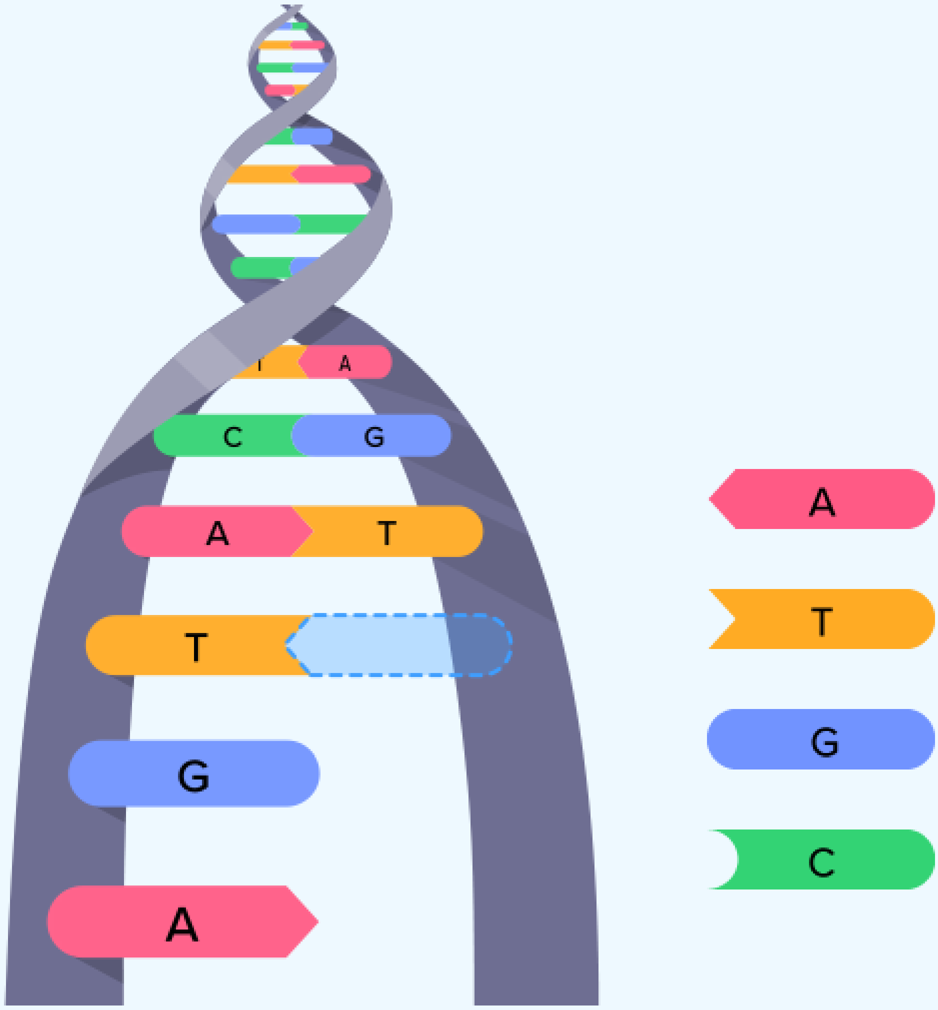
The double helix shape of DNA, together with Chargaff's rules, led to a better understanding of DNA. DNA, as a nucleic acid, is made from nucleotide monomers, and the DNA double helix consists of two polynucleotide chains. Each **nucleotide** consists of a sugar (deoxyribose), a phosphate group, and a nitrogen-containing base (A, C, G, or T).



Scientists concluded that bonds (hydrogen bonds) between complementary bases hold together the two polynucleotide chains of DNA. Adenine always bonds with its complementary base, thymine. Cytosine always bonds with its complementary base, guanine. If you look at the nitrogen bases in the figure above, you will see why. Adenine and guanine have a two-ring structure. Cytosine and thymine have just one ring. If adenine were to bind with guanine and cytosine with thymine, the distance between the two DNA chains would be variable. However, when a one-ring molecule binds with a two-ring molecule, the distance between the two chains is kept constant. This maintains the uniform shape of the DNA double helix. These **base pairs** (A-T or G-C) stick into the middle of the double helix, forming, in essence, the steps of the twisted ladder.

CAN YOU BUILD?

Try to bond the nitrogen bases on the right, with the complementary base. Start by dragging the nitrogen bases on the right.



DNA Replication

Knowledge of DNA's structure helped scientists understand how DNA replicates. **DNA replication** is the process in which DNA is copied. It occurs during the synthesis (S) phase of the eukaryotic cell cycle.

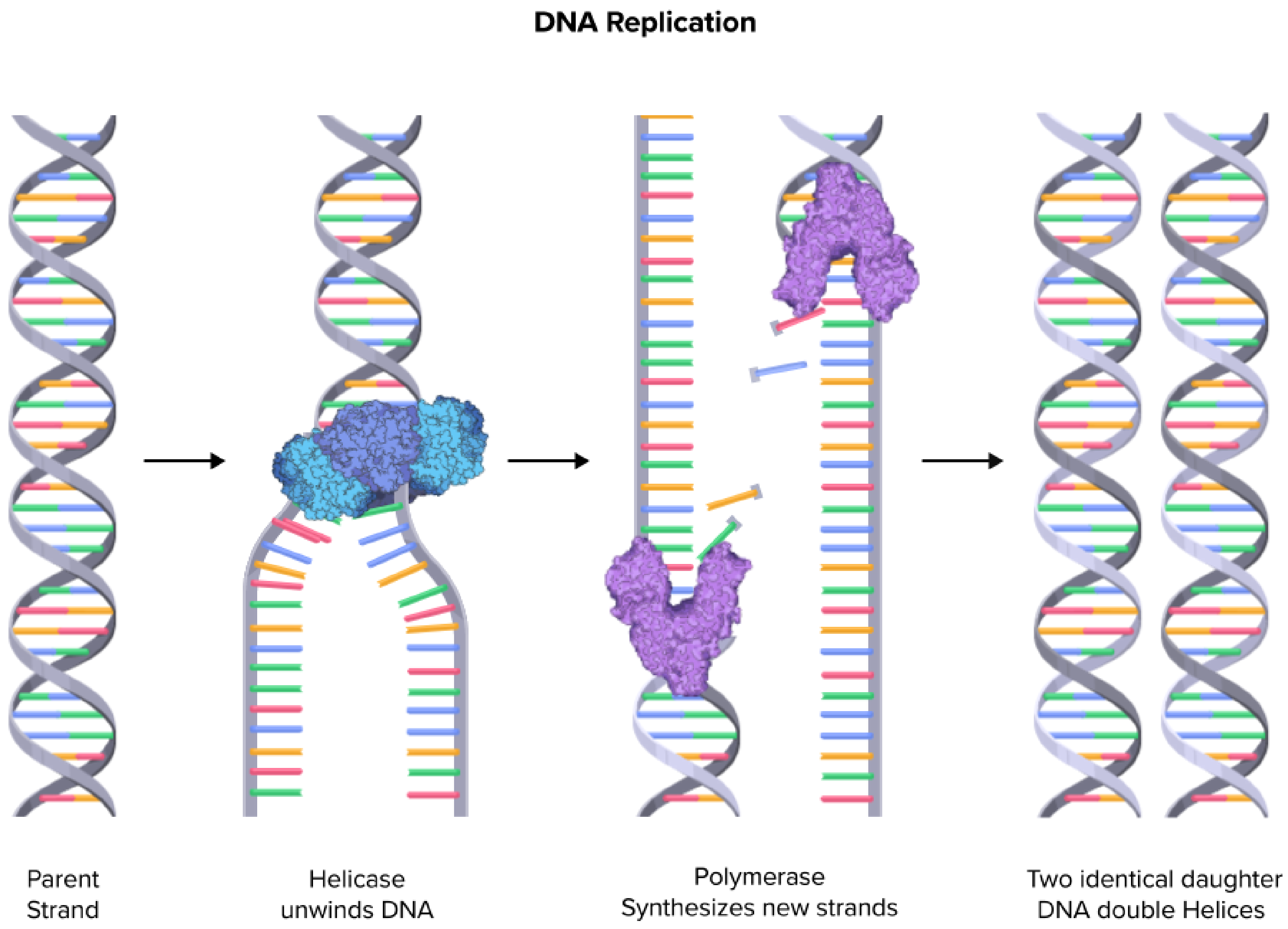
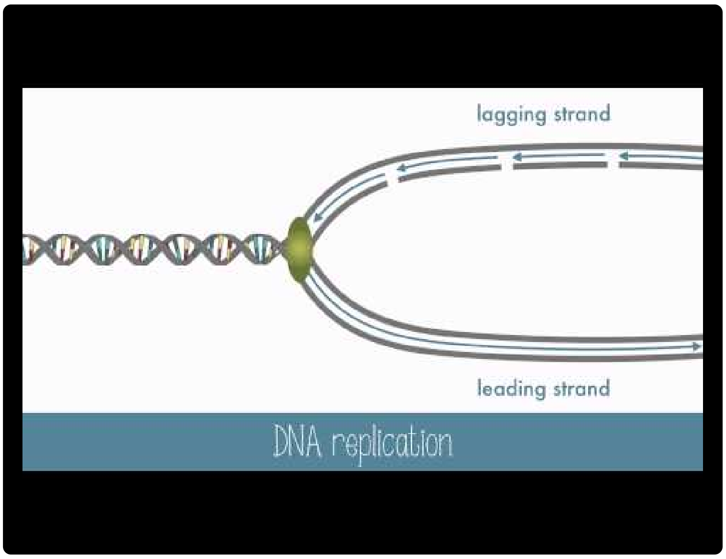


Illustration of enzyme based on images from David S. Goodsell and the RCSB PDB under a CC-BY-4.0 license. Original image: https://pdb101.rcsb.org/motm/168 and https://pdb101.rcsb.org/motm/3.

DNA replication begins when an enzyme, DNA helicase, breaks the bonds between complementary bases in DNA. This exposes the bases inside the molecule so they can be "read" by another enzyme, DNA polymerase, and used to build two new DNA strands with complementary bases, also by DNA polymerase. The two daughter molecules that result each contain one strand from the parent molecule and one new strand that is complementary to it. As a result, the two daughter molecules are identical to the parent molecule. DNA replication is a **semi-conservative** process because half of the parent DNA molecule is conserved in each of the two daughter DNA molecules.

DID YOU KNOW?

DNA polymerase has the remarkable ability to proofread and correct its own mistakes. If it incorporates the wrong base at any point, it corrects itself immediately and only then proceeds with the replication process.



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Summary

- Chargaff's rules state that the amount of A is similar to the amount of T, and the amount of G is similar to the amount of C.
- Watson and Crick discovered that DNA has a double helix shape, consisting of two polynucleotide chains held together by bonds between complementary bases.
- DNA replication is semi-conservative: half of the parent DNA molecule is conserved in each of the two daughter DNA molecules.

Review

1. What are Chargaff's rules?
2. Identify the structure of the DNA molecule.
3. What are nucleotides? What makes up a nucleotide?
4. Why is DNA replication said to be semi-conservative?
5. Create a diagram that shows how DNA replication occurs.
6. What is complementary base pairing? Explain why complementary base pairing is necessary to maintain the double helix shape of the DNA molecule.

Report Content Errors

4.4 RNA

FlexBooks 2.0 > Biology For High School Diploma > RNA

Last Modified: Mar 04, 2022

What you will learn

- How is RNA different from DNA
- Types of RNA and their functions

[Figure 1]

How does the information move from the nucleus, where the DNA is located, to the cytoplasm, where the ribosomes are?

RNA, the other nucleic acid, that's how. Specifically mRNA. RNA, the middle player in the central dogma. This image is an abstract representation of tRNA. Without tRNA, mRNA, and rRNA, protein cannot be made.

RNA

DNA alone cannot "tell" your cell how to make proteins. It needs the help of **RNA**, ribonucleic acid, the other main player in the central dogma of molecular biology. Remember, DNA "lives" in the nucleus, but proteins are made on the ribosome in the cytoplasm. How does the genetic information get from the nucleus to the cytoplasm? RNA is the answer.

RNA vs. DNA

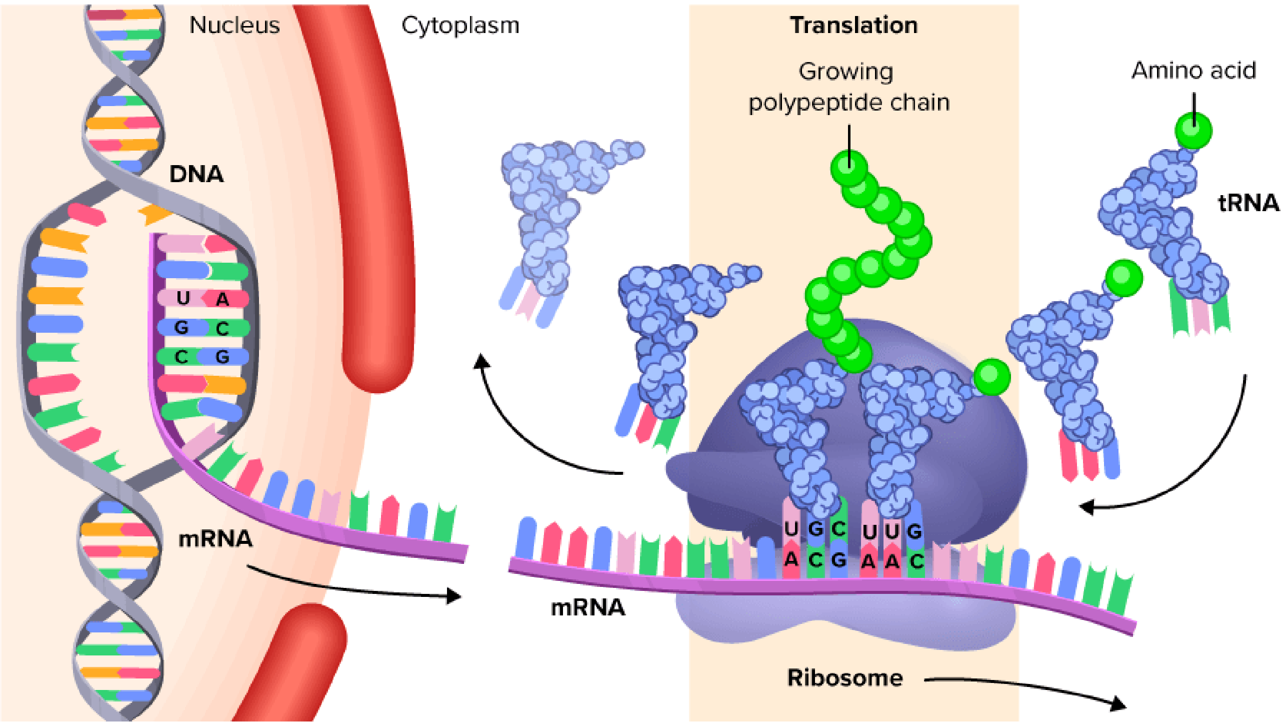
RNA, like DNA, is a nucleic acid. However, RNA differs from DNA in several ways. In addition to being smaller than DNA, RNA also

- consists of one nucleotide chain instead of two,
- contains the nitrogen base uracil (U) instead of thymine,
- contains the sugar ribose instead of deoxyribose.

Types of RNA

There are three main types of RNA, all of which are involved in making proteins.

1. **messenger RNA (mRNA)** copies the genetic instructions from DNA in the nucleus, and carries the instructions to the cytoplasm.
2. **ribosomal RNA (rRNA)** helps form ribosomes, the organelle where proteins are assembled.
3. **transfer RNA (tRNA)** brings amino acid to ribosomes, where they are joined together to form proteins.



[Figure 2]

Shown are the three types of RNA and their roles: (1) mRNA contains the genetic message, (2) tRNA transfers the amino acids to the ribosome, (3) rRNA is the main component of the ribosome.

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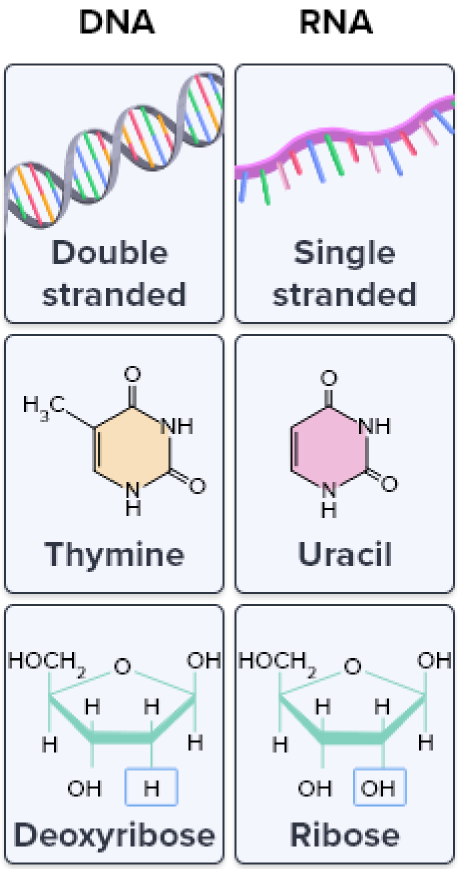
How does DNA differ from RNA?



Summary

- RNA differs from DNA in several ways; RNA is single-stranded instead of double-stranded, contains ribose instead of deoxyribose, and contains uracil instead of thymine.
- There are three main types of RNA: messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA).
- Each type of RNA plays a different in role in making proteins.

Review

1. What are the three main types of RNA? Describe their roles.
2. Compare and contrast DNA and RNA.

Report Content Errors

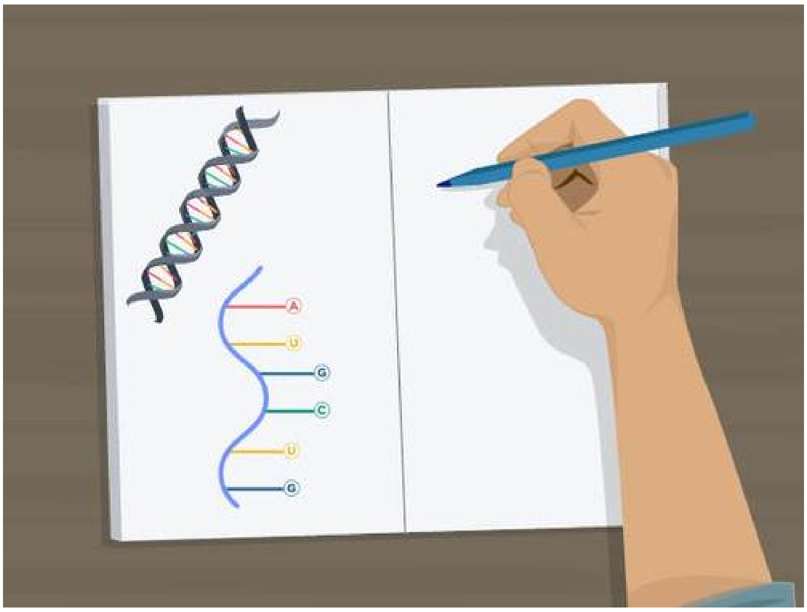
4.5 Transcription

FlexBooks 2.0 > Biology For High School Diploma > Transcription

Last Modified: Mar 04, 2022

What you will learn

- What is transcription
- Steps in the process of transcription
- How is transcribed mRNA processed in eukaryote



[Figure 1]

How does a cell use the information in its DNA?

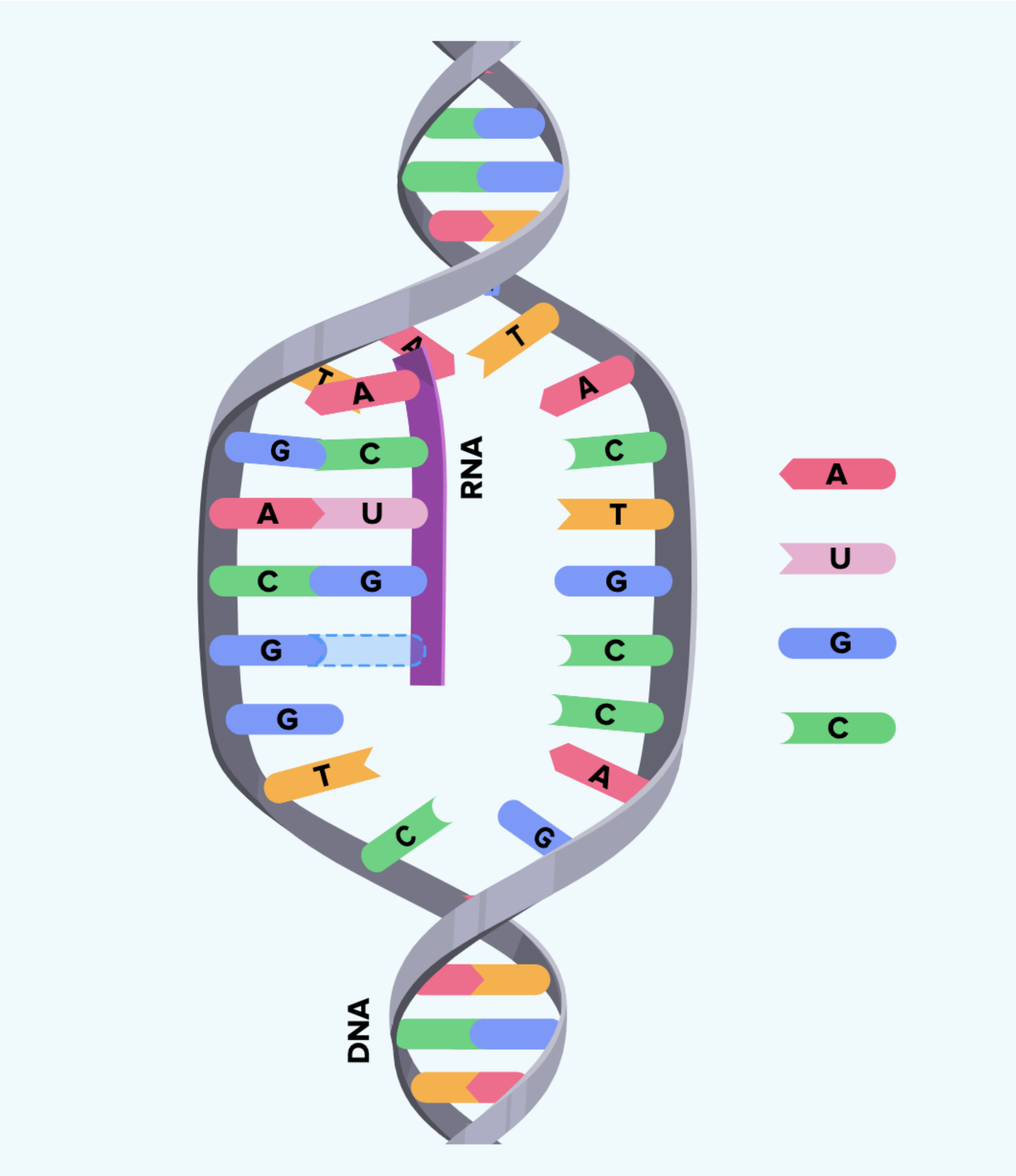
To transcribe means "to paraphrase or summarize in writing". The information in DNA is transcribed - or summarized - into a smaller version - RNA - that can be used by the cell. This process is called transcription.

Transcription

The process in which cells make protein is called **protein synthesis**. It actually consists of two processes: **transcription** and **translation**. Transcription takes place in the nucleus of the eukaryotic cell. It uses DNA as a template to make an RNA molecule. RNA then leaves the nucleus and goes to a ribosome in the cytoplasm, where translation occurs. Translation reads the genetic code in mRNA and makes a protein.

Transcription is the first part of the central dogma of molecular biology: *DNA* → *RNA*. It is the transfer of genetic instructions in DNA to messenger RNA (mRNA). During transcription, a strand of mRNA is made that is complementary to a strand of DNA.

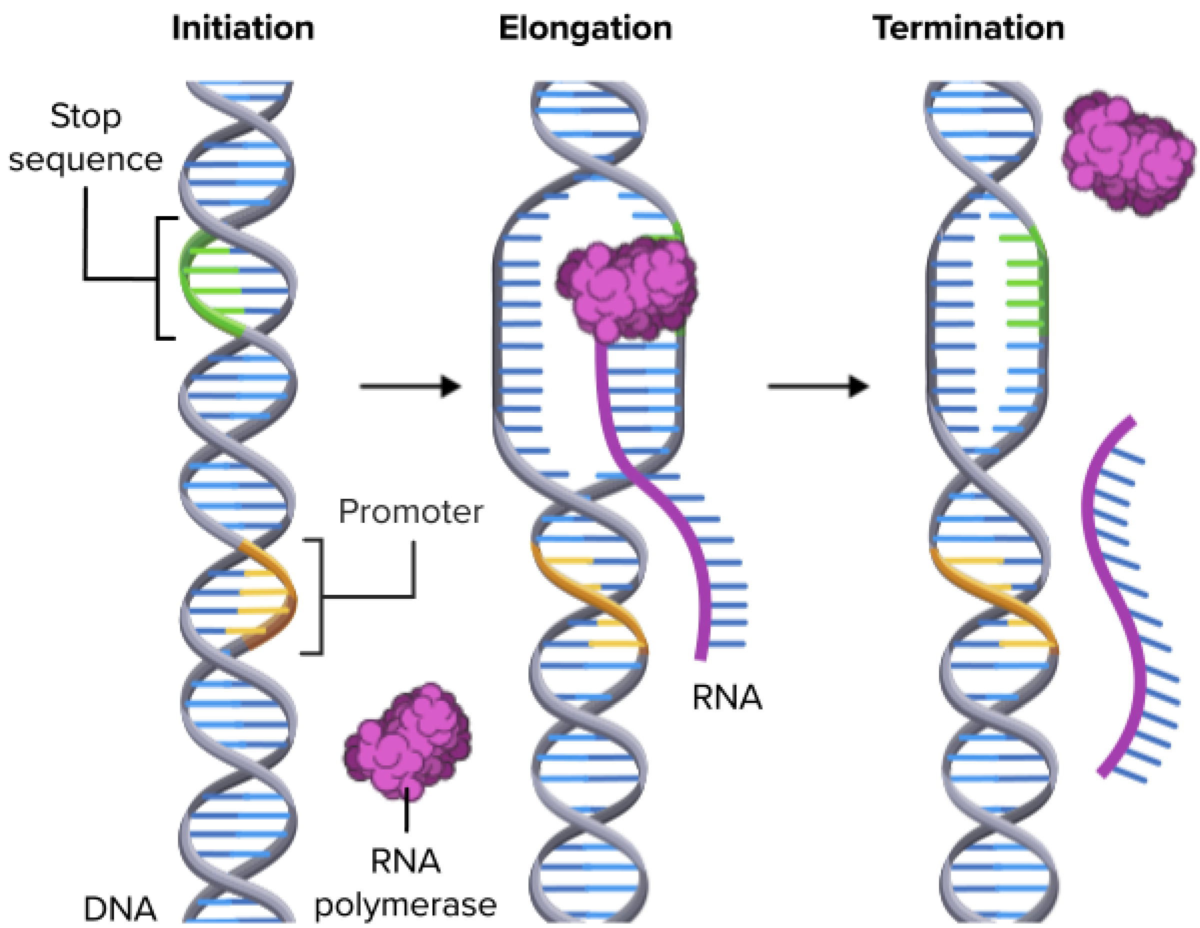
How is DNA transcribed into RNA?



Steps of Transcription

Transcription takes place in three steps: initiation, elongation, and **termination**. The steps are illustrated in the **Figure** below.

1. **Initiation** is the beginning of transcription. It occurs when the enzyme **RNA polymerase** binds to a region of a gene called the **promoter**. This signals the DNA to unwind so the enzyme can "read" the bases in one of the DNA strands. The enzyme is now ready to make a strand of mRNA with a complementary sequence of bases.
2. **Elongation** is the addition of nucleotide to the mRNA strand. RNA polymerase reads the unwound DNA strand and builds the mRNA molecule, using complementary base pair. There is a brief time during this process when the newly formed RNA is bound to the unwound DNA. During this process, adenine (A) in the DNA binds to uracil (U) in the RNA.
3. **Termination** is the ending of transcription and occurs when RNA polymerase crosses a stop (termination) sequence in the gene. The mRNA strand is complete, and it detaches from DNA.



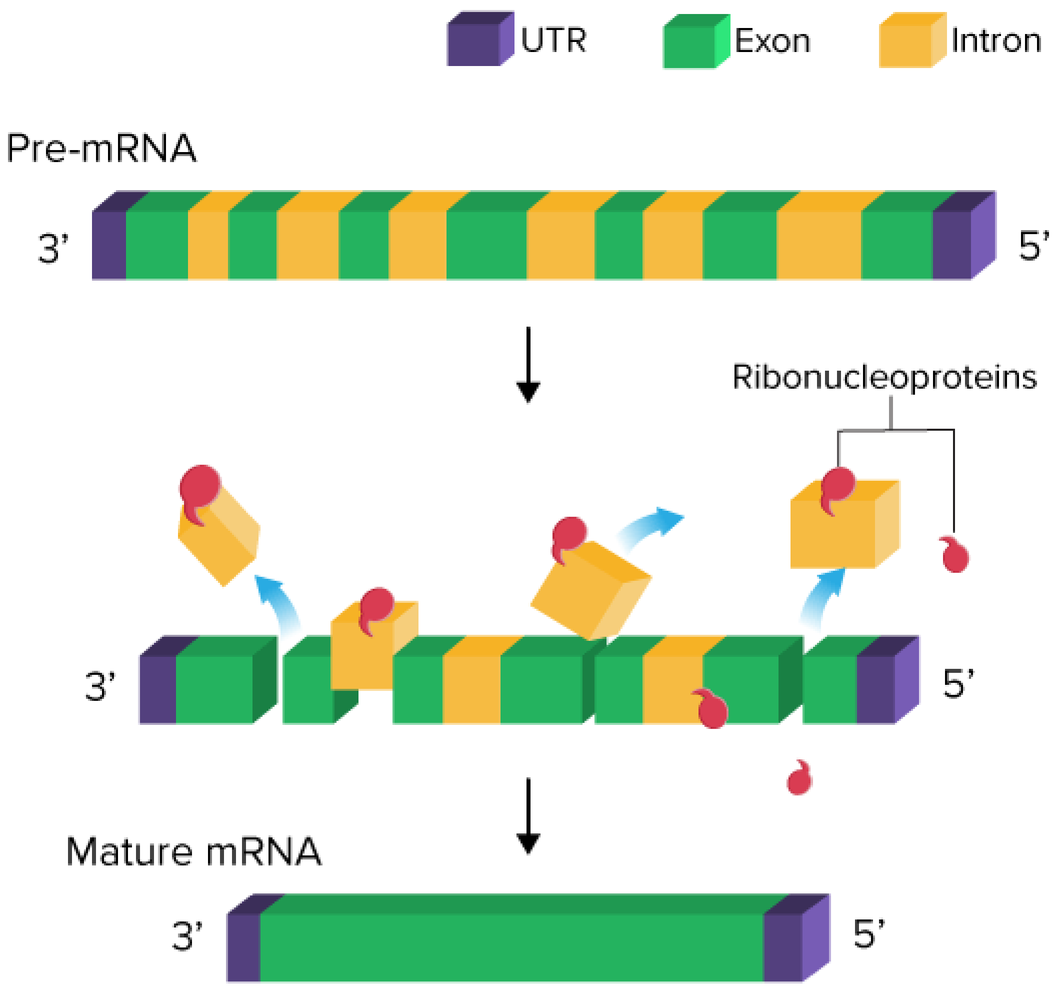
Steps of Transcription. Transcription occurs in the three steps - initiation, elongation, and termination - shown here.

Processing mRNA

In eukaryotes, the new mRNA is not yet ready for translation. It must go through additional processing before it leaves the nucleus. This may include splicing, editing, and

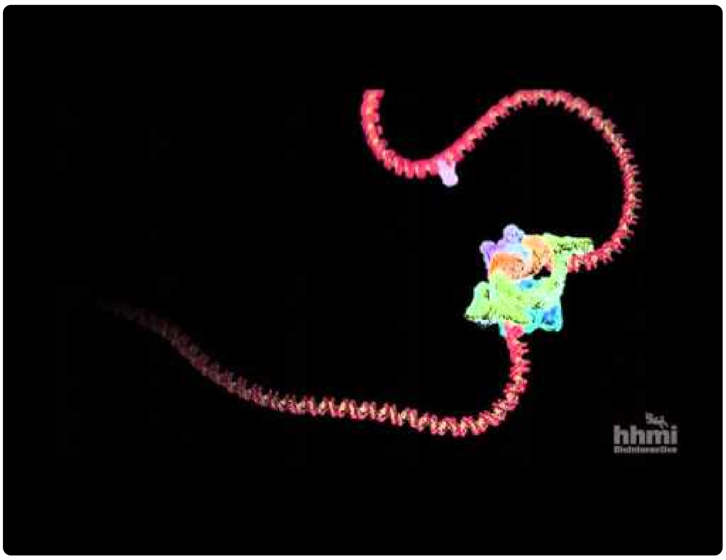
polyadenylation. These processes modify the mRNA in various ways. Such modifications allow a single gene to be used to make more than one protein.

- **Splicing** removes **intron** from mRNA (see the **Figure** below). Introns are regions that do not code for proteins. The remaining mRNA consists only of regions that do code for proteins, which are called **exon**. Ribonucleoproteins are nucleoproteins that contain RNA. Small nuclear ribonucleoproteins are involved in pre-mRNA splicing.
- **Editing** changes some of the nucleotides in mRNA. For example, the human protein called APOB, which helps transport lipid in the blood, has two different forms because of editing. One form is smaller than the other because editing adds a premature stop signal in the mRNA.
- **Polyadenylation** adds a "tail" to the mRNA. The tail consists of a string of As (adenine bases). It signals the end of mRNA. It is also involved in exporting mRNA from the nucleus. In addition, the tail protects mRNA from enzymes that might break it down.



[Figure 2]

Splicing. Splicing removes introns from mRNA. UTR is an untranslated region of the mRNA.



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Summary

- Transcription is the DNA → RNA part of the central dogma of molecular biology.
- Transcription occurs in the nucleus of eukaryotic cells.
- During transcription, a copy of mRNA is made that is complementary to a strand of DNA. In eukaryotes, mRNA may be modified before it leaves the nucleus of eukaryotic cells.
  .

Review

1. What is protein synthesis?
2. What enzyme is involved in transcription?
3. Describe transcription.
4. Describe splicing. Distinguish introns from exons.
5. How may mRNA be modified before it leaves the nucleus?

Report Content Errors

4.6 Genetic Code

FlexBooks 2.0 > Biology For High School Diploma > Genetic Code

Last Modified: Mar 04, 2022

What will you learn

- What is the genetic code
- How the genetic code is read
- The characteristics of the genetic code

[Figure 1]

How do you go from four letters to 20 amino acids?

You need a code. And the code that changes the information embedded in DNA and RNA into ordered amino acid and protein is the genetic code. And every living organism uses the same genetic code.

The Genetic Code

How is the information in a gene encoded? The answer is the genetic code. The **genetic code** consists of the sequence of nitrogen bases—A, C, G, U—in an mRNA chain. The four bases make up the "letters" of the genetic code. The letters are combined in groups of three to form code “words,” called **codon**. Each codon stands for (encodes) one amino acid, unless it codes for a start or stop signal.

There are 20 common amino acids in proteins. There are 64 possible codons, more than enough to code for the 20 amino acids. The genetic code is shown in the **Figure** below.

1st base \ 2nd base	U	C	A	G
U	UUU (Phe/F) Phenylalanine UUC (Phe/F) Phenylalanine UUA (Leu/L) Leucine UUG (Leu/L) Leucine	UCU (Ser/S) Serine UCC (Ser/S) Serine UCA (Ser/S) Serine UCG (Ser/S) Serine	UAU (Tyr/Y) Tyrosine UAC (Tyr/Y) Tyrosine UAA (Stop) UAG (Stop)	UGU (Cys/C) Cysteine UGC (Cys/C) Cysteine UGA (Stop) UGG (Trp/W) Tryptophan
C	CUU (Leu/L) Leucine CUC (Leu/L) Leucine CUA (Leu/L) Leucine CUG (Leu/L) Leucine	CCU (Pro/P) Proline CCC (Pro/P) Proline CCA (Pro/P) Proline CCG (Pro/P) Proline	CAU (His/H) Histidline CAC (His/H) Histidline CAA (Gln/Q) Glutamine CAG (Gln/Q) Glutamine	CGU (Arg/R) Arginine CGC (Arg/R) Arginine CGA (Arg/R) Arginine CGG (Arg/R) Arginine
A	AUU (Ile/I) Isoleucine AUC (Ile/I) Isoleucine AUA (Ile/I) Isoleucine AUG (Met/M) Methionine	ACU (Thr/T) Threonine ACC (Thr/T) Threonine ACA (Thr/T) Threonine ACG (Thr/T) Threonine	AAU (Asn/N) Asparagine AAC (Asn/N) Asparagine AAA (Lys/K) Lysine AAG (Lys/K) Lysine	AGU (Ser/S) Serine AGC (Ser/S) Serine AGA (Arg/R) Arginine AGG (Arg/R) Arginine
G	GUU (Val/V) Valine GUC (Val/V) Valine GUA (Val/V) Valine GUG (Val/V) Valine	GCU (Ala/A) Alanine GCC (Ala/A) Alanine GCA (Ala/A) Alanine GCG (Ala/A) Alanine	GAU (Asp/D) Aspartic acid GAC (Asp/D) Aspartic acid GAA (Glu/E) Glutamic acid GAG (Glu/E) Glutamic acid	GGU (Gly/G) Glycine GGC (Gly/G) Glycine GGA (Gly/G) Glycine GGG (Gly/G) Glycine

(start codon) (stop codon)

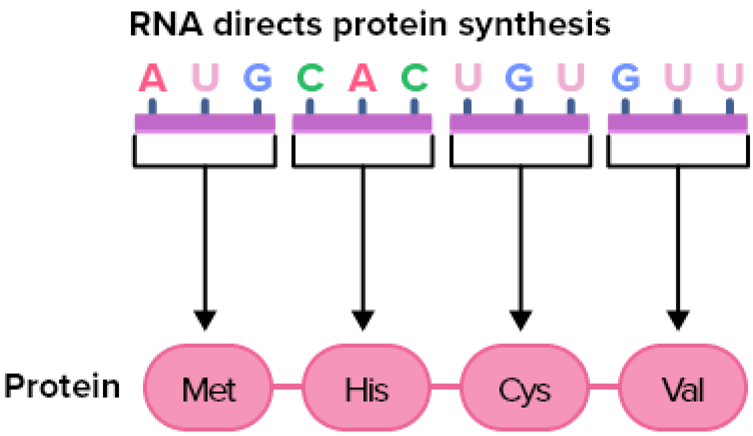
[Figure 2]

The Genetic Code. To find the amino acid for a particular codon, find the cell in the table for the first and second bases of the codon. Then, within that cell, find the codon with the correct third base. For example CUG codes for leucine, AAG codes for lysine, and GGG codes for glycine.

Reading the Genetic Code

As shown in the **Figure** above, the codon AUG codes for the amino acid methionine. This codon is also the **start codon** that begins translation. The start codon establishes the **reading frame** of mRNA. The **reading frame** is the way the letters are divided into codons. After the AUG start codon, the next three letters are read as the second codon. The next three letters after that are read as the third codon, and so on. The mRNA molecule is read, codon by codon, until a **stop codon** is reached. UAG, UGA, and UAA are all stop codons. They do not code for any amino acids. Stop codons are also known as termination codons.

Can you match the amino acids to the codons?



Characteristics of the Genetic Code

The genetic code has a number of important characteristics.

- The genetic code is universal. All known living organisms use the same genetic code. This shows that all organisms share a common evolutionary history.
- The genetic code is unambiguous. Each codon codes for just one amino acid (or start or stop). What might happen if codons encoded more than one amino acid?
- The genetic code is redundant. Most amino acids are encoded by more than one codon. In the **Figure** above, how many codons code for the amino acid threonine? What might be an advantage of having more than one codon for the same amino acid?

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Summary

- The genetic code consists of the sequence of bases in DNA or RNA.
- Groups of three bases form codons, and each codon stands for one amino acid (or start or stop).
- The codons are read in sequence following the start codon until a stop codon is reached.
- The genetic code is universal, unambiguous, and redundant.

Review

1. What is the genetic code?
2. What are codons? How many codons are there?
3. Use the genetic code to translate the following segment of RNA into a sequence of five amino acids: GUC-GCG-CAU-AGC-AAG
4. The genetic code is universal, unambiguous, and redundant. Explain what this means.

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4.7 Translation

FlexBooks 2.0 > Biology For High School Diploma > Translation

Last Modified: Mar 28, 2022

What will you learn

- How protein are made from RNA through translation
- The structure of tRNA and its role in translation

[Figure 1]

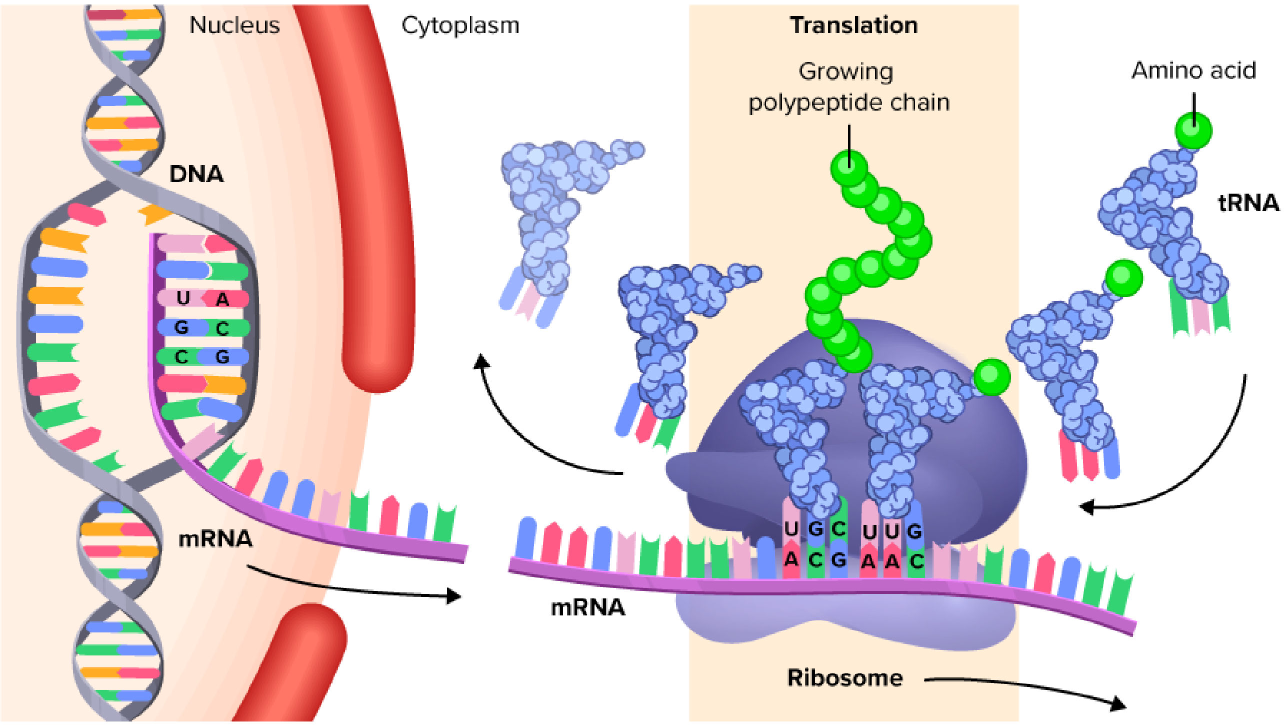
RNA to proteins. How?

You must translate. To go from one language to another. Spanish to English, French to German, or nucleotide to amino acid. Which type is the translation of molecular biology? Obviously, the type of translating discussed here translates from the language of nucleotides to the language of amino acids.

Translation

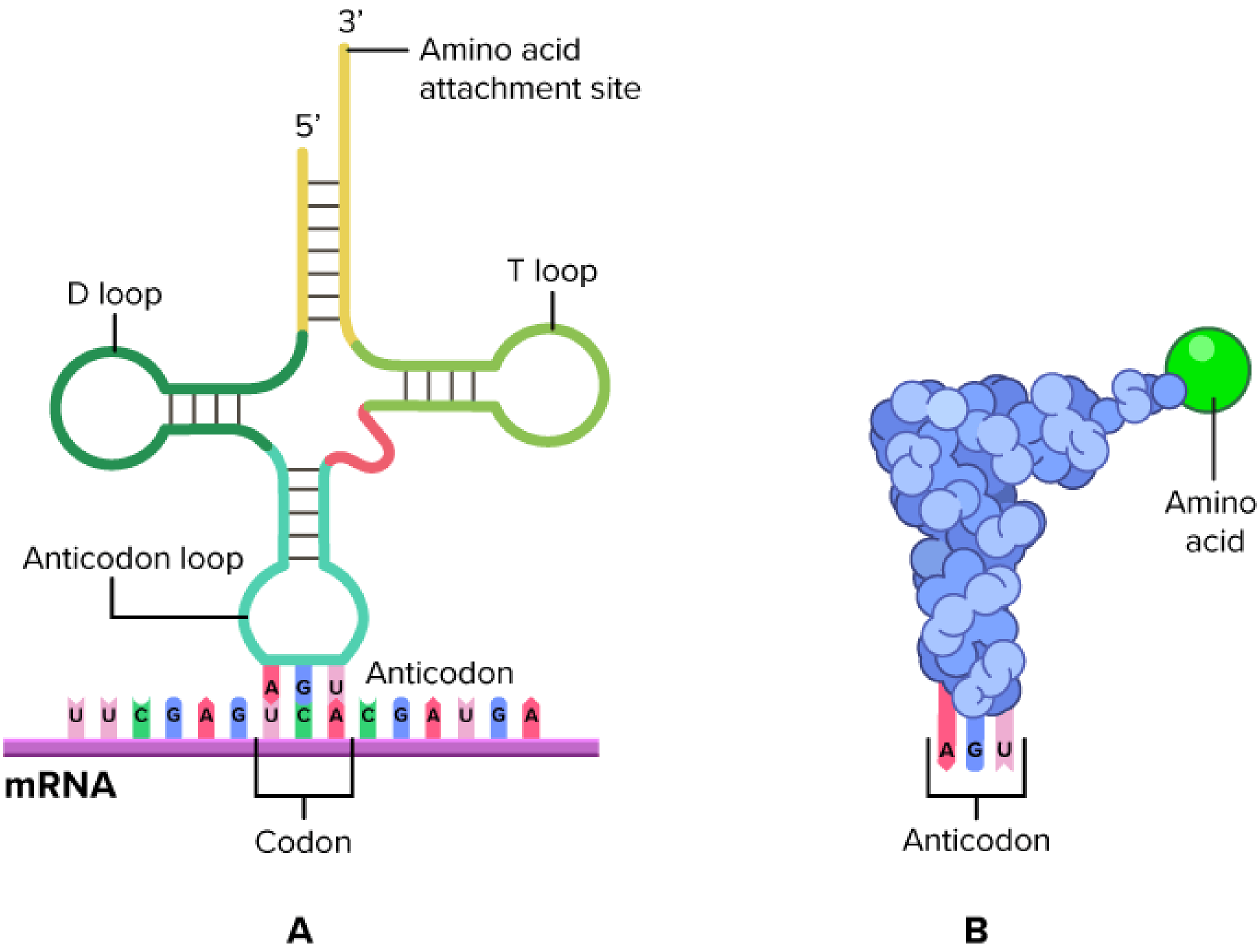
Translation is the second part of the central dogma of molecular biology: *RNA* → *Protein*. It is the process in which the genetic code in **mRNA** is read, one **codon** at a time, to make a protein. After mRNA leaves the nucleus, it moves to a **ribosome**, which consists of **rRNA**

and proteins. The ribosome reads the sequence of codons in mRNA. Molecules of **tRNA** bring amino acids to the ribosome in the correct sequence.



Translation of the codons in mRNA to a chain of amino acids occurs at a ribosome. Notice the growing amino acid chain attached to the tRNAs and ribosome. Find the different types of RNA in the diagram. What are their roles in translation?
Illustration of tRNA based on image from David S. Goodsell and the RCSB PDB under a CC BY 4.0 license. Original image: https://pdb101.rcsb.org/motm/15.

To understand the role of tRNA, you need to know more about its structure. Each tRNA molecule has an **anticodon** for the amino acid it carries. An anticodon is a sequence of 3 bases, and is complementary to the codon for an amino acid. For example, the amino acid lysine has the codon AAG, so the anticodon is UUC. Therefore, lysine would be carried by a tRNA molecule with the anticodon UUC. Wherever the codon AAG appears in mRNA, a UUC anticodon on a tRNA temporarily binds to the codon. While bound to the mRNA, the tRNA gives up its amino acid. Bonds form between adjacent amino acids as they are brought one by one to the ribosome, forming a **polypeptide** chain. The chain of amino acids keeps growing until a stop codon is reached.

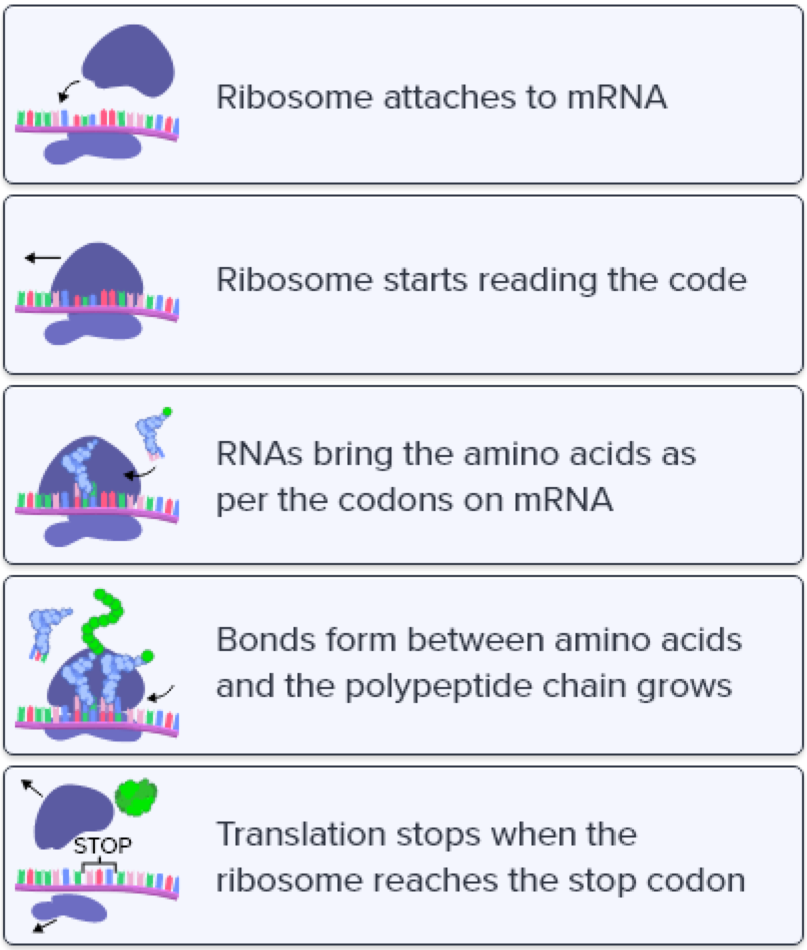


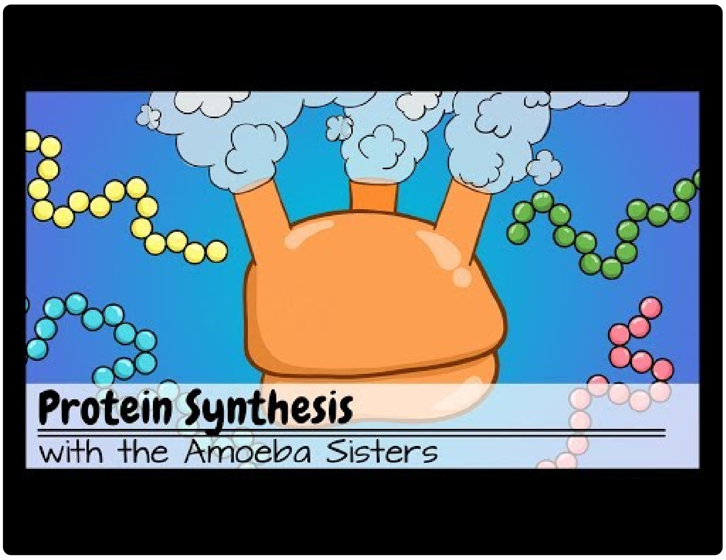
[Figure 2]

The tRNA structure (A) is a very important aspect in its role. Though the molecule folds into a 3-leaf clover structure (B), notice the anticodon arm in the lower segment of the molecule, with the amino acid attached at the opposite end of the molecule (acceptor stem). It is the anticodon that determines which codon in the mRNA the tRNA will bind to.

After a polypeptide chain is synthesized, it may undergo additional processes. For example, it may assume a folded shape due to interactions among its amino acids. It may also bind with other polypeptides or with different types of molecules, such as lipid or carbohydrate. Many proteins travel to the Golgi apparatus to be modified for their specific function.

Can you place the steps in the process of translation in the correct order?





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Summary

- Translation is the *RNA* → *Protein* part of the central dogma.
- Translation occurs at a ribosome.
- During translation, a protein is synthesized using the codons in mRNA as a guide.
- All three types of RNA play a role in translation.

Review

1. Outline the steps of translation.
2. Discuss the structure of a tRNA molecule, and its role in translation.
3. How are transcription and translation related to the central dogma of molecular biology?

Report Content Errors

4.8 Mutation

FlexBooks 2.0 > Biology For High School Diploma > Mutation

Last Modified: Apr 18, 2022

What you will learn

- What are mutations and how are they caused
- Two major categories of mutations
- What are **chromosomal alteration** and its types
- **point mutation** and their effects

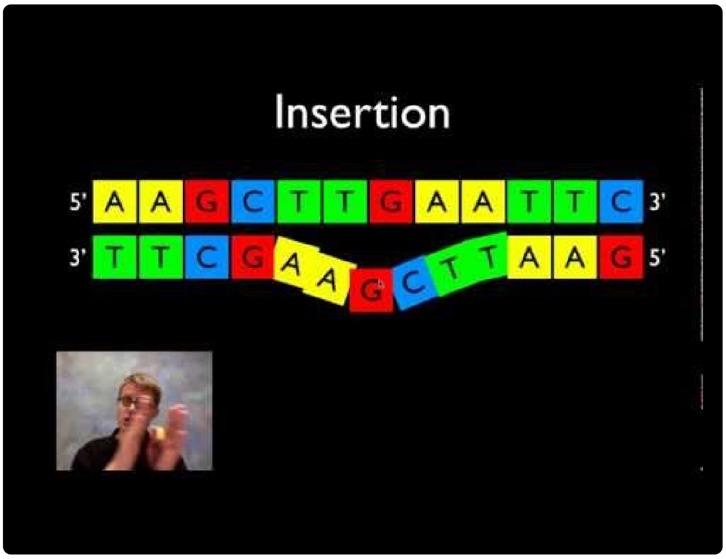
[Figure 1]

What causes albinism?

This rare albino alligator must have the specific "instructions," or DNA, to have this quality. The cause of albinism is a mutation in a gene for melanin, a protein found in skin and eyes. Such a mutation may result in no melanin production at all or a significant decline in the amount of melanin.

Mutations

A change in the sequence of bases in DNA is called a **mutation**. Does the word mutation make you think of science fiction and bug-eyed monsters? Think again. Everyone has mutations. In fact, most people have dozens or even hundreds of mutations in their DNA. Mutations are essential for evolution to occur. They are the ultimate source of all new genetic material - new allele - in a species. Although most mutations have no effect on the organism in which they occur, some mutations are beneficial. Even harmful mutations rarely cause drastic changes in organisms.



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Types of Mutations

There are a variety of types of mutations. Two major categories of mutations are germline mutations and **somatic mutation**.

- **Germline mutations** occur in gamete. These mutations are especially significant because they can be transmitted to offspring and every cell in the offspring will have the mutation.
- **Somatic mutations** occur in other cells of the body. These mutations may have little effect on the organism because they are confined to just one cell and its daughter cell. Somatic mutations cannot be passed on to offspring.

Mutations also differ in the way that the genetic material is changed. Mutations may change the structure of a chromosome or just change a single nucleotide.

Chromosomal Alterations

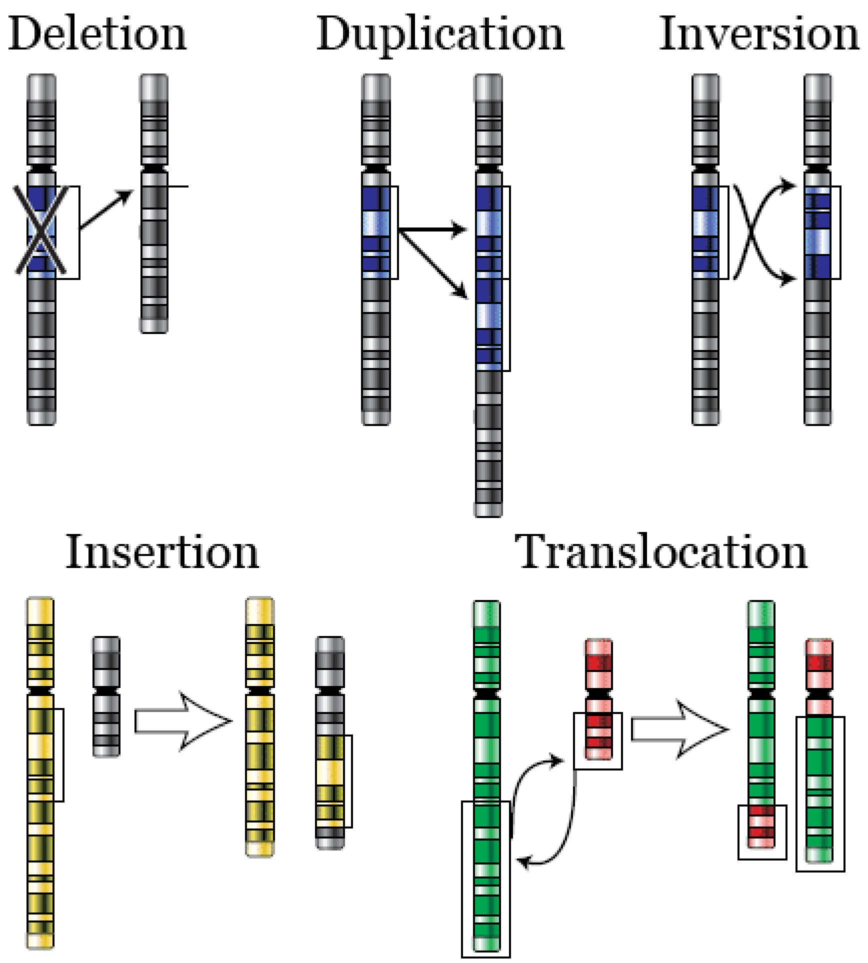
Chromosomal alterations are mutations that change chromosome structure. They occur when a section of a chromosome breaks off and rejoins incorrectly or does not rejoin at all.

Possible types of mutations in chromosomes include:

1. Deletion: When a segment of DNA is lost, so there is a missing segment in the chromosome. These usually result in many genes missing from the chromosome.

2. Duplication: When a segment of DNA is repeated, creating a longer chromosome. These usually result in multiple copies of genes in the chromosome.
3. Inversion: When a segment of DNA is flipped and then reattached to the same chromosome.
4. Insertion: When a segment of DNA from one chromosome is added to another, unrelated chromosome.
5. Translocation: When two segments from different chromosomes change positions.

Possible ways these mutations can occur are illustrated in the **Figure** below.

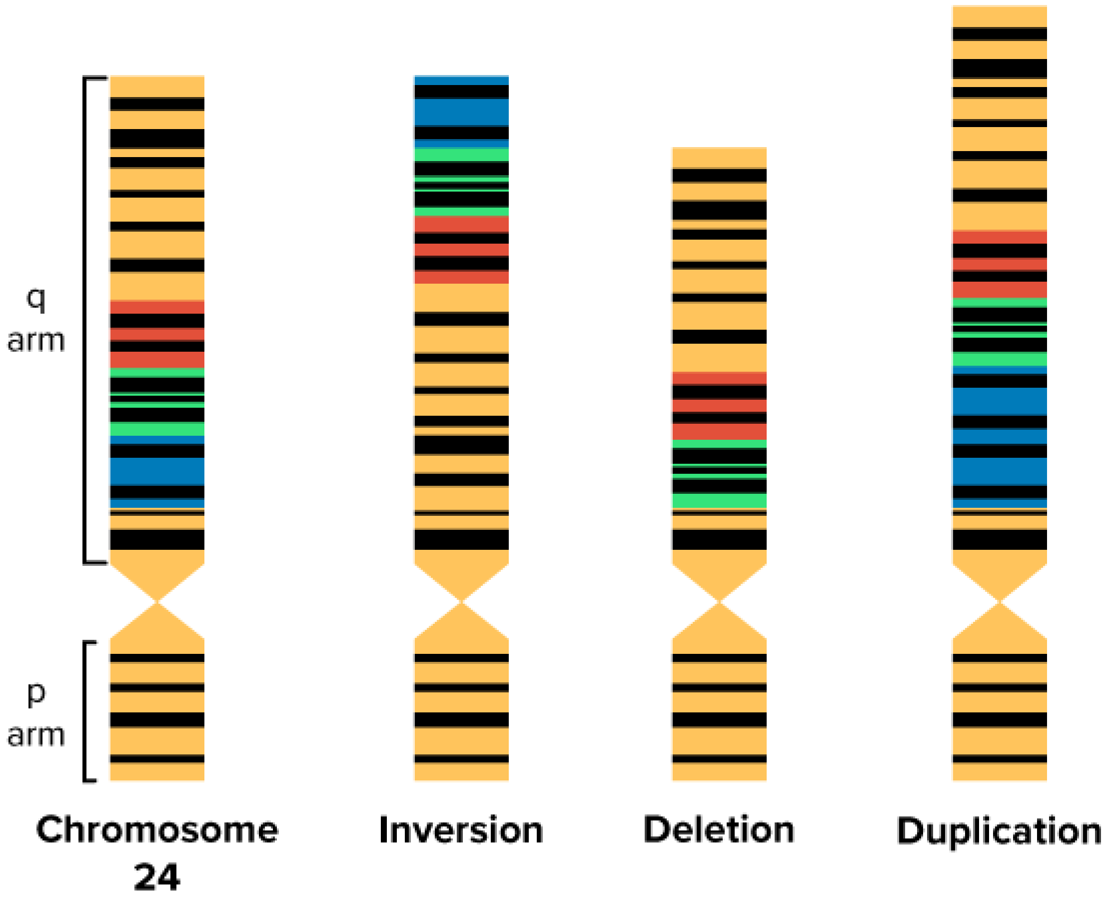


[Figure 2]

Chromosomal Alterations. Chromosomal alterations are major changes in the genetic material.

Chromosomal alterations are very serious. They often result in the death of the organism in which they occur. If the organism survives, it may be affected in multiple ways.

What are the changes in chromosomal structure due to chromosomal alterations?



Point Mutations

A **point mutation** is a change in a single nucleotide in DNA. This type of mutation is usually less serious than a chromosomal alteration. An example of a point mutation is a mutation that changes the codon *UUU* to the codon *UCU*. Point mutations can be silent, missense, or nonsense mutations, as shown in the **Table** below. These types of point mutations are also known as substitutions. Their effects depend on how they change the genetic code.

Type	Description	Example	Effect
Silent	mutated codon codes for the same amino acid	CAA (glutamine) → CAG (glutamine)	none
Missense	mutated codon codes for a different amino acid	CAA (glutamine) → CCA (proline)	variable
Nonsense	mutated codon is a premature stop codon	CAA (glutamine) → UAA (stop)	usually serious

Frameshift Mutations

A **frameshift mutation** (also a type of point mutation) includes a deletion or insertion of one or more nucleotides that changes the reading frame of the base sequence. Deletions remove nucleotides, and insertions add nucleotides. Consider the following sequence of bases in RNA:

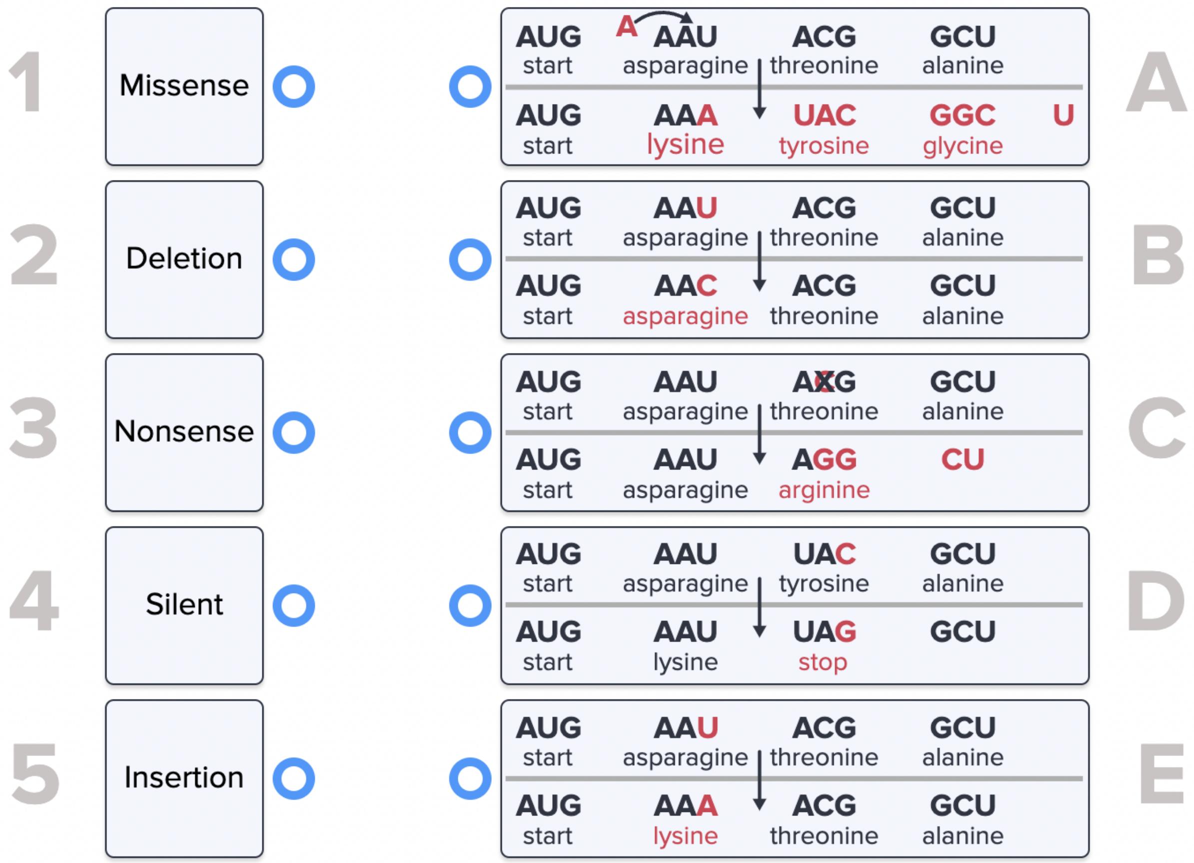
AUG-AAU-ACG-GCU = start-asparagine-threonine-alanine

Now, assume an insertion occurs in this sequence. Let's say an *A* nucleotide is inserted after the start codon *AUG*:

AUG-AAA-UAC-GGC-U = start-lysine-tyrosine-glycine

Even though the rest of the sequence is unchanged, this insertion changes the reading frame and thus all of the codons that follow it. As this example shows, a frameshift mutation can dramatically change how the codons in mRNA are read. This can have a drastic effect on the protein product.

What effect do the different point mutations have on an amino acid sequence?



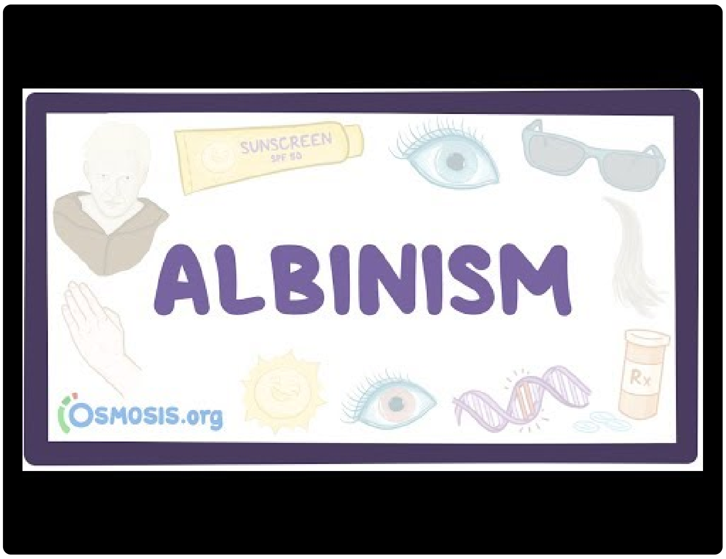
Answers: 1-E, 2-C, 3-D, 4-B, 5-A

DID YOU KNOW?

cystic fibrosis is a genetic disorder caused by mutations in the gene encoding CFTR (cystic fibrosis transmembrane regulator) protein. Most of the mutations that result in the disorder are point mutations.

Albinism

Albinism is not commonly seen in nature because the change in pigmentation is often a disadvantage to organisms in their natural environment. The lack of pigmentation can make the albino organism more vulnerable and an easier target to predator since organisms with albinism, for instance, cannot easily camouflage themselves into their environment. As a result, an albino alligator like the one depicted above may not live long enough to survive and reproduce due to being more vulnerable and easier prey to predators.



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Summary

- Germline mutations occur in gametes. Somatic mutations occur in other body cells.

- Chromosomal alterations are mutations that change chromosome structure.
- Point mutations change a single nucleotide.
- Frameshift mutations are additions or deletions of nucleotides that cause a shift in the reading frame.

Review

1. Identify three types of chromosomal alterations.
2. Distinguish among silent, missense, and nonsense point mutations.
3. What is a frameshift mutation? What causes this type of mutation?
4. Assume that a point mutation changes the codon AUU to AUC. Why is this a silent mutation?
5. Look at the following mutation: AUG-GUC-CCU-AAA → AUG-AGU-CCC-UAA-A. The base A was inserted following the start codon AUG. Describe how this mutation affects the encoded amino acid sequence.
6. Compare and contrast germline mutations and somatic mutations.

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4.9 Mutation Causes

FlexBooks 2.0 > Biology For High School Diploma > Mutation Causes

Last Modified: Mar 04, 2022

What will you learn

- What are the causes of **mutation**
- Types of spontaneous mutations

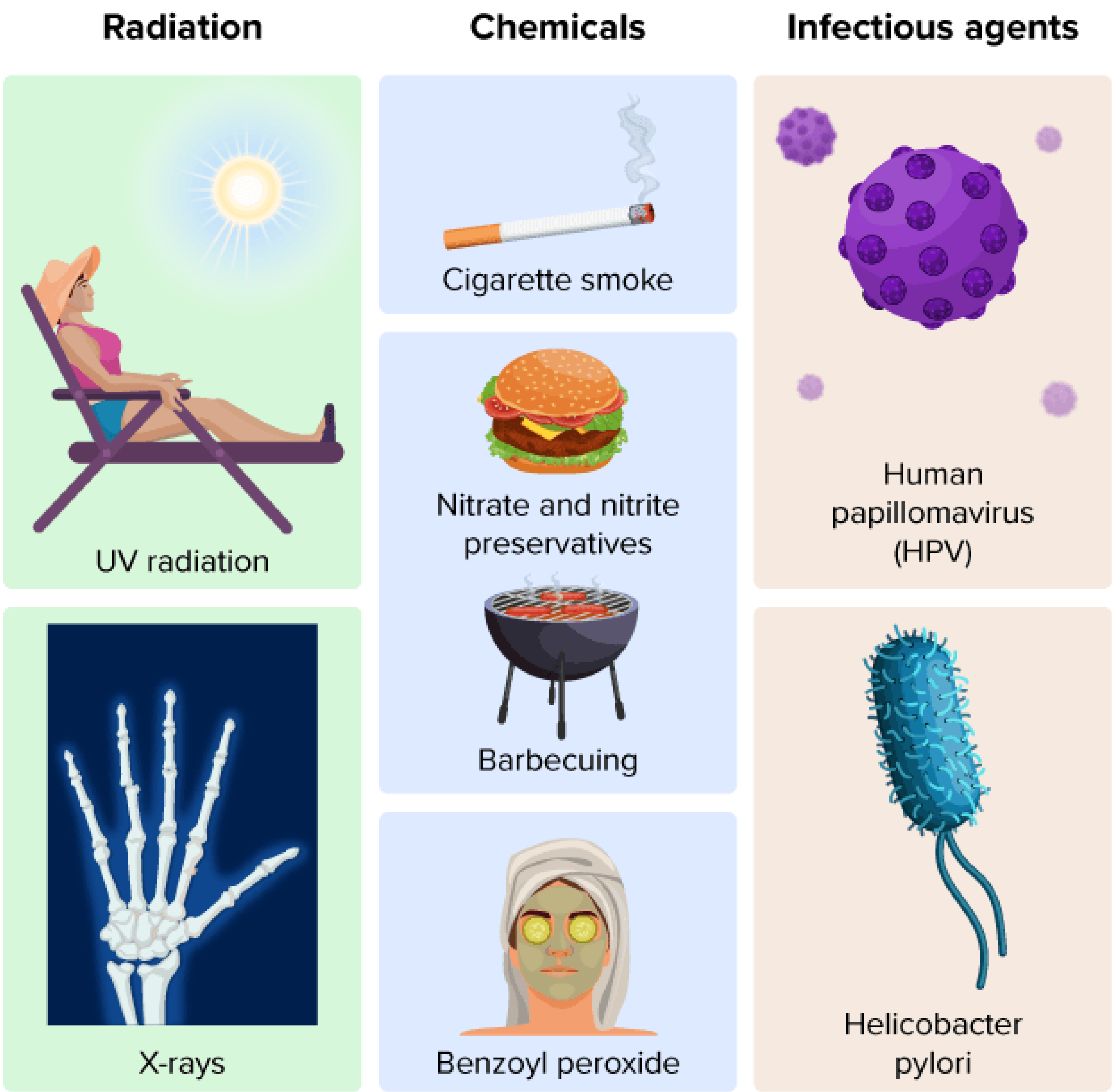
[Figure 1]

What does radiation contamination do?

It mutates DNA. The Chernobyl disaster was a nuclear accident that occurred on April 26, 1986. It is considered the worst nuclear power plant accident in history. A Russian publication concludes that 985,000 excess cancers occurred between 1986 and 2004 as a result of radioactive contamination. The 2011 report of the European Committee on Radiation Risk calculates a total of 1.4 million excess cancers occurred as a result of this contamination.

Causes of Mutation

Mutations have many possible causes. Some mutations seem to happen spontaneously without any outside influence. They can occur when mistakes are made during DNA replication or transcription. Other mutations are caused by environmental factors. Anything in the environment that can cause a mutation is known as a **mutagen**. Examples of mutagens are pictured in the **Figure** below.



[Figure 2]

Examples of Mutagens. Types of mutagens include radiation, chemicals, and infectious agents. Do you know of other examples of each type of mutagen shown here?

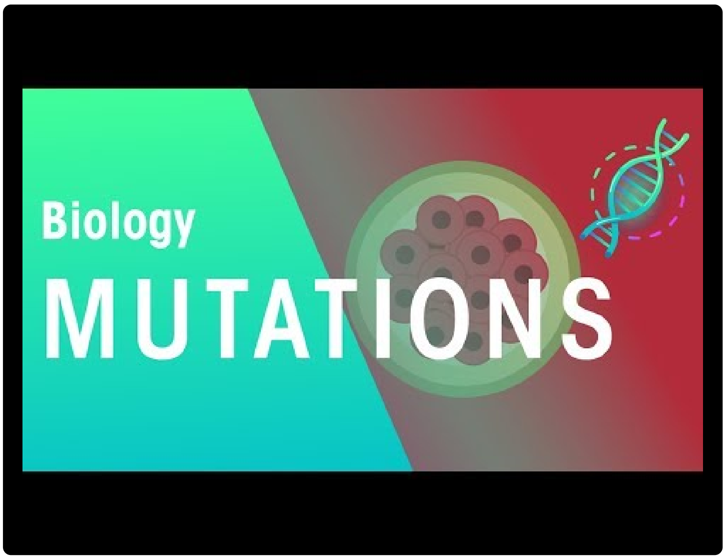
Spontaneous Mutations

There are five common types of spontaneous mutations. These are described in the **Table** below.

Mutation	Description
Tautomerism	a base is changed by the repositioning of a hydrogen atom
Depurination	loss of a purine base (A or G)
Deamination	spontaneous deamination of 5-methycytosine
Transition	a purine to purine (A to G, G to A), or a pyrimidine to pyrimidine (C to T, T to C) change
Transversion	a purine becomes a pyrimidine, or vice versa

The Chernobyl Disaster: Follow-up

Though the area immediately around the Chernobyl disaster may not be safe for human life for thousands of years, the "Exclusion Zone" around the Chernobyl nuclear power station has become a haven for wildlife. As humans were evacuated from the area after the disaster, existing animal population multiplied and rare species not seen for centuries have returned or have been reintroduced, including the lynx, wild boar, wolf, Eurasian brown bear, European bison, Przewalski's horse, and eagle owl. The Exclusion Zone is so lush with wildlife and greenery that in 2007 the Ukrainian government designated it a wildlife sanctuary. It is now one of the largest wildlife sanctuaries in Europe.



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Summary

- Mutations are caused by environmental factors known as mutagens.
- Types of mutagens include radiation, chemicals, and infectious agents.
- Mutations may be spontaneous in nature.

Review

1. Define mutation and mutagen.
2. List three examples of mutagens.
3. Distinguish between a transition and a transversion.

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4.10 Mutation Effects

FlexBooks 2.0 > Biology For High School Diploma > Mutation Effects

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What you will learn

- How do mutation affect an organism
- Beneficial and harmful mutations

[Figure 1]

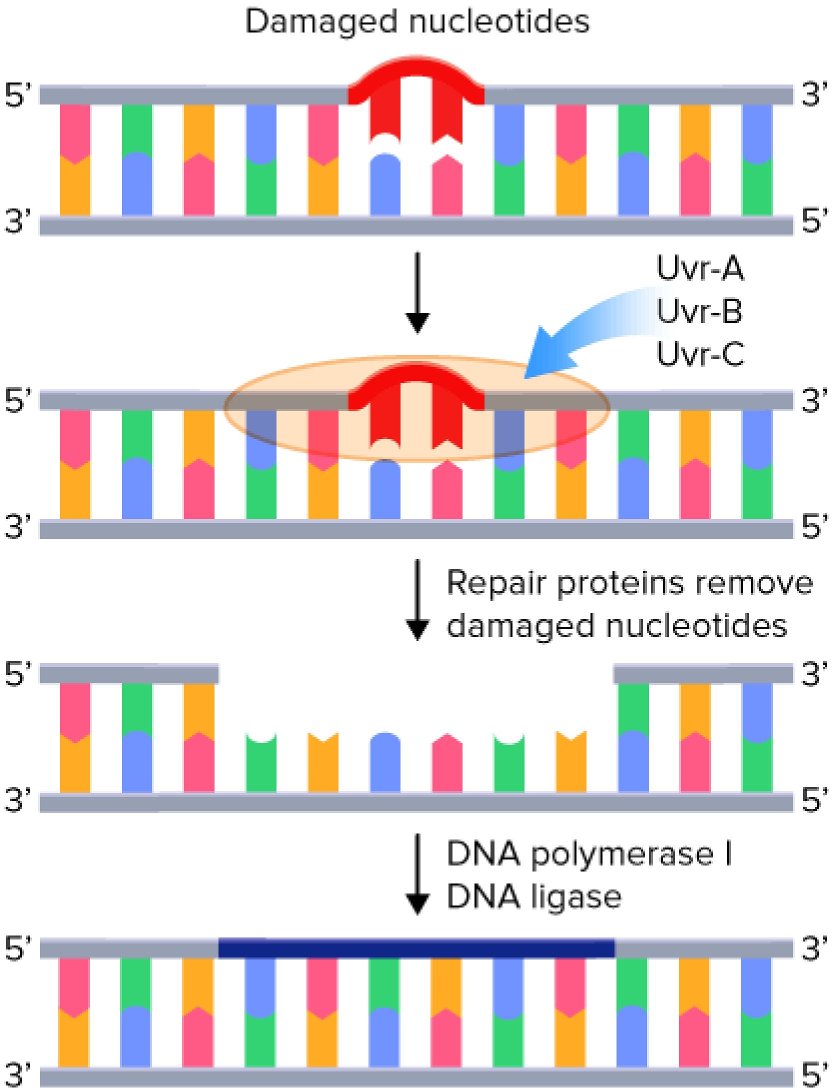
Is this mouse hairless?

Yes. Why? The result of a mutation, a change in the DNA sequence. The effects of mutations can vary widely, from being beneficial, to having no effect, to having lethal consequences, and every possibility in between.

Effects of Mutations

The majority of mutations have neither negative nor positive effects on the organism in which they occur. These mutations are called **neutral mutation**. Examples include silent point mutation. They are neutral because they do not change the amino acid in the protein they encode.

Many other mutations have no effect on the organism because they are repaired before protein synthesis occurs. cell have multiple repair mechanisms to fix mutations in DNA. One way DNA can be repaired is illustrated in the **Figure** below. If a cell's DNA is permanently damaged and cannot be repaired, the cell is likely to be prevented from dividing.



[Figure 2]

DNA Repair Pathway. This flow chart shows one way that damaged DNA is repaired in E. coli bacteria. The repair proteins (Uvr-A, Uvr-B and Uvr-C) cut out the damaged nucleotides. The enzyme DNA polymerase adds correct nucleotides in their place and DNA ligase seals the gap after the repair.

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Beneficial Mutations

Some mutations have a positive effect on the organism in which they occur. They are called **beneficial mutation**. They lead to new versions of proteins that help organisms adapt to changes in their environment. Beneficial mutations are essential for evolution to occur. They increase an organism's chances of surviving or reproducing, so they are likely to become more common over time. There are several well-known examples of beneficial mutations. Here are just two:

1. Mutations in many bacterium that allow them to survive in the presence of antibiotic drug. The mutations lead to **antibiotic-resistant** strains of bacteria.
2. A unique mutation is found in people in a small town in Italy. The mutation protects them from developing atherosclerosis, which is the dangerous buildup of fatty materials in blood vessel. The individual in which the mutation first appeared has even been identified.

Harmful Mutations

Imagine making a random change in a complicated machine such as a car engine. The chance that the random change would improve the functioning of the car is very small. The change is far more likely to result in a car that does not run well or perhaps does not run at all. By the same token, any random change in a gene's DNA is likely to result in a protein that does not function normally or may not function at all. Such mutations are likely to be harmful. Harmful mutations may cause **genetic disorder** or **cancer**.

- A **genetic disorder** is a disease caused by a mutation in one or a few gene. A human example is **cystic fibrosis**. A mutation in a single gene causes the body to produce thick, sticky mucus that clogs the lung and blocks ducts in digestive organ.

- **Cancer** is a disease in which cells grow out of control and form abnormal masses of cells. It is generally caused by mutations in genes that regulate the cell cycle. Because of the mutations, cells with damaged DNA are allowed to divide without limits. Cancer genes can be inherited.

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Summary

- Mutations are essential for evolution to occur because they increase genetic variation and the potential for individuals to differ.
- The majority of mutations are neutral in their effects on the organisms in which they occur.
- Beneficial mutations may become more common through natural selection.
- Harmful mutations may cause genetic disorders or cancer.

Review

1. Why are mutations essential for evolution to occur?

2. What is a genetic disorder?
3. What is cancer? What usually causes cancer?

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4.11 Gene Expression

FlexBooks 2.0 > Biology For High School Diploma > Gene Expression

Last Modified: Mar 04, 2022

What you will learn

- Gene expression and how it is regulated
- **regulatory protein** and their role in gene expression

[Figure 1]

Can your expression change at any moment?

As you know, a person's expression can change moment by moment. The expression that is demonstrated is usually appropriate for that moment's feelings. Gene expression is the use of a gene whose product is necessary for that moment. It may be a moment during development, it may be a moment of increased anxiety, or it may be in response to an environmental change. Whenever a particular protein is needed, gene expression provides it.

Gene Expression

Each of your cell has at least 20,000 genes. In fact, all of your cells have the same genes. Do all of your cells make the same proteins? Obviously not. If they did, then all your cells would be alike. Instead, you have cells with different structures and functions. This is because different cells make different proteins. They do this by using or expressing, different genes. Using a gene to make a protein is called **gene expression**.

How Gene Expression is Regulated

Gene expression is regulated to ensure that the correct proteins are made when and where they are needed. Regulation may occur at any point in the expression of a gene, from the start of transcription to the processing of a protein after translation. Following is a list of stages where gene expression is regulated:

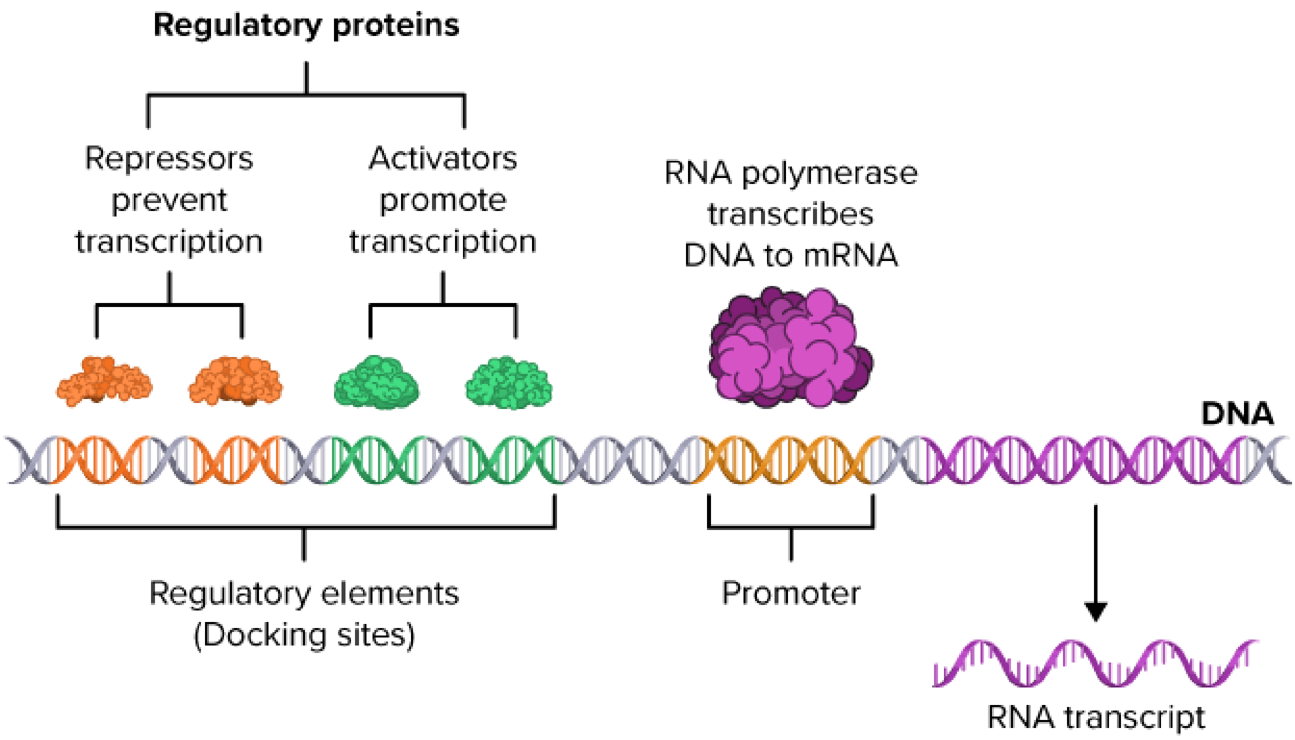
- Chemical and structural modification of DNA or chromatin
- Transcription
- Translation
- Post-transcriptional modification
- RNA transport
- mRNA degradation
- Post-translational modifications

As shown in the **Figure** below, transcription is controlled by **regulatory proteins** binding to the DNA. Specifically, gene regulation at the level of transcription controls when transcription occurs as well as how much RNA is created. A regulatory protein, or a **transcription factor**, is a protein involved in regulating gene expression. It is usually bound to a **cis-regulatory element**, which is part of the DNA. Regulatory proteins often must be bound to a cis-regulatory element to switch a gene on (**activator**), or to turn a gene off (**repressor**).

Transcription of a gene by RNA polymerase can be regulated by at least five mechanisms:

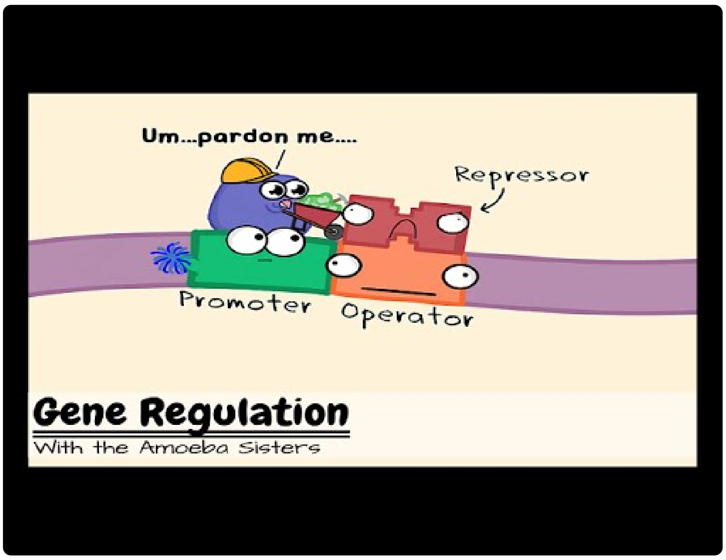
- Transcription factors (proteins) alter the specificity of RNA polymerase for a promoter or set of promoters, making it more or less likely to bind to the promoter and begin transcription.
- Activator proteins enhance the interaction between RNA polymerase and a particular promoter.
- Repressor proteins bind to non-coding sequences on the DNA that are close to or overlap the promoter region, impeding RNA polymerase's progress along the strand.
- Basal factors are transcription factors that help position RNA polymerase at the start of a gene.
- **enhancer** are sites on the DNA strand that are bound by activators in order to loop the DNA, bringing a specific transcription factor to the initiation complex. An **initiation complex** is composed of RNA polymerase and numerous (usually more than one) transcription factors.

As the organism grows more sophisticated, gene regulation becomes more complex, though prokaryotic organisms possess some highly regulated systems. Some human genes are controlled by many activators and repressors working together. Obviously, a mutation in a cis-regulatory region, such as the promoter, can greatly affect the proper expression of a gene. It may keep the gene permanently off, such that no protein can be made, or it can keep the gene permanently on, such that the corresponding protein is constantly made. Both of these can have detrimental effects on the cell.



[Figure 2]

Regulation of Transcription. Regulatory proteins bind to regulatory elements to control transcription. The regulatory elements are embedded within the DNA.



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Summary

- Gene transcription is controlled by regulatory proteins that bind to regulatory elements on DNA.
- The proteins usually either activate or repress transcription.

Review

1. What is gene expression?
2. Why is gene expression regulated?
3. List three stages where gene expression is regulated.
4. Describe how regulatory proteins regulate gene expression.
5. Compare activators to repressors.

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4.12 Prokaryotic Gene Regulation

FlexBooks 2.0 > Biology For High School Diploma > Prokaryotic Gene Regulation

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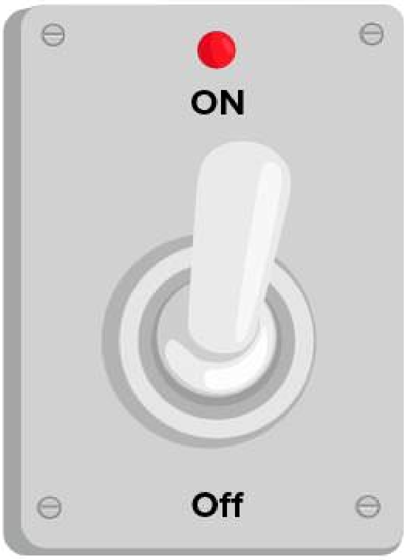
What will you learn

- How transcription is regulated in prokaryote
- The role of **operon** in prokaryotic gene regulation



[Figure 1]

On or off?

When it comes to genes, that is an important question. And if you're a single-celled organism like a bacterium, conserving energy by not producing unnecessary protein is very important.

Prokaryotic Gene Regulation

Transcription is regulated differently in prokaryotes and eukaryote. In general, prokaryotic regulation is simpler than eukaryotic regulation.

The Role of Operons

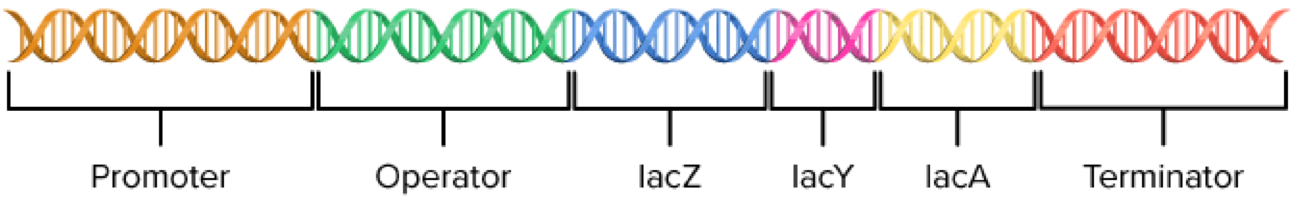
Regulation of transcription in prokaryotes typically involves operons. An **operon** is a region of DNA that consists of one or more genes that encode the proteins needed for a specific function. The operon also includes a **promoter** and an **operator**. The **operator** is a region of the operon where regulatory protein bind. It is located near the **promoter** and helps regulate transcription of the operon genes.

The Lac Operon

A well-known example of operon regulation involves the **lac operon** in *E. coli* bacteria (see the **Figure** below and the video at the link below). The lac operon consists of a promoter, an operator, and three genes that encode the enzyme needed to digest lactose, the sugar found in milk. The lac operon is regulated by lactose in the environment.

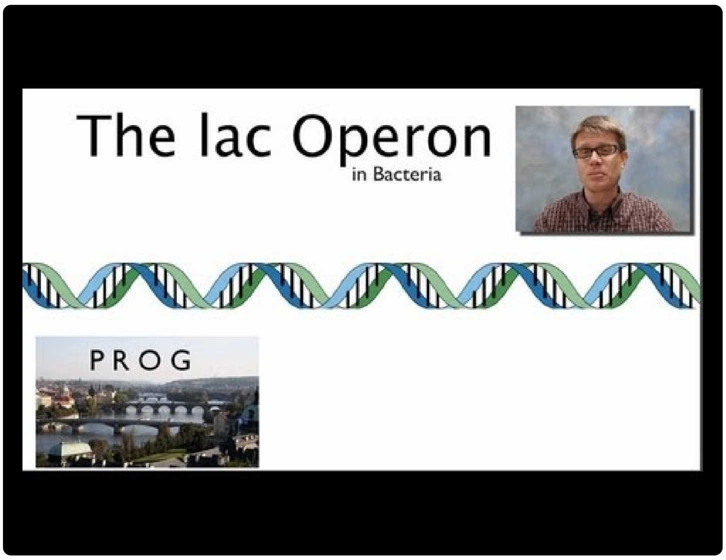
- When lactose is absent, a **repressor** protein binds to the operator. The operator is located between the promoter and the three lac operon genes. The protein blocks the binding of RNA polymerase to the promoter. As a result, the lac genes are not expressed.
- When lactose is present, the repressor protein does not bind to the operator. This allows RNA polymerase to bind to the promoter and begin transcription. As a result, the lac genes are expressed, and lactose is digested.

Why might it be beneficial to express genes only when they are needed? (Hint: synthesizing proteins requires energy and materials.)



[Figure 2]

The three genes of the lac operon are lacZ, lacY, and lacA. They encode proteins needed to digest lactose. The genes are expressed only in the presence of lactose.



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Summary

- Regulation of transcription in prokaryotes typically involves an operon, such as the lac operon in *E. coli*.
- The lac operon is regulated by proteins that behave differently depending on whether lactose is present or absent.

Review

1. What is an operon?
2. Why might it be beneficial to express genes only when they are needed?
3. What is the role of an operon's operator?
4. What happens to the lac operon in the absence of lactose?
5. Draw a diagram to show how the lac operon is regulated.

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4.13 Eukaryotic Gene Regulation

FlexBooks 2.0 > Biology For High School Diploma > Eukaryotic Gene Regulation

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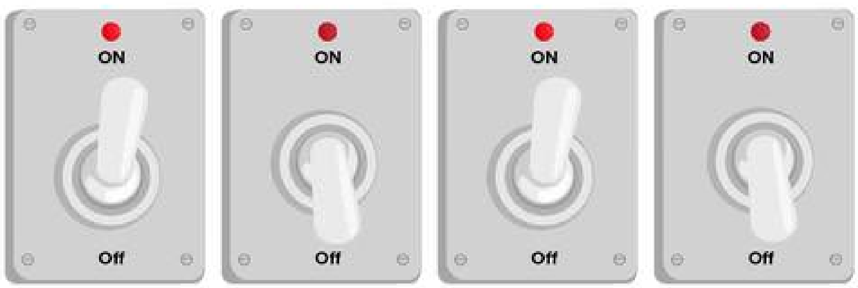
What will you learn

- How transcription is regulated in eukaryote
- The role of regulatory element in eukaryotic gene regulation
- How gene expression regulation is important during the development of an organism
- How cancer develops by altering gene regulation



[Figure 1]

On or Off? On or Off? On or Off?

That is the key question. Gene regulation in eukaryotes is a highly regulated process usually involving many protein, which either bind to each other or bind to the DNA.

Eukaryotic Gene Regulation

In eukaryotic cell, the start of transcription is one of the most complicated parts of gene regulation. There may be many regulatory protein and regulatory elements involved. Regulation may also involve enhancer. **Enhancers** are distant regions of DNA that can loop back to interact with a gene's promoter.

The TATA Box

Different types of cell have unique patterns of regulatory elements that result in only the necessary genes being transcribed. That's why a skin cell and nerve cell, for example, are so different from each other. However, some patterns of regulatory elements are common to all genes, regardless of the cells in which they occur. An example is the **TATA box**, so named because it has a core sequence of *TATAAA*. This is a regulatory element that is part of the promoter of most eukaryotic genes. A number of regulatory proteins bind to the TATA box, forming a multi-protein complex. It is only when all of the appropriate proteins are bound to the TATA box that RNA polymerase recognizes the complex and binds to the promoter. Once RNA polymerase binds, transcription begins.

Regulation During Development

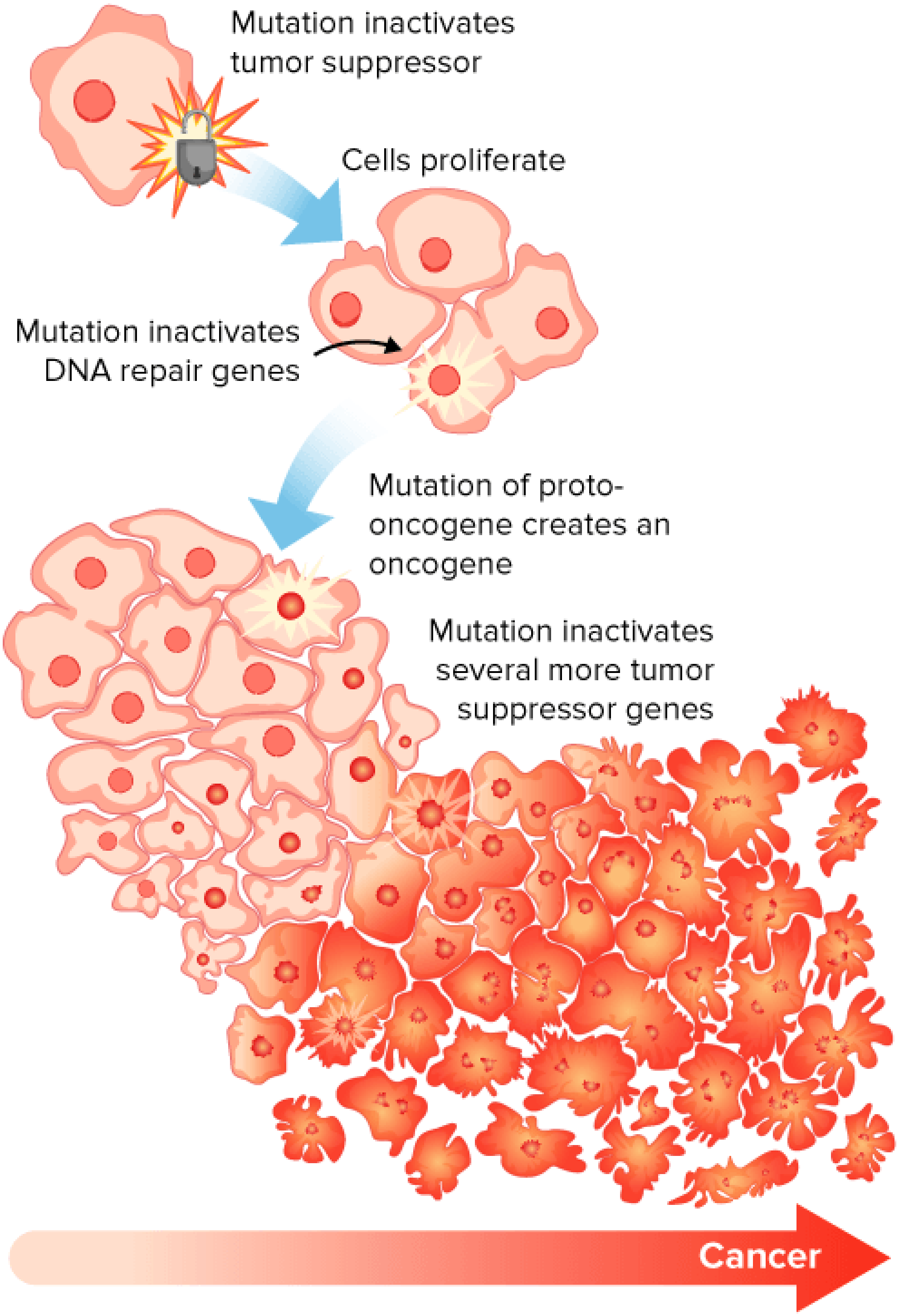
The regulation of gene expression is extremely important during the development of an organism. Regulatory proteins must turn on certain genes in particular cells at just the right time so the organism develops normal organ and organ system. **homeobox gene** are an example of genes that regulate development. They code for regulatory proteins that switch on whole series of major developmental genes. In insects, homeobox genes called **hox gene** ensure that body parts such as limbs develop in the correct place. The **Figure** below shows how a mutation in a hox gene can affect an insect's development. Other organisms, including humans, also have hox genes.

[Figure 2]

Effect of Hox Gene Mutation. Scientists caused a mutation in a hox gene of this fruit fly. As a result of the mutation, a leg grew out of its head where an antenna should have developed.

Gene Expression and Cancer

The mutations that cause cancer generally occur in two types of regulatory genes: **tumor-suppressor gene** and **proto-oncogene** (see the **Figure** below). These genes produce regulatory proteins that control the cell cycle. When the genes mutate, cells with mutations divide rapidly and without limits, potentially resulting in a tumor and cancer.



[Figure 3]

How Cancer Develops. This flow chart shows how a series of mutations in tumor-suppressor genes and proto-oncogenes leads to cancer.

Summary

- Regulation of transcription in eukaryotes is generally more complex than in prokaryotes. It involves unique regulatory elements in different cells as well as common regulatory elements such as the TATA box.
- Regulation is especially important during development. It may involve regulatory genes such as homeobox genes that switch other regulatory genes on or off.
- Mutations in regulatory genes that normally control the cell cycle cause cancer.

Review

1. Identify the TATA box and its function in transcription.
2. What is a homeobox gene?
3. Why is gene regulation especially important during development?
4. What are tumor-suppressor genes and proto-oncogenes?
5. Sketch how an insect with a mutated hox gene might look. Explain your sketch.

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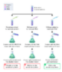
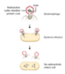
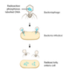
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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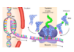	**Credit:** CK-12 Foundation; Illustration of tRNA based on image from David S. Goodsell and the RCSB PDB under a CC-BY-4.0 license. Original image: https://pdb101.rcsb.org/motm/15. **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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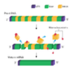	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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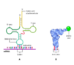	**Credit:** CK-12 Foundation; (A) Based on image from National Human Genome Research Institute (genome.gov). Original image: https://rarediseases.info.nih.gov/GlossaryDescription/474/0. (B) Based on image from David S. Goodsell and the RCSB PDB under a CC BY 4.0 license. Original image: https://pdb101.rcsb.org/motm/15. **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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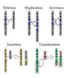	**Credit:** Modified from image courtesy of the National Institutes of Health **Source:** https://commons.wikimedia.org/wiki/File:Types-of-mutation.png **License:** Public Domain
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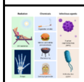	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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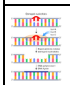
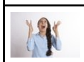
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Robin Higgins **Source:** https://pixabay.com/photos/excited-happy-woman-fun-happiness-2649320/ **License:** Pixabay License

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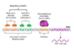	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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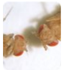
	**Credit:** User:Ktbn/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Antennapedia.jpg **License:** Public Domain

CHAPTER 5

Evolution

Chapter Outline

5.26 References

5.1 History of Life

FlexBooks 2.0 > Biology For High School Diploma > History of Life

Last Modified: Apr 18, 2022

What you will learn

- History of life on Earth
- What are **fossil**

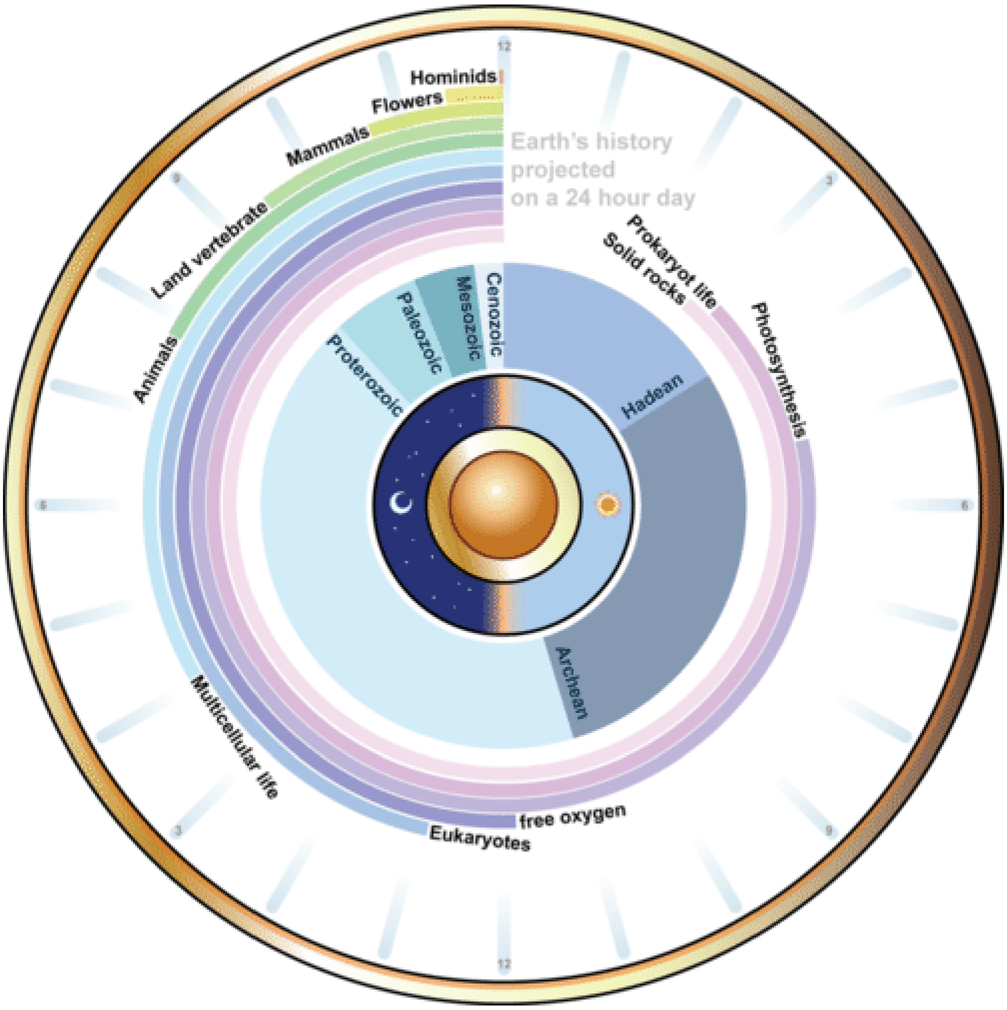
[Figure 1]

How do we learn about the past?

We study the remains of things that existed many years ago. The Ruins of Pompeii have given archeologists, historians, and other scholars a tremendous amount of information about life two thousand years ago. This section discusses studying things that are many thousands of years older than these remains.

Earth in a Day

It's hard to grasp the vast amounts of time since Earth formed and life first appeared on its surface. It may help to think of Earth's history as a 24-hour day, as shown in **Figure** below. Humans would have appeared only during the last minute of that day. If we are such newcomers on planet Earth, how do we know about the vast period of time that went before us? How have we learned about the distant past?



[Figure 2]

History of Earth in a Day. In this model of Earth's history, the planet formed at midnight. What time was it when the first prokaryotes evolved?

Learning About the Past

Much of what we know about the history of life on Earth is based on the **fossil record**. Detailed knowledge of modern organism also helps us understand how life evolved.

The Fossil Record

Fossils are the preserved remains or traces of organisms that lived in the past. The soft parts of organisms almost always decompose quickly after death. On occasion, the hard parts—mainly bone, teeth, or shells—remain long enough to mineralize and form fossils. An example of a complete fossil skeleton is shown in **Figure** below. The **fossil record** is the record of life that unfolded over four billion years and pieced back together through the analysis of fossils.

[Figure 3]

Extinct Lion Fossil. This fossilized skeleton represents an extinct lion species. It is rare for fossils to be so complete and well preserved as this one.

To be preserved as fossils, remains must be covered quickly by sediments or preserved in some other way. For example, they may be frozen in glaciers or trapped in tree resin, like the fly in **Figure** below. Sometimes traces of organisms—such as footprints or burrows—are preserved (see the fossil footprints in **Figure** below). The conditions required for fossils to form rarely occur. Therefore, the chance of an organism being preserved as a fossil is very low.

[Figure 4]

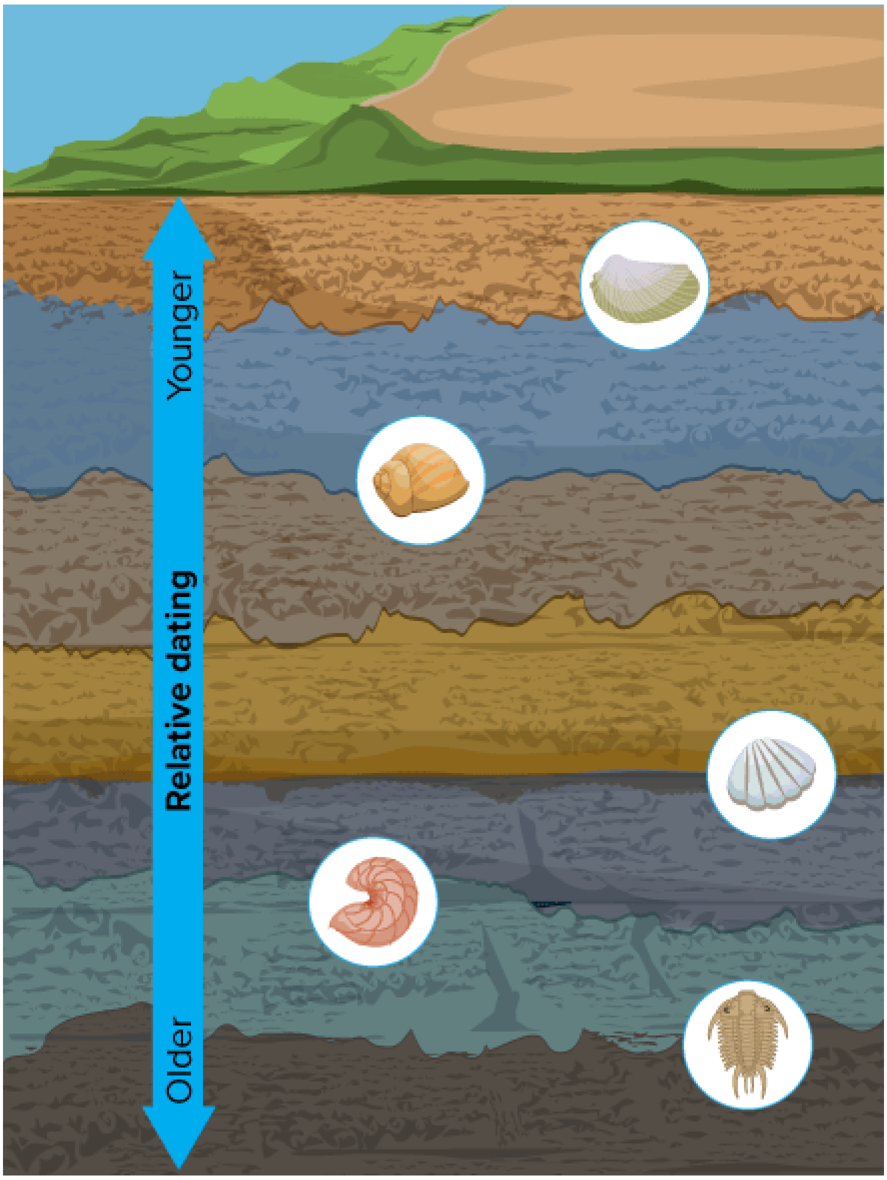
[Figure 5]

The fossil footprints of a dinosaur.

A fly trapped in hardened tree resin, or amber.

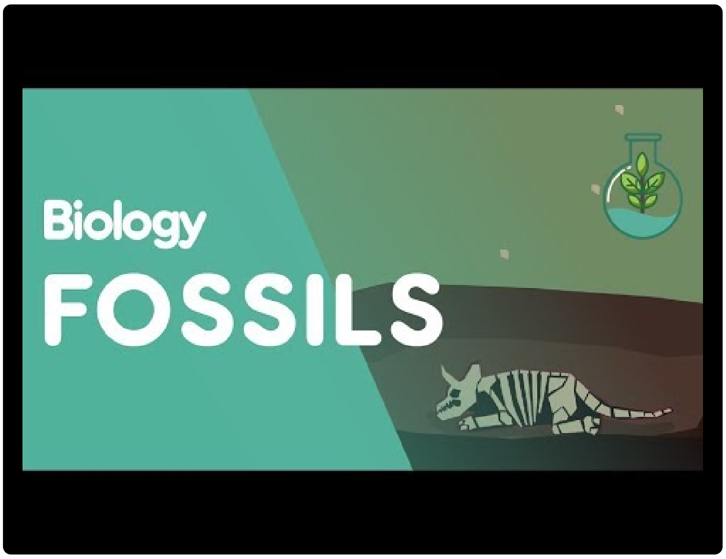
In order for fossils to "tell" us the story of life, they must be dated. Then they can help scientists reconstruct how life changed over time. Fossils can be dated in two different ways: **relative dating** and **absolute dating**. Both are described below.

- **Relative dating** determines which of two fossils is older or younger than the other, but not their age in years. Relative dating is based on the positions of fossils in rock layers. Lower layers were laid down earlier, so they are assumed to contain older fossils. This is illustrated in **Figure** below.
- **Absolute dating** determines about how long ago a fossil organism lived. This gives the fossil an approximate age in years. Absolute dating is often based on the amount of carbon-14 or other radioactive element that remains in a fossil.



[Figure 6]

Relative Dating Using Rock Layers. Relative dating establishes which of two fossils is older than the other. It is based on the rock layers in which the fossils formed.



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Molecular Clocks

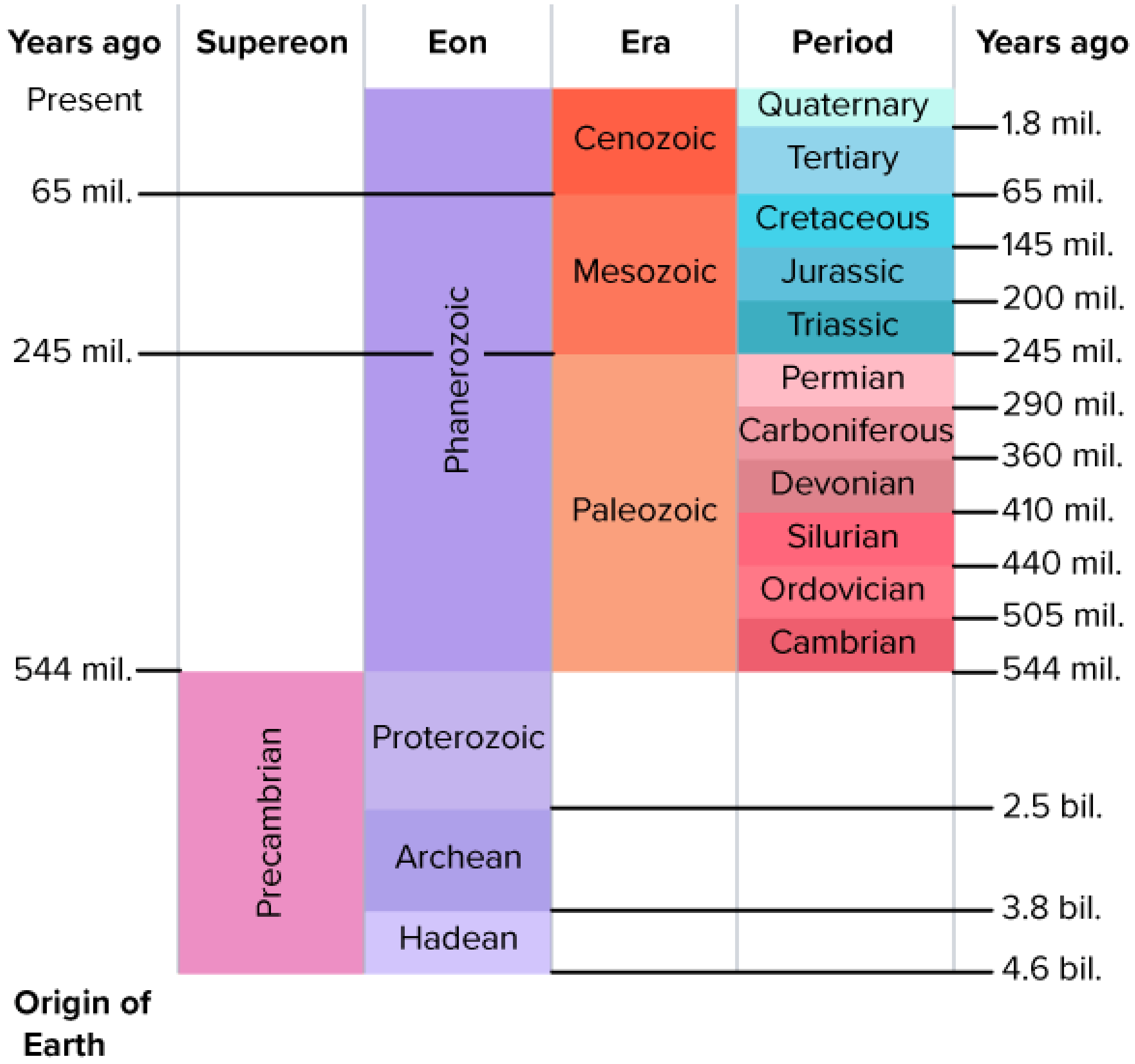
evidence from the fossil record can be combined with data from molecular clocks. A **molecular clock** uses DNA sequences (or the protein they encode) to estimate relatedness among species. Molecular clocks estimate the time in geologic history when related species diverged from a common ancestor. Molecular clocks are based on the assumption that mutation accumulate through time at a steady average rate for a given region of DNA. Species that have accumulated greater differences in their DNA sequences are assumed to have diverged from their common ancestor in the more distant past. Molecular clocks based on different regions of DNA may be used together for more accuracy.

Consider the example in **Table** below. The table shows how similar the DNA of several animal species is to human DNA. Based on these data, which organism do you think shared the most recent common ancestor with humans?

Organism	Similarity with Human DNA (percent)
Chimpanzee	98
Mouse	85
Chicken	60
fruit Fly	44

Geologic Time Scale

Another tool for understanding the history of Earth and its life is the **geologic time scale**, shown in **Figure** below. The geologic time scale divides Earth's history into divisions (such as eons, eras, and periods) that are based on major changes in geology, climate, and the evolution of life. It organizes Earth's history and the evolution of life on the basis of important events instead of time alone. It also allows more focus to be placed on recent events, about which we know the most.



[Figure 7]

Geologic Time Scale. The geologic time scale divides Earth's history into units that reflect major changes in Earth and its life forms. During which eon did Earth form? What is the present era?

Summary

- Much of what we know about the history of life on Earth is based on the fossil record.

- Molecular clocks are used to estimate how long it has been since two species diverged from a common ancestor.
- The geologic time scale is another important tool for understanding the history of life on Earth.

Review

1. What are fossils?

2. Describe how fossils form.

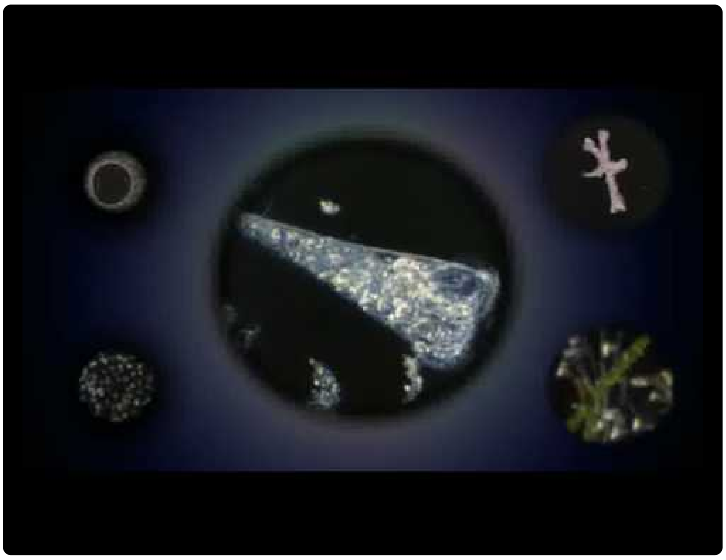
3. Distinguish relative dating from absolute dating.

4. This table shows DNA sequence comparisons for some hypothetical species. Based on the data, describe evolutionary relationships between Species A and the other four species. Explain your answer.

Species	DNA Similarity with Species A
Species B	42%
Species C	85%
Species D	67%
Species E	91%

5. Describe the geologic time scale.

Resources



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5.2 Formation of Earth

FlexBooks 2.0 > Biology For High School Diploma > Formation of Earth

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What you will learn

- How Earth formed
- Features of ancient Earth

[Figure 1]

What alien planet is represented by this picture?

Would it surprise you to learn that the picture represents Earth? After Earth first formed about 4.6 billion years ago, it may well have looked like this. Instead of rivers of water, rivers of molten rock flowed over its surface. Life as we know it could not have survived in such a place. How did this fiery hot planet become today's Earth, covered with water and teeming with life? The long and incredible story of Earth's history starts with this section.

How Earth Formed: We Are Made of Stardust!

We'll start the story of life at the very beginning when Earth and the rest of the solar system first formed. The solar system began as a rotating cloud of stardust. "Dust, rocks, and gas" may not sound inspiring, but this cloud contained the **element** which somehow combine to form every corner – living and nonliving – of Earth. Initially, the **Big Bang** (14 billion years ago) gave rise to the building blocks of matter – the quarks and electrons of which we are all made. Quarks aggregated producing protons and neutrons which combined into nucleus, ultimately forming the first atoms which were mainly hydrogen and helium. Stars such as red giants fused hydrogen and helium nuclei to form elements from carbon (the foundation of life) to calcium (now our bones and teeth). Supernova explosions formed and ejected heavier elements such as iron (for red blood cells). We are not just "dust." We - and our world - are stardust!

How did this rotating cloud of stardust become our solar system? About 4.5 billion years ago, a nearby star exploded and sent a shock wave through the dust cloud, increasing its rate of spin. As a result, most of the mass became concentrated in the middle, forming the sun. Smaller concentrations of mass rotating around the center formed the planets, including Earth.

At first, Earth was molten and lacked an atmosphere and oceans. Gradually, the planet cooled and formed a solid crust. As the planet continued to cool, volcanoes released gases, which eventually formed an **atmosphere**. The early atmosphere contained ammonia, methane, water vapor, and carbon dioxide but only a trace of oxygen. As the atmosphere became denser, clouds formed and rain fell. Water from rain, and perhaps from comets and asteroids that struck Earth as well, eventually formed the oceans. The ancient atmosphere and oceans represented by the picture in **Figure** below would be toxic to today's life, but they set the stage for life to begin.

[Figure 2]

Ancient Earth. This is how ancient Earth may have looked after its atmosphere and oceans formed.

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Summary

- Earth formed about 4.5 to 4.6 billion years ago.
- At first, Earth was molten and lacked an atmosphere and oceans.
- Gradually, the atmosphere formed, followed by the oceans.

Review

1. Give an overview of how Earth formed.
2. How did Earth's atmosphere form?
3. How did Earth's oceans form?
4. Describe Earth's early atmosphere.

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5.3 First Organic Molecules

FlexBooks 2.0 > Biology For High School Diploma > First Organic Molecules

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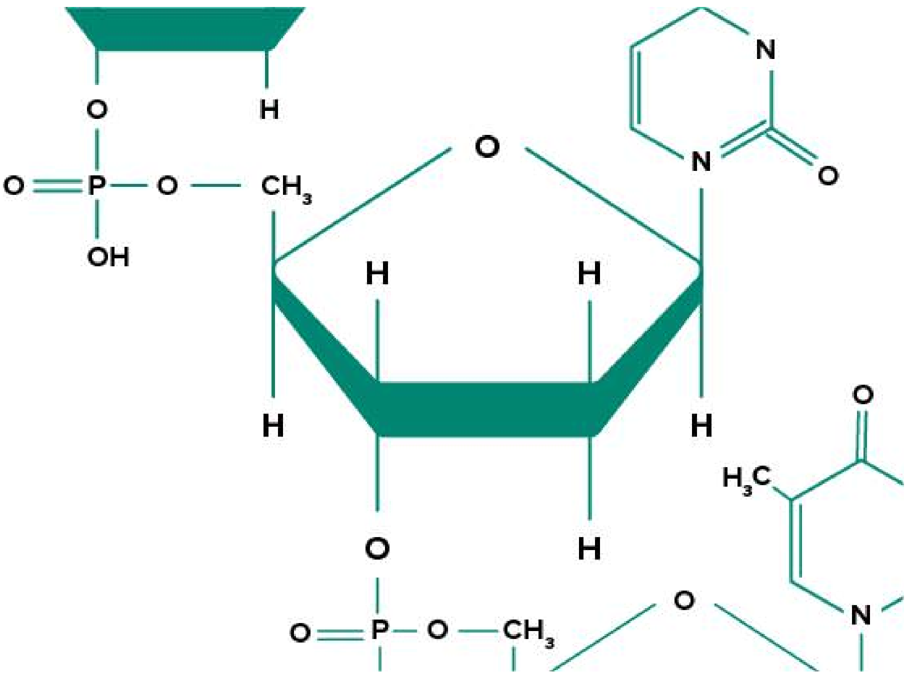
What you will learn

- What were the first **organic molecule** and how were they created
- Miller and Urey's experiment
- What is **RNA world hypothesis**



[Figure 1]

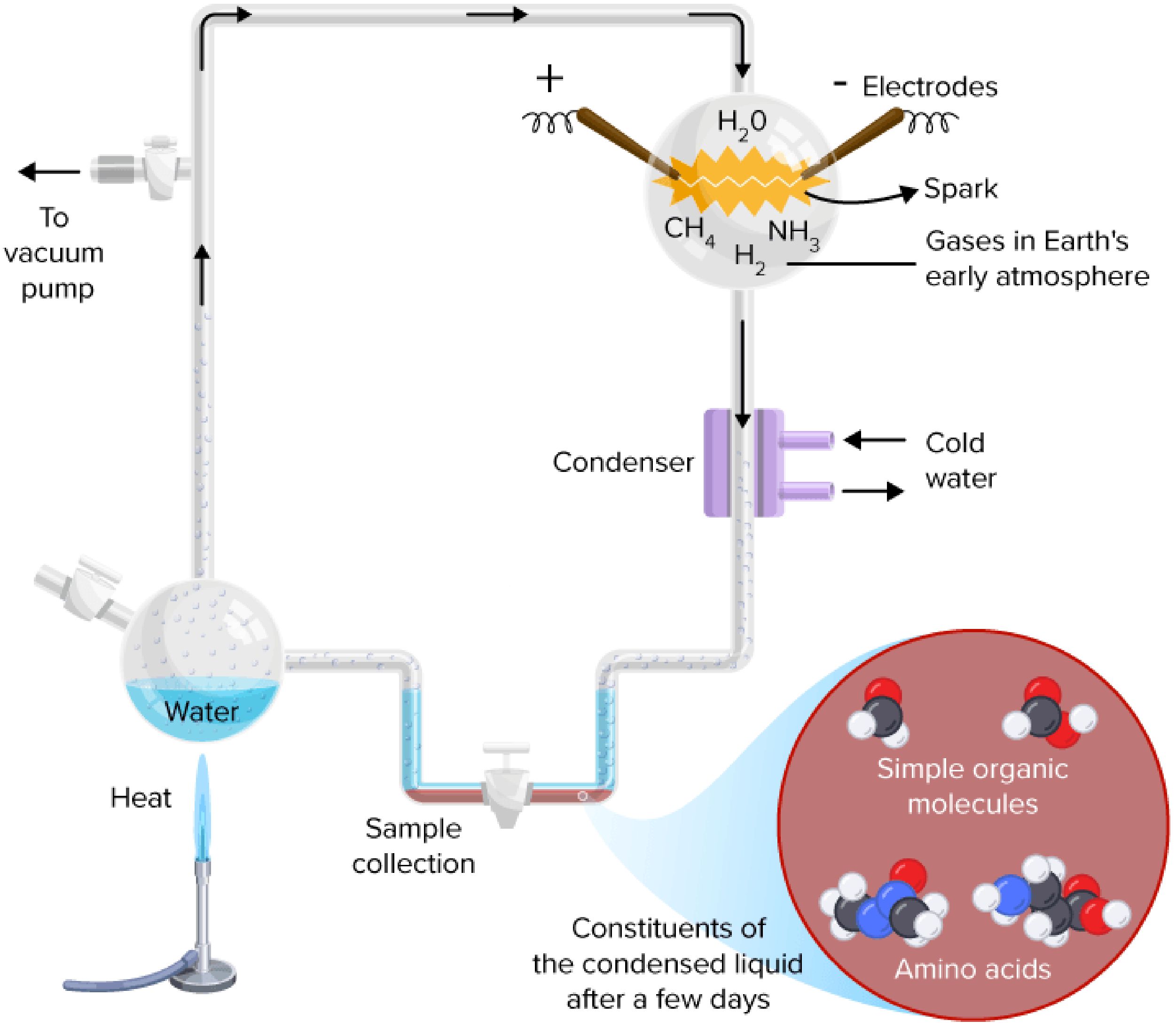
How do you make large molecules?

From smaller ones. The first organic molecules were probably very simple carbon-based molecules made of few atoms. These molecules then combined with other simple molecules to form more complex molecules. Over many years and probably trillions and trillions of chemical reaction, more complex molecules, and more stable molecules, formed.

The First Organic Molecules

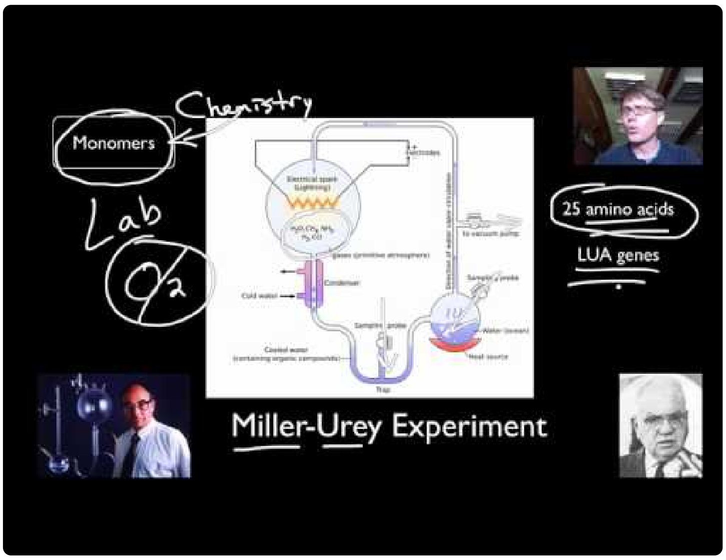
All living things consist of **organic molecules**, centered around the element carbon. Therefore, it is likely that organic molecules evolved before cell, perhaps as long as 4 billion years ago. How did these building blocks of life first form?

Scientists think that lightning sparked chemical reactions in Earth's early atmosphere. The early atmosphere contained gases such as ammonia, methane, water vapor, and carbon dioxide. Scientists hypothesize that this created a "soup" of organic molecules from inorganic chemicals. In 1953, scientists Stanley Miller and Harold Urey used their imaginations to test this hypothesis. They created a simulation experiment to see if organic molecules could arise in this way (see **Figure** below). They used a mixture of gases to represent Earth's early atmosphere. Then, they passed sparks through the gases to represent lightning. Within a week, several simple organic molecules had formed.



[Figure 2]

Miller and Urey experiment. Miller and Urey demonstrated that organic molecules could form under simulated conditions of early Earth. What assumptions were their simulation based upon?



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Which Organic Molecule Came First?

Living things need organic molecules to store genetic information and to carry out the chemical work of cells. Modern organism use DNA to store genetic information and protein to catalyze chemical reactions. So, did DNA or proteins evolve first? This is like asking whether the chicken or the egg came first. DNA encodes proteins and proteins are needed to make DNA, so each type of organic molecule needs the other for its own existence. How could either of these two molecules have evolved before the other? Did some other organic molecule evolve first, instead of DNA or proteins?

RNA World Hypothesis

Some scientists speculate that RNA may have been the first organic molecule to evolve. In fact, they think that early life was based solely on RNA and that DNA and proteins evolved later. This is called the **RNA world hypothesis.** Why RNA? It can encode genetic instructions (like DNA), and some RNAs can carry out chemical reactions (like proteins). Therefore, it solves the chicken-and-egg problem of which of these two molecules came first. Other evidence also suggests that RNA may be the most ancient of the organic molecules.

Summary

- The first organic molecules formed about 4 billion years ago.
- This may have happened when lightning sparked chemical reactions in Earth's early atmosphere.
- RNA may have been the first organic molecule to form as well as the basis of early life.

Review

1. Describe Miller and Urey's experiment. What did it demonstrate?
2. State the RNA world hypothesis.

Resources

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5.4 First Cell

FlexBooks 2.0 > Biology For High School Diploma > First Cell

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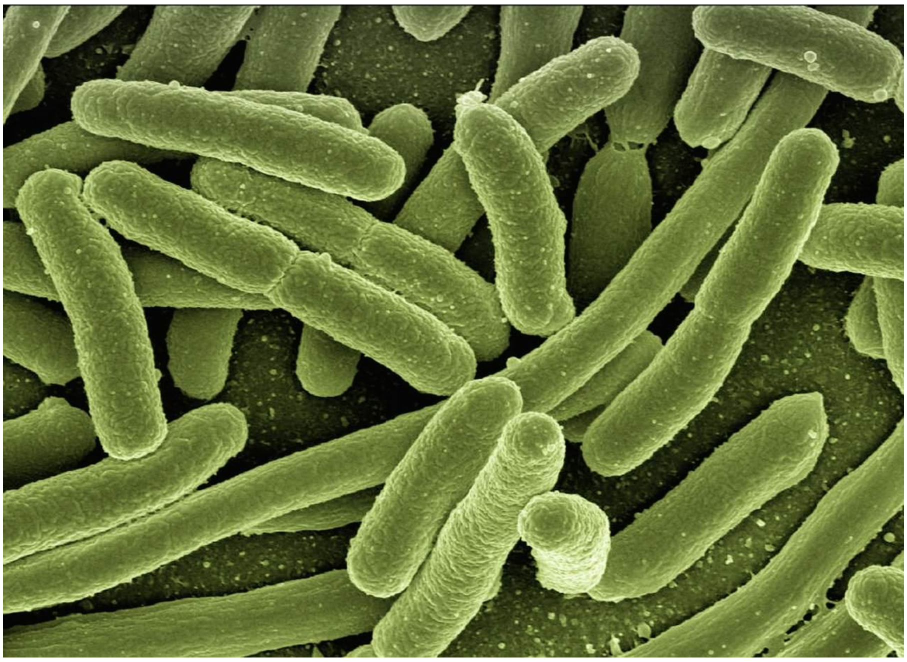
What you will learn

- How organic molecule could have formed the first cell
- LUCA the **Last Universal Common Ancestor**
- How photosynthesis evolved and then led to the evolution of cellular respiration



[Figure 1]

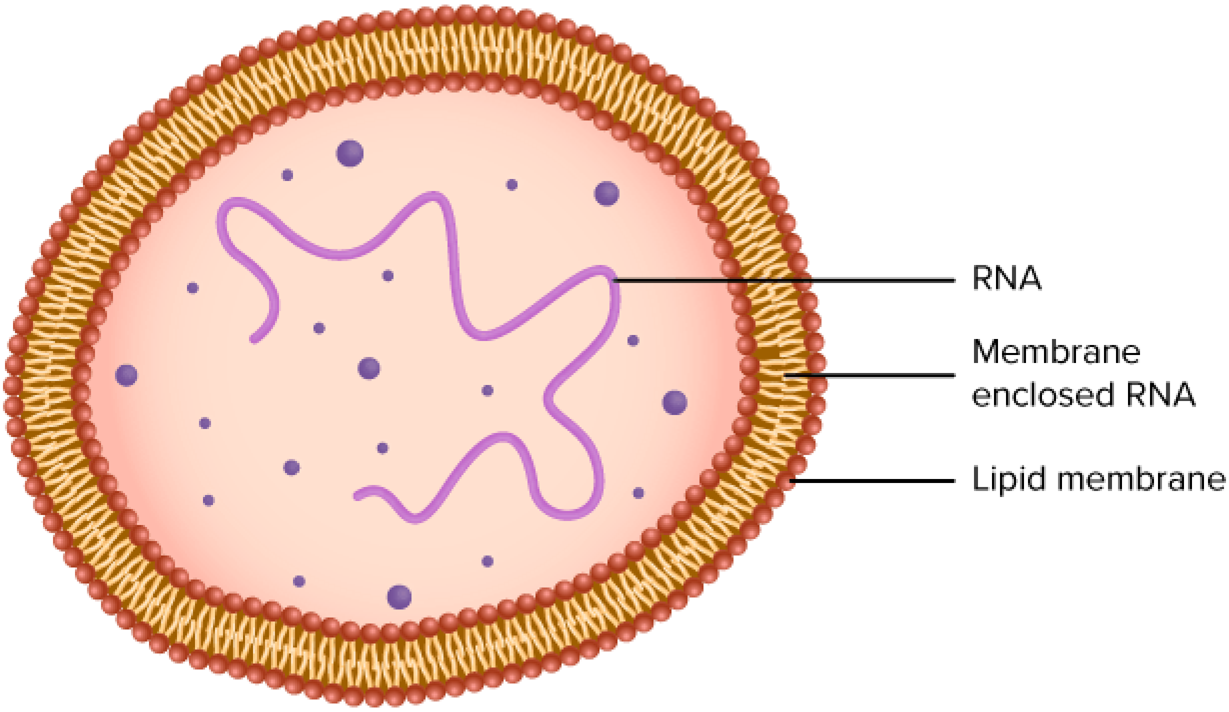
How do you make complex cells?

You start with simple ones. The first cells were most likely primitive prokaryotic-like cells, even more simplistic than these *E. coli* bacterium. The first cells were probably no more than organic compound, such as a simplistic RNA, surrounded by a membrane. Was it a phospholipid bilayer membrane? Probably not — it was likely a simplistic membrane able to separate the inside from the outside. Over time, as other organic compounds such as DNA and protein developed, cells also evolved into more complex structures. Once a cell was able to be stable, reproduce itself, and pass its genetic information to the next generation, then there was life.

The First Cells

What was needed for the first cell? Some sort of membrane surrounding organic molecules? Probably.

How organic molecules such as RNA developed into cells is not known for certain. Scientists speculate that lipid membranes grew around the organic molecules. The membranes prevented the molecules from reacting with other molecules, so they did not form new compounds. In this way, the organic molecules persisted, and the first cells may have formed. The **Figure** below shows a model of the hypothetical first cell. Were these first cells the first living organism? Were they able to live and reproduce while passing their genetic information to the next generation? If so, then yes, these first cells could be considered the first living organisms.



[Figure 2]

Hypothetical First Cell. The earliest cells may have consisted of little more than RNA inside a lipid membrane.

LUCA

No doubt there were many early cells of this type. However, scientists think that only one early cell (or group of cells) eventually gave rise to all subsequent life on Earth. That one cell is called the **Last Universal Common Ancestor,** or **LUCA.** It probably existed around 3.5 billion years ago. LUCA was one of the earliest **prokaryotic cell**. It would have lacked a nucleus and other membrane-bound organelle.

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Photosynthesis and Cellular Respiration

The earliest cells were probably **heterotroph**. Most likely they got their energy from other molecules in the organic "soup." However, by about 3 billion years ago, a new way of obtaining energy evolved. This new way was **photosynthesis**. Through photosynthesis, organisms could use sunlight to make food from carbon dioxide and water. These organisms were the first **autotroph**. They provided food for themselves and for other organisms that began to consume them.

After photosynthesis evolved, oxygen started to accumulate in the atmosphere. This has been dubbed the "oxygen catastrophe." Why? Oxygen was toxic to most early cells because they had evolved in its absence. As a result, many of them died out. The few that survived evolved a new way to take advantage of the oxygen. This second major innovation was **cellular respiration**. It allowed cells to use oxygen to obtain more energy from organic molecules.

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Summary

- The first cells consisted of little more than an organic molecule such as RNA inside a lipid membrane.
- One cell (or group of cells), called the last universal common ancestor (LUCA), gave rise to all subsequent life on Earth.
- Photosynthesis evolved about 3 billion years ago and released oxygen into the atmosphere.
- Cellular respiration evolved after that to make use of the oxygen.

Review

1. What was LUCA? What were its characteristics?
2. Which evolved first, autotrophs or heterotrophs? Why?
3. Why could cellular respiration evolve only after photosynthesis had evolved?

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5.5 Eukaryote Evolution

FlexBooks 2.0 > Biology For High School Diploma > Eukaryote Evolution

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What you will learn

- How did eukaryote evolve
- What is **endosymbiotic theory**

[Figure 1]

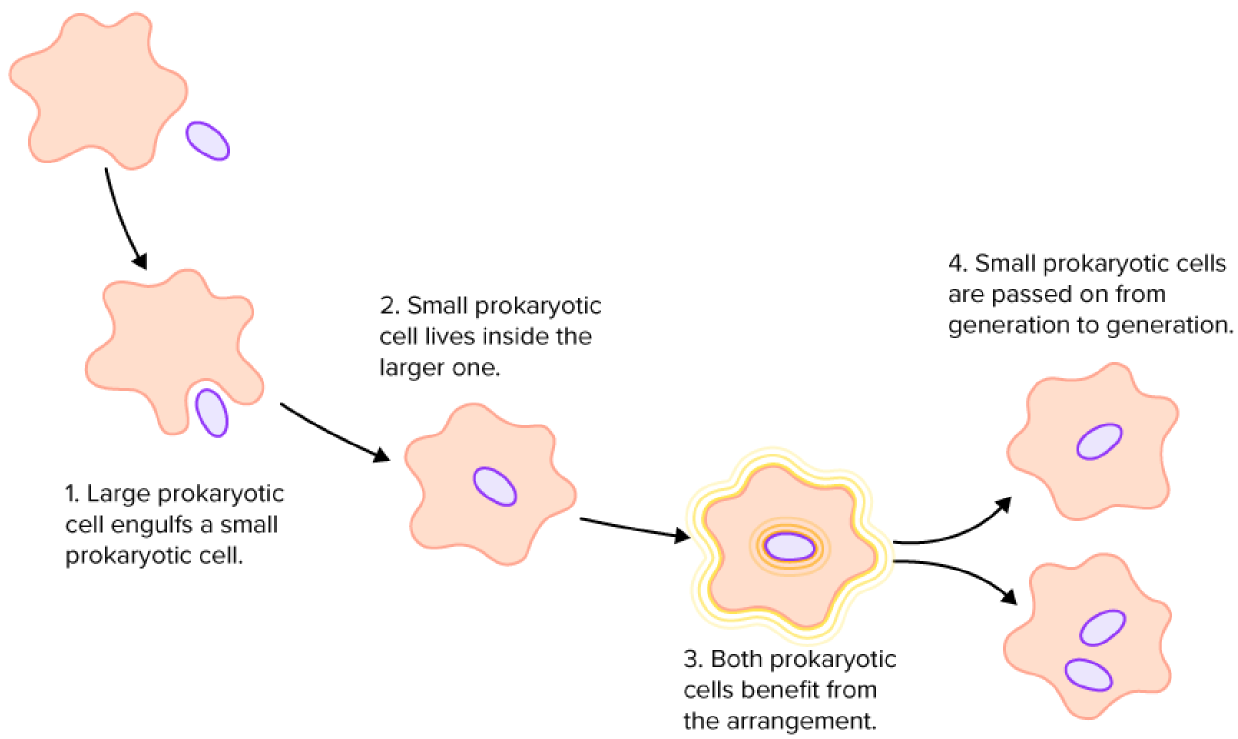
Why can this fish live in these tentacles, but other fish cannot?

Anemones and Clown fish have a well-known symbiotic relationship. In the ocean, the Clown Fish are protected from predator fish by the stinging tentacles of the anemone, and the anemone receives protection from polyp-eating fish, which the Clown Fish chases away. But what about symbiotic relationships at a much smaller scale? Is it possible for two single-celled organism to have a symbiotic relationship? As you will find out, yes it is!

Evolution of Eukaryotes

Our own **eukaryotic cell** protect DNA in chromosome with a nuclear membrane, make ATP with mitochondrion, move with flagellum (in the case of sperm cells), and feed on cell which make our food with chloroplast. All multicellular organism and the unicellular protist share this cellular intricacy. Bacterial (prokaryotic) cells are orders of magnitude smaller and have none of this complexity. What quantum leap in evolution created this vast chasm of difference?

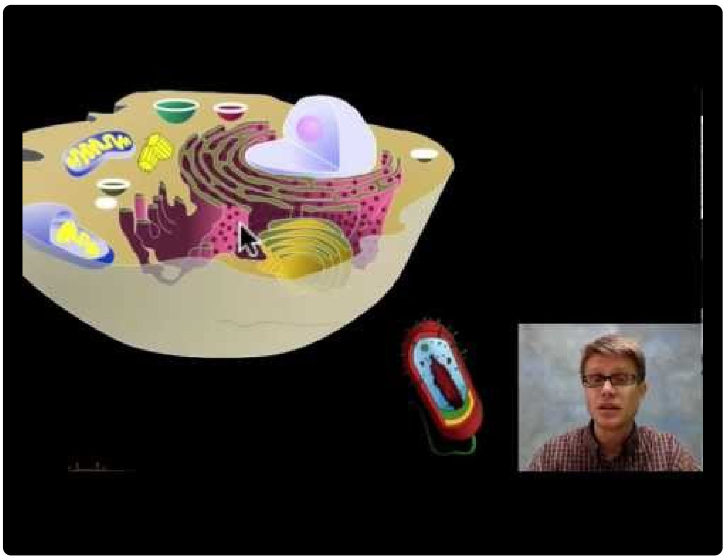
The first **eukaryotic cells** - cells with a **nucleus** and internal membrane-bound **organelle** - probably evolved about 2 billion years ago. This is explained by the **endosymbiotic theory**. As shown in the **Figure** below, **endosymbiosis** came about when large cells engulfed small cells. The small cells were not digested by the large cells. Instead, they lived within the large cells and evolved into organelles.



[Figure 2]

From Independent Cell to Organelle. The endosymbiotic theory explains how eukaryotic cells evolved.

The large and small cells formed a **symbiotic relationship** in which both cells benefited. Some of the small cells were able to break down the large cell's wastes for energy. They supplied energy not only to themselves but also to the large cell. They became the mitochondria of eukaryotic cells. Other small cells were able to use sunlight to make food. They shared the food with the large cell. They became the chloroplasts of eukaryotic cells.



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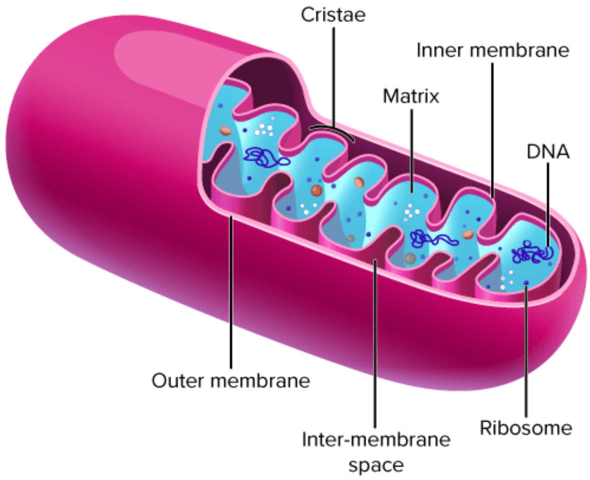
Mitochondria and Chloroplasts

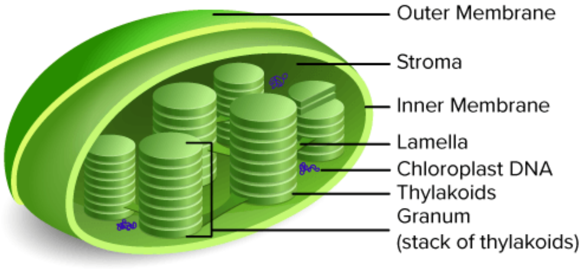
What is the evidence for this evolutionary pathway? biochemistry and electron microscopy provide convincing support. The mitochondria and chloroplasts **(Figures** below**)** within our eukaryotic cells share the following features with prokaryotic cell:

- Their organelle DNA is short and circular, and the DNA sequences do not match DNA sequences found in the nucleus.
- Molecules that make up organelle membranes resemble those in prokaryotic membranes – and differ from those in eukaryotic membranes.
- ribosome in these organelles are similar to those of bacterial ribosomes, and different from eukaryotic ribosomes.
- reproduction is by binary fission, not by mitosis.
- Biochemical pathways and structures show closer relationships to prokaryote.
- Two or more membranes surround these organelles.



[Figure 3]

Mitochondria



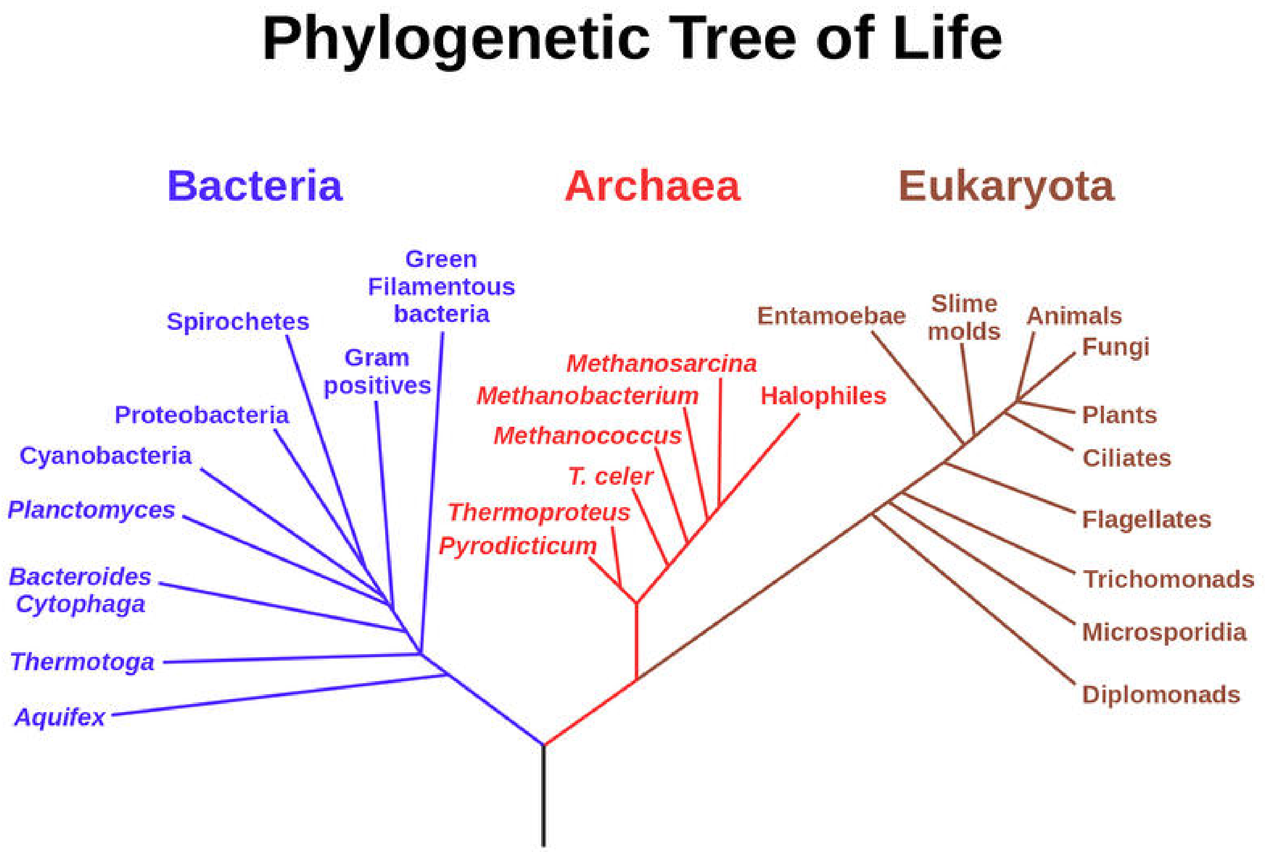
[Figure 4]

Chloroplast

The "host" cell membrane and biochemistry are more similar to those of Archaea, so scientists believe eukaryotes descended more directly from that major group (**Figure** below). The timing of this dramatic evolutionary event (more likely a series of events) is not clear. The oldest fossil clearly related to modern eukaryotes is a red alga dating back to 1.2 billion years ago. However, many scientists place the appearance of eukaryotic cells at about 2 billion years. Some time within Proterozoic Eon, then, all three major groups of life – bacterium, Archaea, and Eukaryotes – became well established.

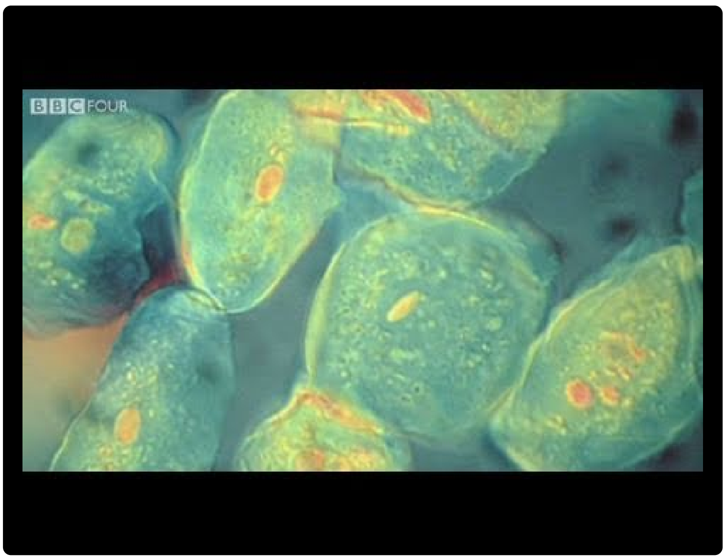
What Does It All Mean?

Eukaryotic cells, made possible by endosymbiosis, were powerful and efficient. That power and efficiency gave them the potential to evolve new characteristics: multicellularity, cell specialization, and large size. They were the key to the spectacular diversity of animal, plants, and fungus that populate our world today. Nevertheless, as we close the history of early life, reflect once more on the remarkable but often unsung patterns and processes of early evolution. Often, as humans, we focus our attention on plants and animals, and ignore bacteria. Our human senses cannot directly perceive the unimaginable variety of single cells, the architecture of organic molecule, or the intricacy of biochemical pathways. Let your study of early evolution give you a new perspective – a window into the beauty and diversity of unseen worlds, now and throughout Earth's history. In addition to the mitochondria that call your 100 trillion cells home, your body contains more bacterial cells than human cells. You, mitochondria, and your resident bacteria share common ancestry – a continuous history of the gift of life.



[Figure 5]

The three major domains of life had evolved by 1.5 billion years ago. Biochemical similarities show that eukaryotes share more recent common ancestors with the Archaea, but our organelles probably descended from bacteria by endosymbiosis.



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Summary

- Eukaryotic cells probably evolved about 2 billion years ago. Their evolution is explained by endosymbiotic theory.
- Mitochondria and chloroplasts evolved from prokaryotic organisms.
- Eukaryotic cells would go on to evolve into the diversity of eukaryotes we know today.

Review

1. When did the first eukaryotic cells evolve?
2. Describe the endosymbiotic theory.
3. Discuss the evidence for the evolution of mitochondria and chloroplasts.

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5.6 Late Precambrian

FlexBooks 2.0 > Biology For High School Diploma > Late Precambrian

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What you will learn

- Earth's geologic and climatic conditions in the late Precambrian
- How life evolved during the late Precambrian
- The Precambrian **mass extinction**

[Figure 1]

What did early eukaryotic life look like?

Some looked like this. This is a fossil of an ammonite. Ammonites are excellent index fossils, and it is often possible to link the rock layer in which they are found to specific geological time periods.

Multicellular Life: Setting the Stage

Nearly 80% of Earth's history passed before multicellular life evolved. Up until then, all organism existed as single cell. Why did multicellular organism evolve? What led up to this major step in the evolution of life? To put the evolution of multicellularity in context, let's return to what was happening on planet Earth during this part of its history.

The Late Precambrian

The **late Precambrian** is the time from about 2 billion to half a billion years ago. During this long span of time, Earth experienced many dramatic geologic and climatic changes.

- Continents drifted. They collided to form a gigantic supercontinent and then broke up again and moved apart. Continental drift changed climates worldwide and caused intense volcanic activity.
- Carbon dioxide levels in the atmosphere rose and fell. This was due to volcanic activity and other factors. When the levels were high, they created a **greenhouse effect**. More heat was trapped on Earth's surface, and the climate became warmer. When the levels were low, less heat was trapped and the planet cooled. Several times, cooling was severe enough to plunge Earth into an ice age. One ice age was so cold that snow and ice completely covered the planet. Earth during this ice age has been called **snowball Earth** (see **Figure** below).

[Figure 2]

Snowball Earth. During the late Precambrian, Earth grew so cold that it was covered with snow and ice. Earth during this ice age has been called snowball Earth.

Life During the Late Precambrian

The dramatic changes of the late Precambrian had a major impact on Earth's life forms. Living things that could not adapt died out. They were replaced by organisms that evolved new adaptation. These adaptations included **sexual reproduction**, specialization of cells, and **multicellularity**.

- Sexual reproduction created much more variety among offspring. This increased the chances that at least some of them would survive when the environment changed. It also increased the speed at which evolution could occur.
- Some cells started to live together in colonies. In some colonies, cells started to specialize in doing different jobs. This made the cells more efficient as a colony than as individual cells.
- By 1 billion years ago, the first multicellular organisms had evolved. They may have developed from colonies of specialized cells. Their cells were so specialized they could no longer survive independently. However, together they were mighty. They formed an organism that was bigger, more efficient, and able to do much more than any single-celled organism ever could.

The Precambrian Extinction

At the close of the Precambrian 544 million years ago, a mass extinction occurred. In a **mass extinction**, many or even most species abruptly disappear from Earth. There have been five mass extinctions in Earth's history. Many scientists think we are currently going through a sixth mass extinction. What caused the Precambrian mass extinction? A combination of climatic and geologic events was probably responsible. No matter what the cause, the extinction paved the way for a burst of new life, called the Cambrian explosion, during the following Paleozoic Era.

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Summary

- During the late Precambrian, continents drifted, carbon dioxide levels fluctuated, and climates changed. Many organisms could not survive the changes and died out.
- Other organisms evolved important new adaptations. These include sexual reproduction, cell specialization, and multicellularity.
- The Precambrian ended with a mass extinction, which paved the way for the Cambrian explosion.

Review

1. When was the late Precambrian?
2. Describe geologic and climatic changes that occurred during the late Precambrian.
3. What is the greenhouse effect?
4. What three significant evolutionary events occurred during the late Precambrian?
5. What is a mass extinction?

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5.7 Paleozoic Era

FlexBooks 2.0 > Biology For High School Diploma > Paleozoic Era

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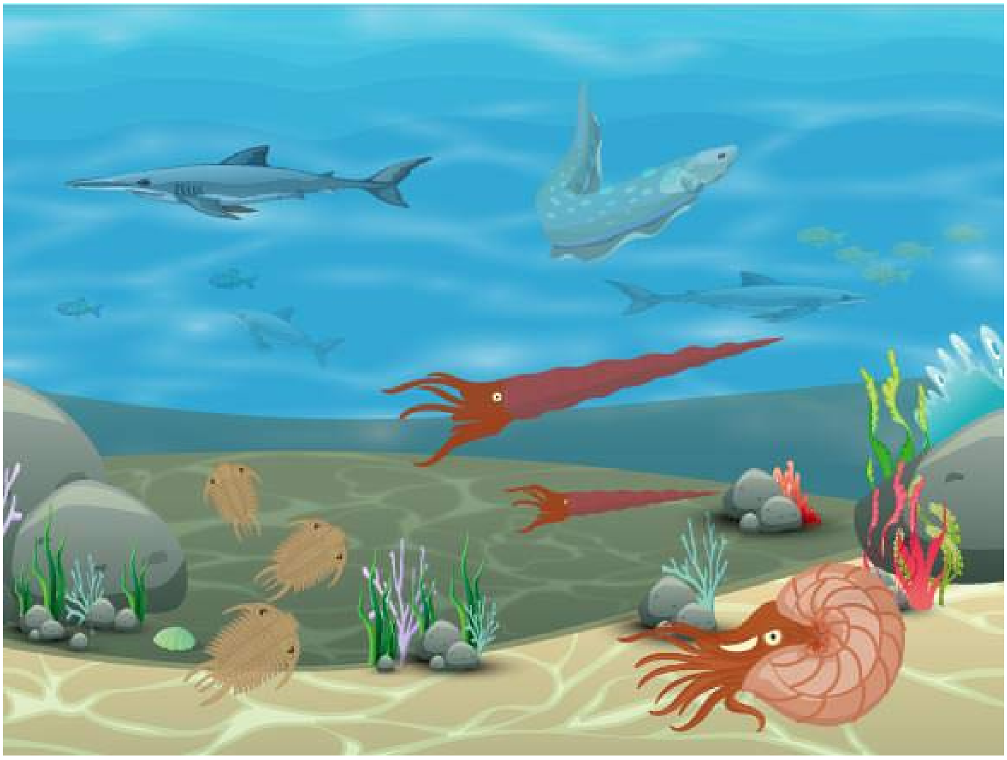
What you will learn

- What were the major events in the periods of the Paleozoic Era
- Diversification of plant and animal life during the Paleozoic Era



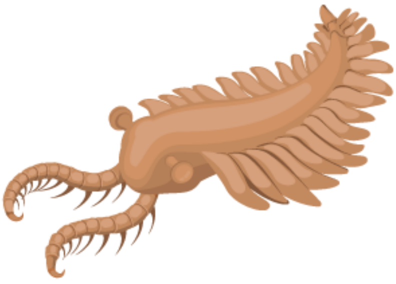
[Figure 1]

What was early life like?

Prehistoric underwater life exploded with amazing new creatures during the Paleozoic Era. Evolution allowed life to take many diverse forms, eventually developing the necessary adaptation to move from the ocean onto land.

Life During the Paleozoic

The **Paleozoic Era** is literally the era of "old life." It lasted from 544 to 245 million years ago and is divided into six periods (see the **Figure** below). The era began with a spectacular burst of new life. This is called the **Cambrian explosion.** The era ended with the biggest mass extinction the world had ever seen. This is known as the **Permian extinction.**

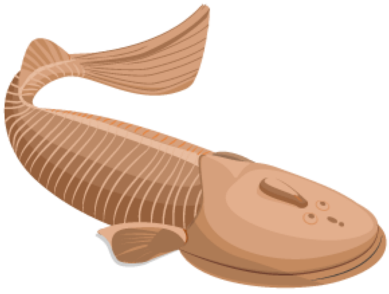


[Figure 2]

Cambrian Period (544–505 million years ago)

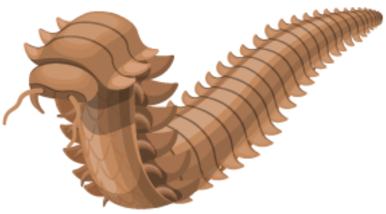
[Figure 3]

Ordovician Period (505–440 million years ago)



[Figure 4]

Silurian Period (440–410 million years ago)



[Figure 5]

Devonian Period (410–360 million years ago)

[Figure 6]

Carboniferous Period (360–290 million years ago)

[Figure 7]

Permian Period (290–245 million years ago)

The Paleozoic Era

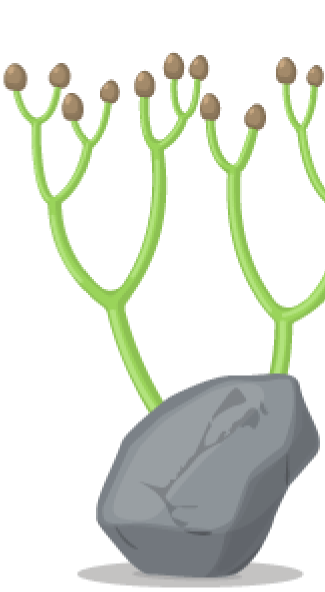
The Cambrian Period: Following the Precambrian mass extinction, there was an explosion of new kinds of organism in the Cambrian Period (544–505 million years ago). Many types of primitive animals called sponges evolved. Small ocean invertebrate called **trilobite** became abundant.

[Figure 8]

Cambrian explosion: Early arthropods known as trilobites were abundant during the Cambrian and later became extinct; however, the phyla they represent persist to this day.

The Ordovician Period: During the next period, the Ordovician Period (505–440 million years ago), the oceans became filled with invertebrates of many types. Also during this period, the first fish evolved and plants colonized the land for the first time. But animals still remained in the water.

The Silurian Period: During the Silurian Period (440–410 million years ago), corals appeared in the oceans, and fish continued to evolve. On land, vascular plant appeared. With special tissue to circulate water and other materials, these plants could grow larger than the earlier nonvascular plant.



[Figure 9]

Cooksonia, a branching vascular plant with sporangia at the tips of each branch. Cooksonia fossils measure just centimeters in height and date from the Silurian period.

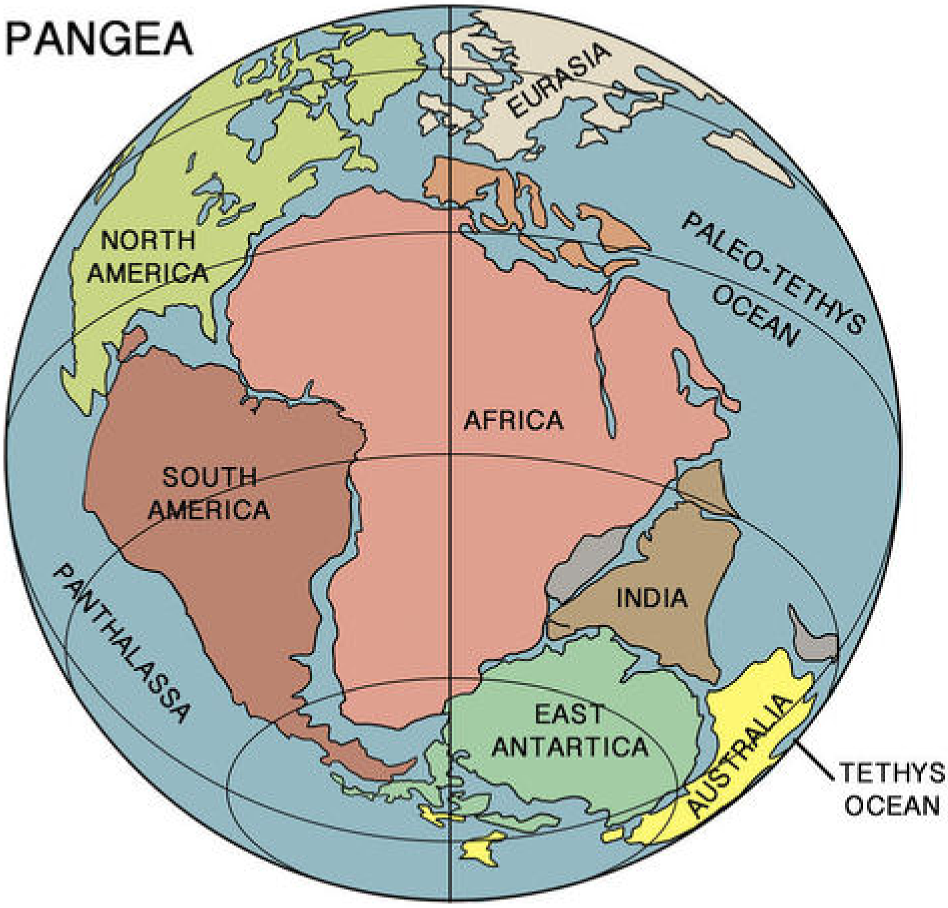
The Devonian Period: During the Devonian Period (410–360 million years ago), the first seed plants evolved. Seeds have a protective coat and stored food to help these plants survive. Seed plants eventually became the most common type of land plants. In the oceans, fish with lobe fins evolved. They could breathe air when they raised their heads above water. Breathing would be necessary for animals to eventually colonize the land.

[Figure 10]

On land, club mosses, horsetails, and ferns joined primitive seed plants and early trees to form the first forests.

The Carboniferous Period: Next, during the Carboniferous Period (360–290 million years ago), widespread forests of huge plants left massive deposits of carbon that eventually turned to coal. The first amphibian evolved to move out of the water and colonize land, but they had to return to the water to reproduce. Soon after amphibians arose, the first reptile evolved. They were the first animals that could reproduce on dry land.

The Permian Period: During the Permian Period (290–245 million years ago), all the major land masses collided to form a supercontinent called **Pangaea**. Temperatures were extreme, and the climate was dry. Plants and animals evolved adaptations to dryness, such as waxy leaves or leathery skin to prevent water loss. The Permian Period ended with a mass extinction.

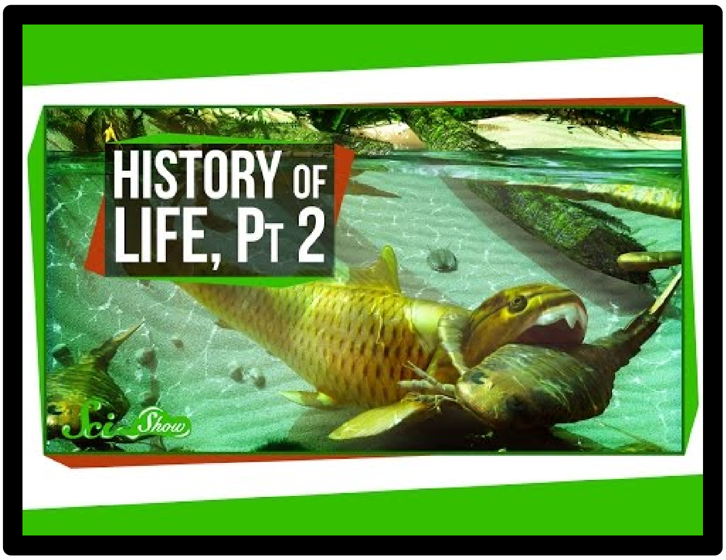


[Figure 11]

The supercontinent Pangaea encompassed all of today's continents in a single land mass. This configuration limited shallow coastal areas which harbor marine species, and may have contributed to the dramatic event which ended the Permian - the most massive extinction ever recorded.

In the mass extinction that ended the Permian, the majority of species went extinct. Many hypothesis have been offered to explain why this mass extinction occurred. These include huge meteorites striking Earth and enormous volcanoes spewing ashes and gases into the atmosphere. Both could have darkened the skies with dust for many months. This, in turn, would have shut down photosynthesis and cooled the planet.

Despite the great loss of life, there was light at the end of the tunnel. The Permian extinction paved the way for another burst of new life at the start of the following Mesozoic Era. This included the evolution of the dinosaur.



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Summary

- The Paleozoic Era began with the Cambrian explosion. It ended with the Permian extinction.
- During the era, invertebrate animals diversified in the oceans. Plants, amphibians, and reptiles also moved to the land.

Review

1. What was the Cambrian explosion?
2. What was the Permian extinction?
3. List important evolutionary events that occurred during the Cambrian Period.
4. List important evolutionary events that occurred during the Ordovician Period.
5. List important evolutionary events that occurred during the Carboniferous Period.
6. Describe Pangaea. When did Pangaea form?

Report Content Errors

5.8 Mesozoic Era

FlexBooks 2.0 > Biology For High School Diploma > Mesozoic Era

Last Modified: Apr 18, 2022

What you will learn

- Why Mesozoic era was the age of dinosaur
- The three periods of the Mesozoic Era: the Triassic, the Jurassic, and the Cretaceous
- What caused the extinction of dinosaurs

[Figure 1]

What exactly is a dinosaur?

Two dinosaurs wade through shallow waters to get to the vegetation on this island. The Mesozoic Era is the age of dinosaurs. These animal grew so large they dominated the planet. Dinosaurs were so dominant that it took a catastrophic, environment-changing event for mammal to be able to take over.

Mesozoic Era: The Age of Dinosaurs

The **Mesozoic Era** is literally the era of "middle life." It is also known as the age of **dinosaurs**. It lasted from 245 to 65 million years ago and is divided into three periods. The Mesozoic began with the supercontinent **Pangaea**. Then, during the era, Pangaea broke up and the continents drifted apart. The movement of continents changed climates. It also caused tremendous volcanic activity.

mass extinction occurred at the end of the Triassic and Cretaceous Periods. The first extinction paved the way for a dinosaur takeover. In the second extinction, the dinosaurs finally disappeared.


[Figure 2]

Triassic Period
(245–200 million years ago)


[Figure 3]

Jurassic Period
(200–145 million years ago)


[Figure 4]

Cretaceous Period
(145–65 million years ago)

The Triassic Period: During the Triassic Period (245–200 million years ago), the first dinosaurs branched off from the reptile and colonized the land, air, and water. Huge seed fern and conifer dominated the forests, and modern corals, fish, and insects evolved. The supercontinent Pangaea started to separate into **Laurasia** (today's Northern Hemisphere continents) and **Gondwanaland** (today's Southern Hemisphere continents). The Triassic Period ended with a mass extinction.

The Jurassic Period: The next period, the Jurassic Period (200–145 million years ago), began after the mass extinction that ended the Triassic Period. This mass extinction allowed dinosaurs to flourish in the Jurassic Period. This was the golden age of dinosaurs. Also during the Jurassic, the earliest bird evolved from reptile ancestors, and all the major groups of mammals evolved, though individual mammals were still small in size. Flowering plants appeared for the first time, and new insects also evolved to pollinate the flower. The continents continued to move apart, and volcanic activity was especially intense.

The Cretaceous Period: During the Cretaceous Period (145–65 million years ago), dinosaurs reached their peak in size and distribution. *Tyrannosaurus Rex*, weighed at least 7 tons. By the end of the Cretaceous, the continents were close to their present locations. Earth's overall climate was warm; even the poles lacked ice. The period ended with the dramatic extinction of the dinosaurs.

What happened to the dinosaurs? Why did they go extinct at the end of the Cretaceous Period? Some scientists think a comet or asteroid may have collided with Earth, causing skies to darken, photosynthesis to shut down, and climates to change. A collision was probably at least a contributing factor. Without the dinosaurs, there were many opportunities for new organism to exploit in the next era, the Cenozoic. Which living things do you think took over where the dinosaurs left off?

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Summary

- The Mesozoic Era is the age of dinosaurs. They evolved from earlier reptiles to fill niches on land, in the water, and in the air.
- Mammals also evolved but were small in size.
- Flowering plants appeared for the first time.
- Dinosaurs went extinct at the end of the Mesozoic.

Review

1. Describe how the continents shifted during the Mesozoic Era.
2. Create a timeline of major evolutionary events during the Mesozoic Era.
3. Explain why scientists believe dinosaurs went extinct.

Report Content Errors

5.9 Cenozoic Era

FlexBooks 2.0 > Biology For High School Diploma > Cenozoic Era

Last Modified: Apr 18, 2022

What you will learn

- How mammal evolved and flourished in the Cenozoic era
- What were the major events during the tertiary and quaternary period of the Cenozoic Era

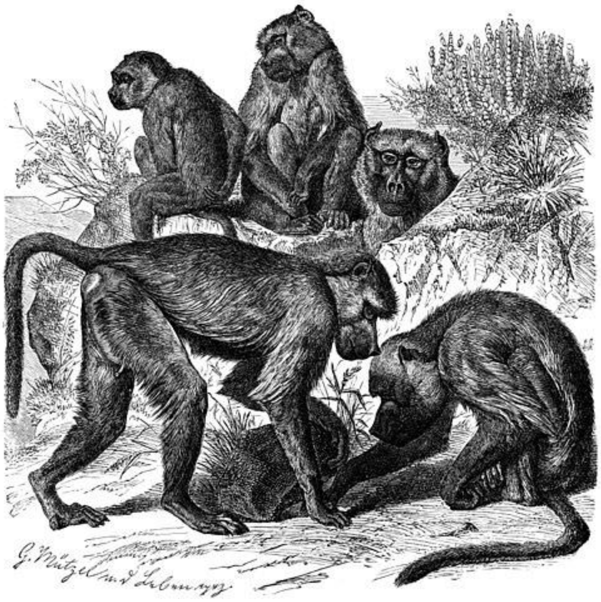
[Figure 1]

What allowed mammals to outlast the dinosaurs?

With dinosaur around, mammals could not thrive. It took a catastrophic event to rid the planet of dinosaurs. Luckily for mammals, the extinction of the dinosaurs left many opportunities for mammals to take over and flourish.

The Cenozoic Era: Age of Mammals

The **Cenozoic Era** literally means the era of "modern life." It is also called the age of mammals. Mammals took advantage of the extinction of the dinosaurs. They flourished and soon became the dominant animal on Earth. The Cenozoic began 65 million years ago and continues to the present. It may be divided into the two periods described in the **Figure** below.



[Figure 2]

Mammals called primates evolved during the Tertiary Period (65-1.8 million years ago).

[Figure 3]

Mammals like woolly mammoths adapted to the cold during the Quaternary Period (1.8 million years ago- present).

The Tertiary Period: During the Tertiary Period (65–1.8 million years ago), Earth's climate was generally warm and humid. This allowed mammals to evolve further and fill virtually all niches vacated by the dinosaurs. Many mammals increased in size. Mammals called **primates** evolved, including human ancestors. Modern rain forests and grasslands appeared, and flowering plants and insects were numerous and widespread.

The Quaternary Period: During the Quaternary Period (1.8 million years ago–present), Earth's climate cooled, leading to a series of ice ages. Sea levels fell because so much water was frozen in glaciers. This created land bridges between continents, allowing land animals to move to new areas. Some mammals, like the woolly mammoths adapted to the cold by evolving very large size and thick fur. Other animals moved closer to the equator or went extinct, along with many plants.

The last ice age ended about 12,000 years ago. By that time, our own species, ***Homo sapiens***, had evolved. After that, we were witnesses to the unfolding of life's story. Although we don't know all the details of the recent past, it is far less of a mystery than the billions of years that preceded it.

KQED: The Last Ice Age

Imagine a vast grassy ecosystem covered with herd of elephants, bison, and camels stretching as far as the eye can see. Africa? Maybe. But this also describes Northern California at the end of the last Ice Age. What happened to all this wildlife? Were they over-hunted and killed off? Did global warming destroy their population? Scientists are not sure, but this relatively recent loss of life does raise many interesting questions.

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Summary

- The Cenozoic Era is the age of mammals. They evolved to fill virtually all the niches vacated by dinosaurs.
- The ice ages of the Quaternary Period of the Cenozoic led to many extinctions.
- The last ice age ended 12,000 years ago. By that time, *Homo sapiens* had evolved.

Review

1. What explains why mammals were able to flourish during Cenozoic Era?
2. Create a timeline of major evolutionary events during the Cenozoic Era.
3. Discuss climate changes during the Tertiary and Quaternary Periods, and the effects of these changes on geology and vegetation.

5.10 Classification

FlexBooks 2.0 > Biology For High School Diploma > Classification

Last Modified: Jun 13, 2022

What you will learn

- The Linnaean system of classification of living organism
- What is **binomial nomenclature**
- Revisions in the Linnaean system of classification

[Figure 1]

What characteristics help classify us as human?

Humans share many characteristics with other mammal like having body hair, mammary gland, and being warm-blooded. However, there are quite a few characteristics that make humans different from other mammals like the ability to solve problems through complex reasoning and to use language for communication.

Linnaean Classification

The evolution of life on Earth over the past 4 billion years has resulted in a huge variety of **species**. For more than 2,000 years, humans have been trying to classify the great diversity of life. The science of classifying organisms is called **taxonomy.** Classification is an important step in understanding the present diversity and past evolutionary history of life on Earth.

All modern classification systems have their roots in the **Linnaean classification** system. It was developed by Swedish botanist Carolus Linnaeus in the 1700s. He tried to classify all living things that were known at his time. He grouped together organisms that shared obvious physical traits, such as number of legs or shape of leaves. For his contribution, Linnaeus is known as the "father of taxonomy."

The Linnaean system of classification consists of a hierarchy of groupings, called **taxon** (singular, taxon). Taxa range from the **kingdom** to the species (see the **Figure** below). The **kingdom** is the largest and most inclusive grouping. It consists of organisms that share just a few basic similarities. Examples are the plant and animal kingdoms. The **species** is the smallest and most exclusive grouping. It consists of organisms that are similar enough to produce fertile offspring together. Closely related species are grouped together in a **genus.**

Taxon	Human	Chimpanzee	Blue whale	Snake
Species	*sapiens*	*troglodytes*	*musculus*	*naja*
Genus	*Homo*	*Pan*	*Balaenoptera*	*Naja*
Family	Hominidae	Hominidae	Balaenopteridae	Elapidae
Order	Primates	Primates	Artiodactyla	Squamata
Class	Mammalia	Mammalia	Mammalia	Reptilia
Phylum	Chordata	Chordata	Chordata	Chordata
Kingdom	Animalia	Animalia	Animalia	Animalia

[Figure 2]

Linnaean Classification System: This chart shows the taxa of the Linnaean classification system. Each taxon is a subdivision of the taxon below it in the chart. For example, a species is a subdivision of a genus.

Check your understanding!

PROGRESS 0 / 3

1. Which taxon among the following is different among humans and chimpanzees?

a class

b genus

c order

d family

Check It

Hint

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DID YOU KNOW?

Platypus, an animal that belongs to the order Monotremata, is unique in having characteristics of both bird and mammals. Like birds, it has webbed feet, a beak instead of mouth, and it lays egg. Like mammals, it has body hair and produces milk to suckle its young. Scientists classify it as a mammal because most of its anatomical features are closer to mammals than birds.

Binomial Nomenclature

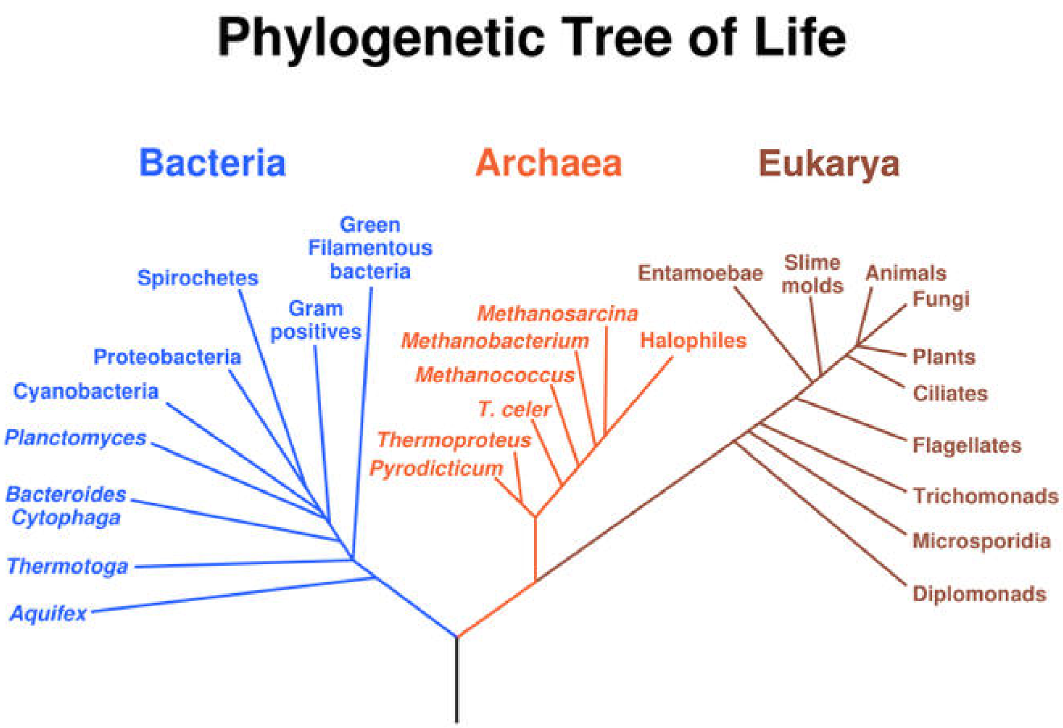
Perhaps the single greatest contribution Linnaeus made to science was his method of naming species. This method, called **binomial nomenclature**, gives each species a unique, two-word Latin name consisting of the genus name and the species name. An example is *Homo sapiens*, the two-word Latin name for humans. It literally means "wise human." This is a reference to our big brains.

Why is having two names so important? It is similar to people having a first and a last name. You may know several people with the first name Michael, but adding Michael's last name usually pins down exactly whom you mean. In the same way, having two names uniquely identifies a species.

Revisions in Linnaean Classification

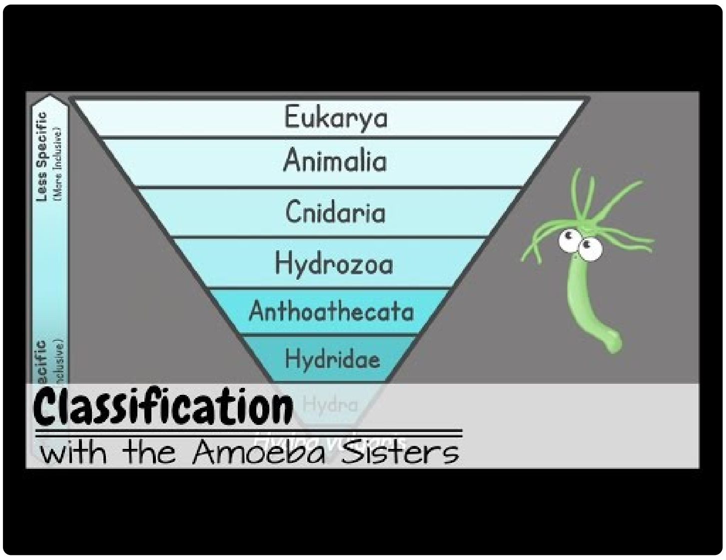
Linnaeus published his classification system in the 1700s. Since then, many new species have been discovered. The biochemistry of many organisms has also become known. Eventually, scientists realized that Linnaeus's system of classification needed revision.

A major change to the Linnaean system was the addition of a new taxon called the **domain**. A **domain** is a taxon that is larger and more inclusive than the kingdom. Most biologists agree there are three domains of life on Earth: bacterium, Archaea, and Eukarya (see the **Figure** below). Both Bacteria and Archaea consist of single-celled prokaryote. Eukarya consists of all eukaryote, from single-celled protist to humans. This domain includes the Animalia (animals), Plantae (plants), fungus (fungi), and Protista (protists) kingdoms.



[Figure 3]

This phylogenetic tree is based on comparisons of ribosomal RNA base sequences among living organisms. The tree divides all organisms into three domains: Bacteria, Archaea, and Eukarya. Humans and other animals belong to the Eukarya domain. From this tree, organisms that make up the domain Eukarya appear to have shared a more recent common ancestor with Archaea than Bacteria.



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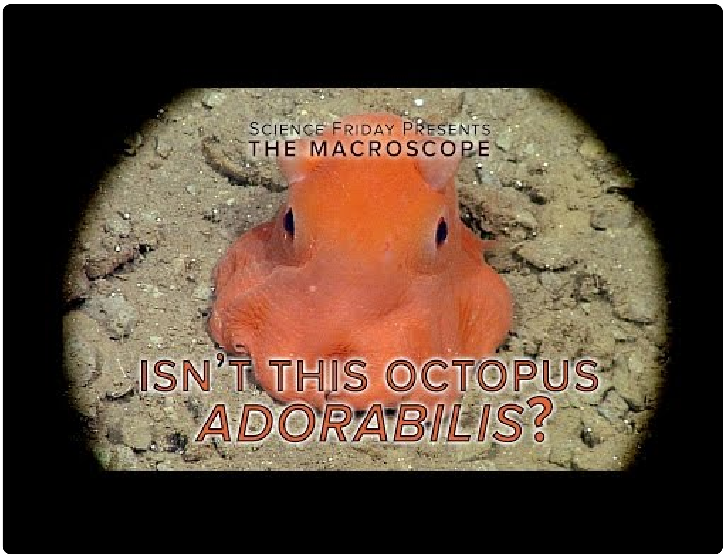
Science Friday: Isn't this Octopus Adorable?

What do you call a tiny octopus with big eyes, gelatinous skin and is cute as a button? Nobody knows quite yet! In this video by Science Friday, Stephanie Bush aims to classify and name this presently undescribed deep-sea cephalopod.



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Summary

- Classification is an important step in understanding life on Earth.
- All modern classification systems have their roots in the Linnaean classification system.
- The Linnaean system is based on similarities in obvious physical traits. It consists of a hierarchy of taxa, from the kingdom to the species.
- Each species is given a unique two-word Latin name.
- The recently added domain is a larger and more inclusive taxon than the kingdom.

Review

1. What is taxonomy?
2. Define taxon and give an example.

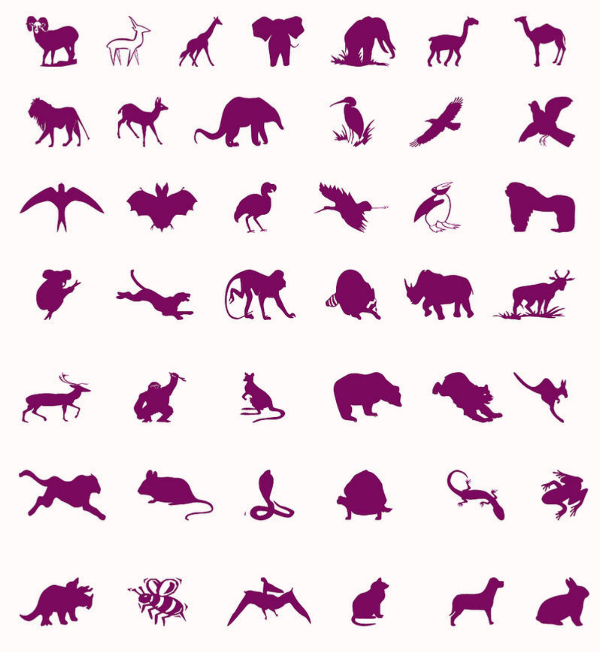
3. What is binomial nomenclature? Why is it important?
4. What is a domain? What are the three domains of life on Earth?
5. Create a taxonomy, modeled on the Linnaean classification system, for a set of common objects, such as motor vehicles, tools, or office supplies. Identify the groupings that correspond to the different taxa in the Linnaean system.

Report Content Errors

5.11 Phylogeny and Cladistics

FlexBooks 2.0 > Biology For High School Diploma > Phylogeny and Cladistics

Last Modified: Oct 05, 2020



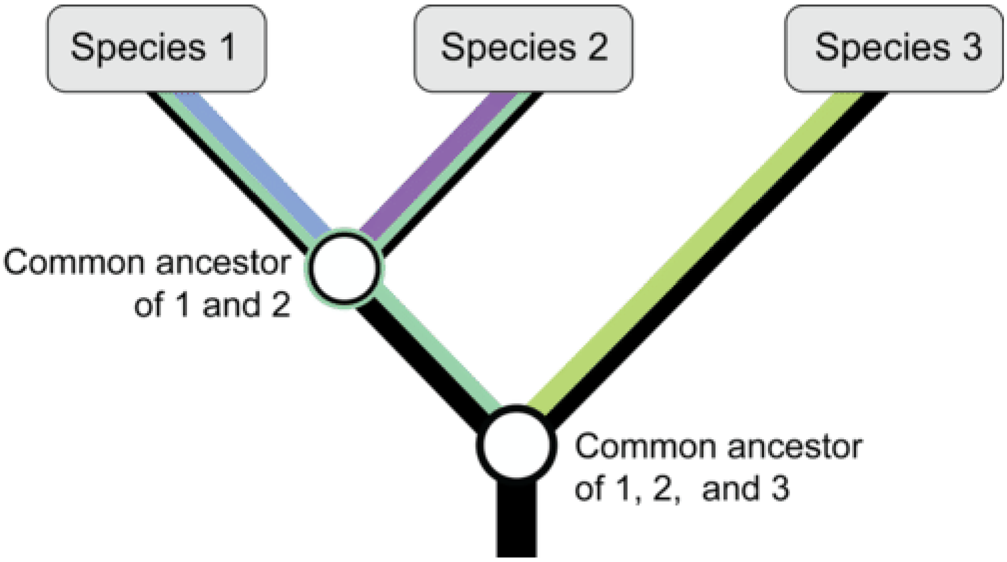
[Figure 1]

Can two different species be related?

Of course they can. For example, there are many different species of mammal, or of one type of mammal, such as mice. And they are all related. In other words, how close or how far apart did they separate from a common ancestor during evolution? Determining how different species are evolutionarily related can be a tremendous task.

Phylogenetic Classification

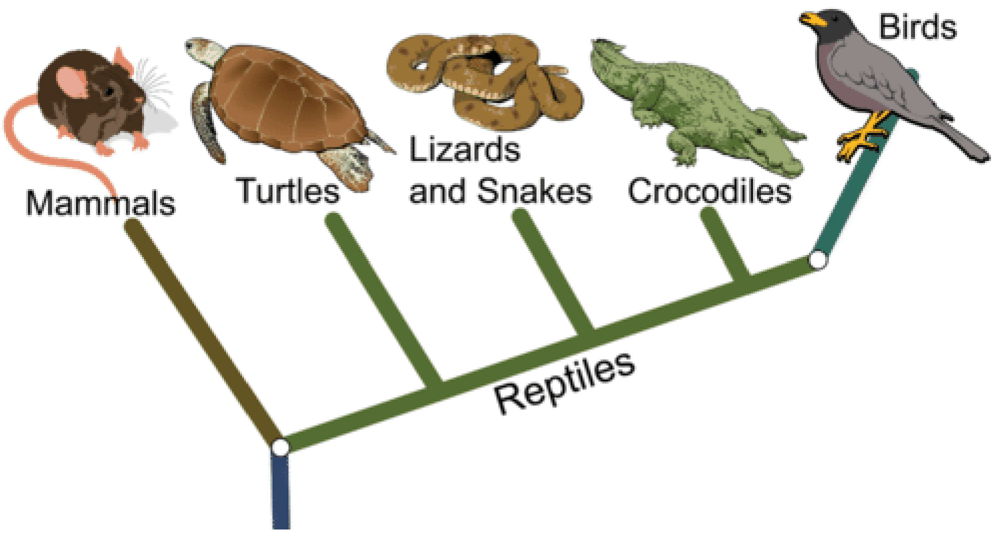
Linnaeus classified organism based on obvious physical traits. Basically, organisms were grouped together if they looked alike. After Darwin published his theory of evolution in the 1800s, scientists looked for a way to classify organisms that showed **phylogeny**. **Phylogeny** is the evolutionary history of a group of related organisms. It is represented by a **phylogenetic tree**, like the one in **Figure** below.



[Figure 2]

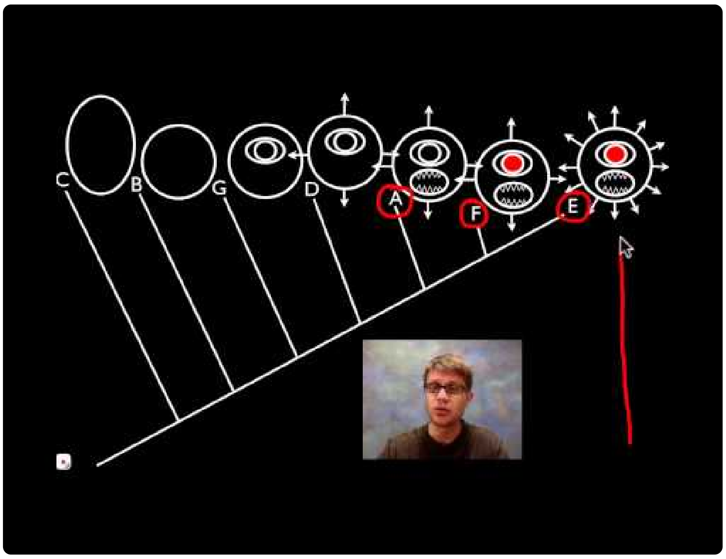
Phylogenetic Tree. This phylogenetic tree shows how three hypothetical species are related to each other through common ancestors. Do you see why Species 1 and 2 are more closely related to each other than either is to Species 3?

One way of classifying organisms that shows phylogeny is by using the **clade**. A **clade** is a group of organisms that includes an ancestor and all of its descendants. Clades are based on **cladistics**. This is a method of comparing traits in related species to determine ancestor-descendant relationships. Clades are represented by **cladogram**, like the one in **Figure** below. This cladogram represents the mammal and reptile clades. The reptile clade includes bird. It shows that birds evolved from reptiles. Linnaeus classified mammals, reptiles, and birds in separate classes. This masks their evolutionary relationships.



[Figure 3]

This cladogram classifies mammals, reptiles, and birds in clades based on their evolutionary relationships.



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Summary

- Phylogeny is the evolutionary history of group of related organisms. It is represented by a phylogenetic tree that shows how species are related to each other through common ancestors.
- A clade is a group of organisms that includes an ancestor and all of its descendants. It is a phylogenetic classification, based on evolutionary relationships.

Review

1. What is a clade?
2. What is cladistics, and what is it used for?
3. Explain why reptiles and birds are placed in the same clade.
4. Dogs and wolves are more closely related to each other than either is to cats. Draw a phylogenetic tree to show these relationships.

Report Content Errors

5.12 Darwin

FlexBooks 2.0 > Biology For High School Diploma > Darwin

Last Modified: Apr 18, 2022

What you will learn

- Darwin's theory of evolution
- Darwin's voyage on the HMS Beagle to the **Galápagos Islands**
- What Darwin observed during his voyage

[Figure 1]

What's that big red pouch?

The Frigate bird of the Galápagos Islands. This bird can be found throughout the tropical Atlantic down to the Galápagos Islands and Ecuador, but not in Europe or South America, so Darwin may never have come across one until he landed on the Galápagos. Such a unique creature was bound to make a **naturalist** such as Darwin wonder why. Why do they look the way they do? What's that big red pouch? What are the advantages?

Darwin's Theory

The Englishman **Charles Darwin** is one of the most famous scientists who ever lived. His place in the history of science is well deserved. Darwin's theory of evolution represents a giant leap in human understanding. It explains and unifies all of biology.

Darwin's theory of evolution actually contains two major ideas:

1. One idea is that evolution occurs. In other words, organism change over time. Life on Earth has changed as descendants diverged from common ancestors in the past.
2. The other idea is that evolution occurs by **natural selection**. Natural selection is the process that results in living things with beneficial traits producing more offspring than others. This results in changes in the traits of living things over time.

In Darwin's day, most people believed that all species were created at the same time and remained unchanged thereafter. They also believed that Earth was only about 6,000 years old. Therefore, Darwin's ideas revolutionized biology. How did Darwin come up with these important ideas? It all started when he went on a voyage.

The Voyage of the *Beagle*

In 1831, when Darwin was just 22 years old, he set sail on a scientific expedition on a ship called the ***HMS Beagle***. He was the **naturalist** on the voyage. As a naturalist, it was his job to observe and collect specimens of plants, animal, rocks, and fossil wherever the expedition went ashore. The route the ship took and the stops they made are shown in the **Figure** below.

[Figure 2]

Voyage of the Beagle. This map shows the route of Darwin's 5-year voyage on the HMS Beagle. Each stop along the way is labeled. Darwin and the others on board eventually circled the globe.

Darwin was fascinated by nature, so he loved his job on the *Beagle*. He spent more than 3 years of the 5-year trip exploring nature on distant continents and islands. While he was away, a former teacher published Darwin's accounts of his observation. By the time Darwin finally returned to England, he had become famous as a naturalist.

Darwin's Observations

During the long voyage, Darwin made many observations that helped him form his theory of evolution. For example:

- He visited tropical rainforests and other new habitat where he saw many plants and animals he had never seen before. This impressed him with the great diversity of life.
- He experienced an earthquake that lifted the ocean floor 2.7 meters (9 feet) above sea level. He also found rocks containing fossil sea shells in mountains high above sea level. These observations suggested that continents and oceans had changed dramatically over time and continue to change in dramatic ways.
- He visited rock ledges that had clearly once been beaches that had gradually built up over time. This suggested that slow, steady processes also change Earth's surface.
- He dug up fossils of gigantic extinct mammal, such as the ground sloth. This was hard evidence that organisms looked very different in the past. It suggested that living things —like Earth's surface—change over time.

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The Galápagos Islands

Darwin's most important observations were made on the **Galápagos Islands**. This is a group of 16 small volcanic islands 966 kilometers (600 miles) off the west coast of Ecuador, South America. Individual Galápagos islands differ from one another in important ways. Some are rocky and dry. Others have better soil and more rainfall. Darwin noticed that the plants and animals on the different islands also differed. For example, the giant tortoises on one island had saddle-shaped shells, while those on another island had dome-shaped shells. People who lived on the islands could even tell the island a turtle came from by its shell. This started Darwin thinking about the origin of species. He wondered how each island came to have its own type of tortoise.

[Figure 3]

[Figure 4]

Galápagos Tortoises. Galápagos tortoises have differently shaped shells depending on which island they inhabit. Tortoises with saddle-shaped shells can reach up to eat plant leaves above their head. Tortoises with dome-shaped shells cannot reach up in this way. These two types of tortoises live on islands with different environments and food sources. How might this explain the differences in their shells?

DID YOU KNOW?

Due to their remote location, the Galápagos Islands have many unique animals found nowhere else in the world. These animals evolved over millions of years without the fear of natural predator or human activity. However, since their discovery in the 1500s, the impact of human activity on these islands has increased, threatening its fragile ecosystem.

The Farallon Islands – "California's Galápagos"

One of the most productive marine food web on the planet is located on the Farallon Islands, just 28 miles off the San Francisco, California coast. These islands also host the largest seabird breeding colony in the continental United States, with over 300,000 breeding seabirds. The islands are known as the Galápagos of California. Why?

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Summary

- Darwin’s theory of evolution by natural selection states that living things with beneficial traits produce more offspring than others do. This produces changes in the traits of living things over time.
- During his voyage on the *Beagle*, Darwin made many observations that helped him develop his theory of evolution.
- Darwin's most important observations were made on the Galápagos Islands.

Review

1. State the two main ideas in Darwin's theory.
2. What was Darwin's role on the *Beagle?*
3. Describe two observations Darwin made on his voyage on the *Beagle* that helped him develop his theory of evolution.

4. Why did Darwin's observations of Galápagos tortoises cause him to wonder how species originate?

Report Content Errors

5.13 Influences on Darwin

FlexBooks 2.0 > Biology For High School Diploma > Influences on Darwin

Last Modified: Apr 18, 2022

What you will learn

- How the ideas of earlier thinkers influenced Darwin
- What is **artificial selection**
- How Wallace's theory influenced Darwin

[Figure 1]

How do structures like this form?

Cathedral Rock in Sedona, Arizona. Though Arizona was not on Darwin's itinerary, the work of others that saw and studied Earth's changing landscape influenced him. One geologist, Charles Lyell, proposed that gradual geological processes have shaped Earth's surface, inferring that Earth must be far older than most people believed. How else could structures like those shown here develop? If in fact, Earth was much older than just 6,000 years, Darwin believed there would have been plenty of time for evolution to occur.

Influences on Darwin

science, like evolution, always builds on the past. Darwin didn't develop his theory completely on his own. He was influenced by the ideas of earlier thinkers.

Earlier Thinkers Who Influenced Darwin

1. Jean Baptiste **Lamarck** (1744–1829) was an important French naturalist. He was one of the first scientists to propose that species change over time. However, Lamarck was wrong about how species change. His idea of the **inheritance of acquired characteristics** is incorrect. Traits an organism develops during its own lifetime cannot be passed on to offspring, as Lamarck believed.
2. Charles **Lyell** (1797–1875) was a well-known English geologist. Darwin took Lyell's book, *Principles of Geology,* with him on the *Beagle*. In the book, Lyell argued that gradual geological processes have gradually shaped Earth’s surface. From this, Lyell inferred that Earth must be far older than most people believed.
3. Thomas **Malthus** (1766–1834) was an English economist. He wrote an essay titled *On population*. In the essay, Malthus argued that human populations grow faster than the resources they depend on. When populations become too large, famine and disease break out. In the end, this keeps populations in check by killing off the weakest members.

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Artificial Selection

These weren’t the only influences on Darwin. He was also aware that humans could breed plants and animal to have useful traits. By selecting which animals were allowed to reproduce, they could change an organism’s traits. The pigeons shown below are good examples. Pigeon hobbyists breed pigeons to have certain characteristics. Both the carrier pigeon and the fantail pigeon were bred from the common rock pigeon. Darwin called this type of change in organisms **artificial selection**. He used the word “artificial” to distinguish it from natural selection.


[Figure 2]

Common rock pigeon


[Figure 3]

Carrier pigeon


[Figure 4]

Fantail pigeon

Did you ever hear the saying that "great minds think alike?" It certainly applies to Charles Darwin and another English naturalist named Alfred Russel **Wallace**. Wallace lived at about the same time as Darwin. He also traveled to distant places to study nature. Wallace wasn't as famous as Darwin. However, he developed basically the same theory of evolution. While working in distant lands, Wallace sent Darwin a paper he had written. In the paper, Wallace explained his evolutionary theory. This served to confirm what Darwin already thought.

Check your understanding!

PROGRESS 0 / 3

1. Ear-piercing is a common practice in people across the world for cosmetic or cultural reasons. However, the pierced-ear trait is not passed on to their offspring. Which scientist would have claimed that the trait could be passed on to offspring?

a Thomas Malthus

b Charles Lyell

c Jean Baptiste Lamarck

Check It

Hint

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Summary

- Darwin was influenced by other early thinkers, including Lamarck, Lyell, and Malthus.
- Darwin was also influenced by his knowledge of artificial selection.
- Wallace's paper on evolution confirmed Darwin's ideas.

Review

1. What is the inheritance of acquired characteristics? What scientist developed this mistaken idea?
2. Who was Charles Lyell? How did he influence Darwin?
3. What is artificial selection? How does it work?
4. How did Alfred Russel Wallace influence Darwin?

Report Content Errors

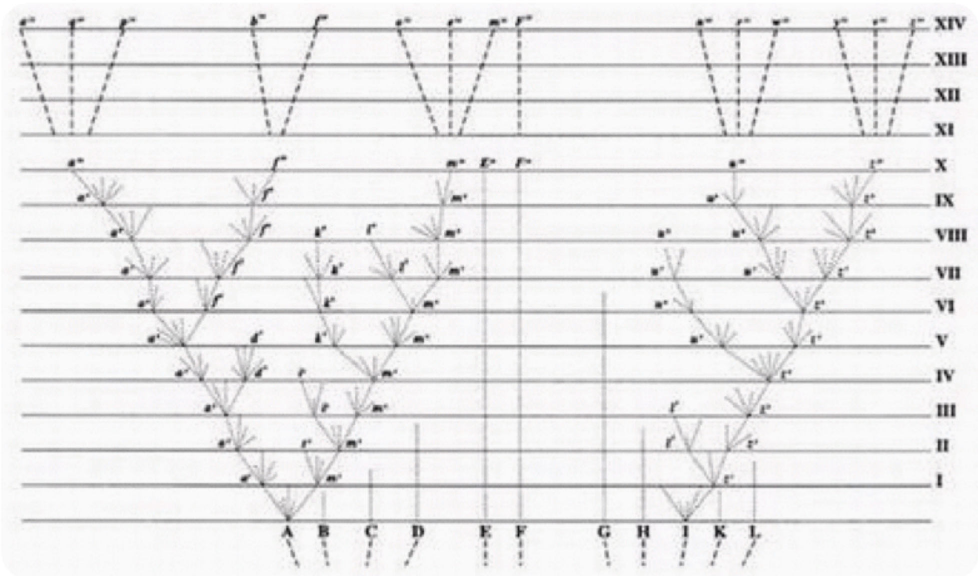
5.14 Theory of Evolution

FlexBooks 2.0 > Biology For High School Diploma > Theory of Evolution

Last Modified: Apr 18, 2022

What you will learn

- How Darwin was influenced by the work of Lamarck, Malthus, and Lyell
- Darwin's theory of evolution by natural selection



[Figure 1]

How do new species form?

This is the only illustration in Charles Darwin's 1859 book *On the Origin of species*, showing his ideas describing the divergence of species from common ancestors.

Darwin's Theory of Evolution by Natural Selection

Darwin spent many years thinking about the work of Lamarck, Lyell, and Malthus, what he had seen on his voyage, and artificial selection. What did all this mean? How did it all fit together? It fits together in Darwin's **theory of evolution by natural selection**. It's easy to see how all of these influences helped shape Darwin's ideas.

Evolution of Darwin's Theory

It took Darwin years to form his theory of evolution by natural selection. His reasoning went like this:

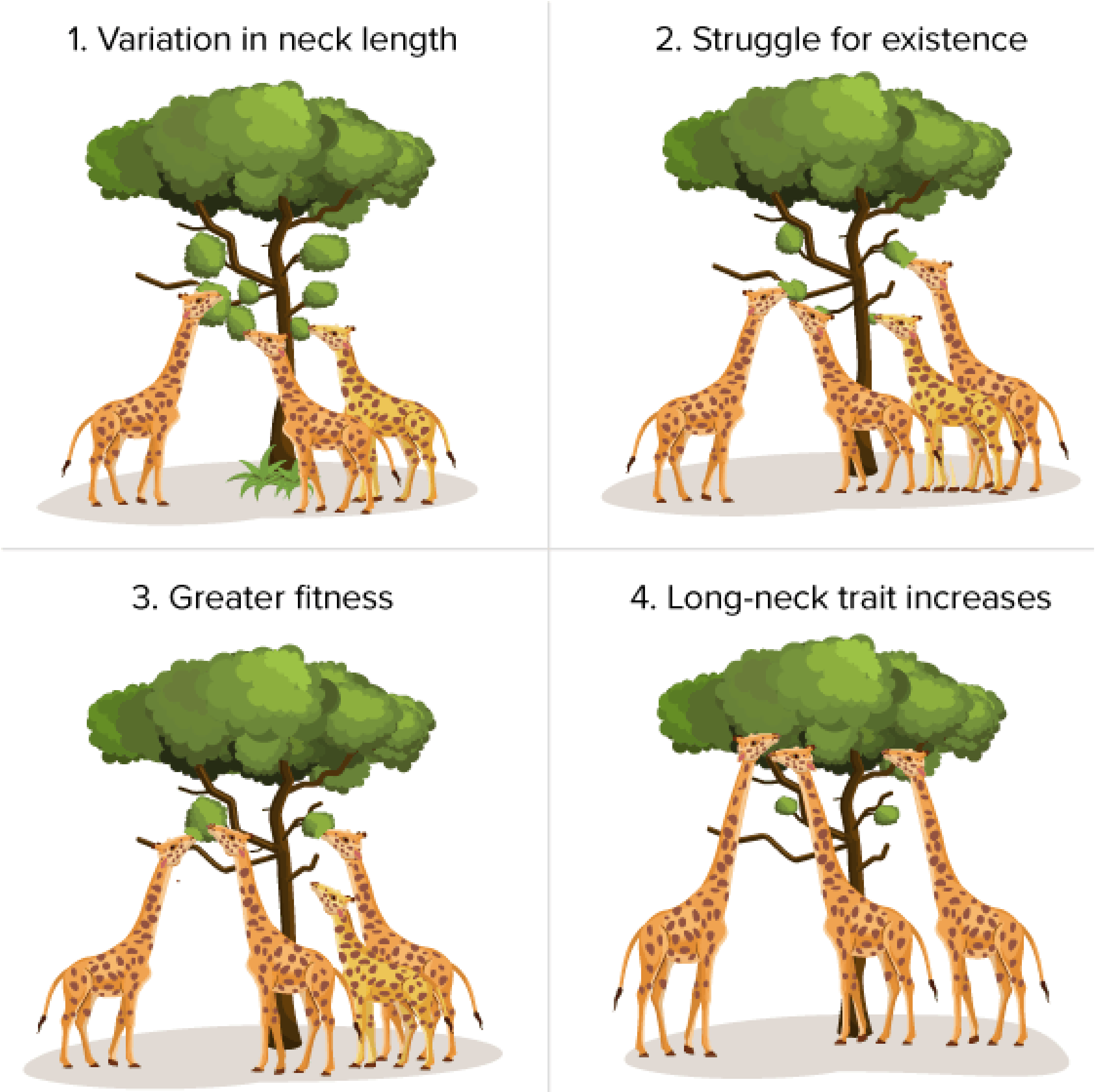
1. Like Lamarck, Darwin assumed that species can change over time. The fossil he found helped convince him of that.
2. From Lyell, Darwin saw that Earth and its life were very old. Thus, there had been enough time for evolution to produce the great diversity of life Darwin had observed.
3. From Malthus, Darwin knew that population could grow faster than their resources. This "overproduction of offspring" led to a "struggle for existence," in Darwin's words.
4. From artificial selection, Darwin knew that some offspring have variations that occur by chance, and that can be inherited. In nature, offspring with certain variations might be more likely to survive the "struggle for existence" and reproduce. If so, they would pass their favorable variations to their offspring.
5. Darwin coined the term **fitness** to refer to an organism's relative ability to survive and produce fertile offspring. Nature selects the variations that are most useful. Therefore, he called this type of selection **natural selection**.
6. Darwin knew artificial selection could change domestic species over time. He inferred that natural selection could also change species over time. In fact, he thought that if a species changed enough, it might evolve into a new species.

Wallace's paper not only confirmed Darwin's ideas. It also pushed him to finish his book, *On the Origin of Species*. Published in 1859, this book changed science forever. It clearly spelled out Darwin's theory of evolution by natural selection and provided convincing arguments and evidence to support it.

Applying Darwin's Theory

The following example applies Darwin's theory. It explains how giraffes came to have such long necks (see **Figure** below).

- In the past, giraffes had short necks. But there was chance variation in neck length. Some giraffes had necks a little longer than the average.
- Then, as now, giraffes fed on tree leaves. Perhaps the environment changed, and leaves became scarcer. There would be more giraffes than the trees could support. Thus, there would be a "struggle for existence."
- Giraffes with longer necks had an advantage. They could reach leaves other giraffes could not. Therefore, the long-necked giraffes were more likely to survive and reproduce. They had greater fitness.
- These giraffes passed the long-neck trait to their offspring. Each generation, the population contained more long-necked giraffes. Eventually, all giraffes had long necks.



[Figure 2]

Evolution of long-neck giraffes: Example of Darwin's Theory of Evolution by Natural Selection.

As this example shows, chance variations may help a species survive if the environment changes. Variation among species helps ensure that at least one will be able to survive environmental change.

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KQED: Chasing Beetles, Finding Darwin

It's been over 150 years since Charles Darwin published *On the Origin of Species*. Yet his ideas remain as central to scientific exploration as ever, and has been called the unifying concept of all biology. Is evolution continuing today? Of course it is.

QUEST follows researchers who are still unlocking the mysteries of evolution, including entomologist David Kavanaugh of the California Academy of Sciences, who predicted that a new beetle species would be found on the Trinity Alps of Northern California.

It's rare for a biologist to predict the discovery of a new species. For his prediction, Kavanaugh drew inspiration from Darwin's own 1862 prediction. When Darwin observed an orchid from Madagascar with a foot-long nectar, he predicted that a pollinator would be found with a tongue long enough to reach the nectar inside the orchid's very thin, elongated nectar ‘‘pouch’’, though he had never seen such a bird or insect. Darwin's prediction was based on his finding that all species are related to each other and that some of them evolve together, developing similar **adaptation**. Darwin's prediction came true in 1903, when a moth was discovered in Madagascar with a long, thin proboscis, which it uncurls to reach the nectar in the orchid's nectar. In the process of feeding from the orchid, the moth serves as its pollinator. The moth was given the scientific name *Xanthopan morganii praedicta*, in honor of Darwin’s prediction.

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As you view *Chasing Beetles, Finding Darwin,* focus on the following concepts:

1. the relationship between studying beetles and evolution,
2. the development of new species,
3. the relationship between genetic make-up of an organism and evolution,
4. the role of *beneficial* mutation,
5. the role of "habitat islands",
6. the selection for certain traits among breeders, such as pigeon breeders,
7. the importance of identifying new species.

Science Friday: Sex, Lies and Orchids

Orchids utilize a wide variety of techniques to manipulate other species into becoming their pollinators. In this video by Science Friday, curator Marc Hachadourian describes some of these deceptive methods.

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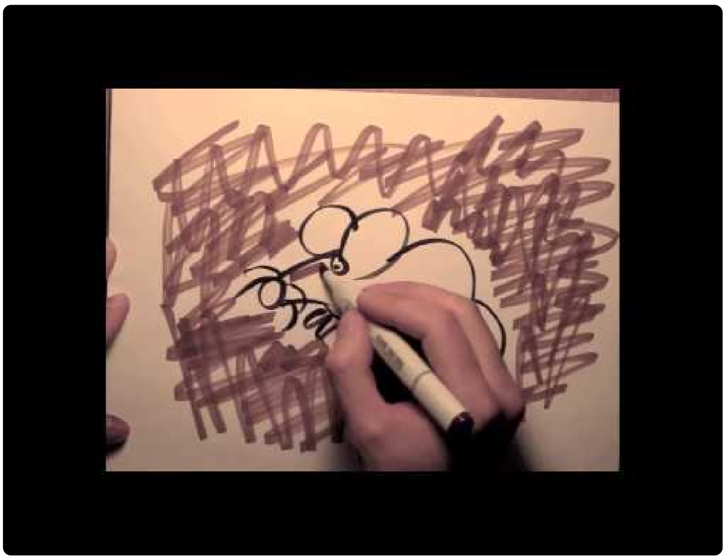
Summary

- Darwin's book *On the Origin of Species* clearly spells out his theory.
- Darwin's book also provides evidence and logic to support that evolution occurs and that it occurs by natural selection.

Review

1. Define fitness.
2. Apply Darwin's theory of evolution by natural selection to a specific case. For example, explain how Galápagos tortoises could have evolved saddle-shaped shells.
3. Explain how the writings of Charles Lyell and Thomas Malthus helped Darwin develop his theory of evolution by natural selection.
4. Discuss the role artificial selection had on Darwin's theory.

Resources



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Report Content Errors

5.15 Fossils

FlexBooks 2.0 > Biology For High School Diploma > Fossils

Last Modified: Apr 18, 2022

What you will learn

- How fossils provide evidence for evolution

[Figure 1]

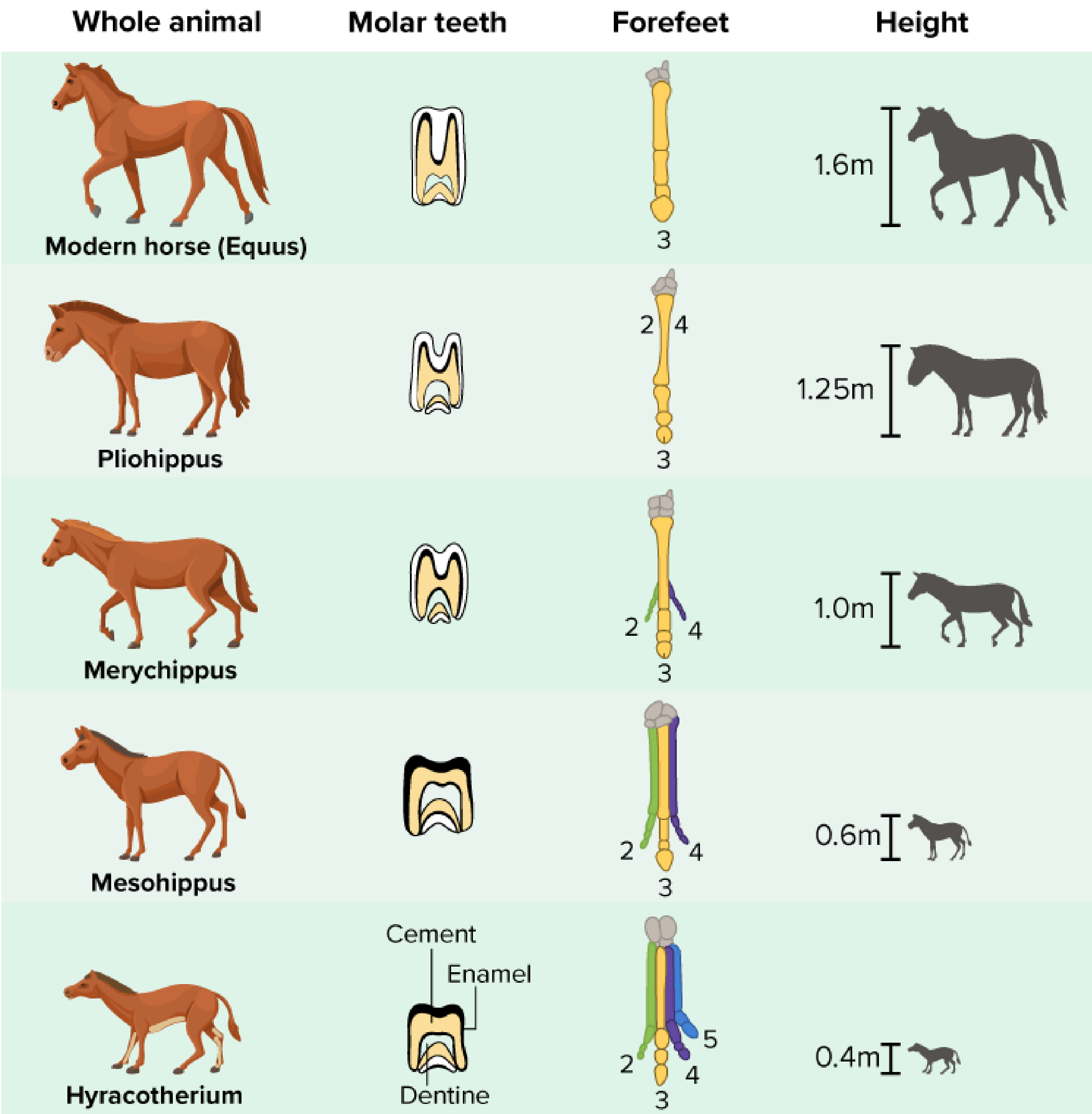
Would this be evidence of evolution?

Fossils, like this dinosaur fossil, provide evidence of species that lived in the past and have since gone extinct. In other words, these fossils are evidence of evolution.

Fossil Evidence

In his book *On the Origin of Species*, Darwin included evidence to show that evolution had taken place. He also made logical arguments to support his theory that evolution occurs by natural selection. Since Darwin's time, much more evidence has been gathered. The evidence includes a huge number of fossils. It also includes more detailed knowledge of living things, right down to their DNA.

Fossils are a window into the past. They provide clear evidence that evolution has occurred. Scientists who find and study fossils are called **paleontologist**. How do they use fossils to understand the past? Consider the example of the horse, shown in the **Figure** below. The fossil record shows how the horse evolved.



[Figure 2]

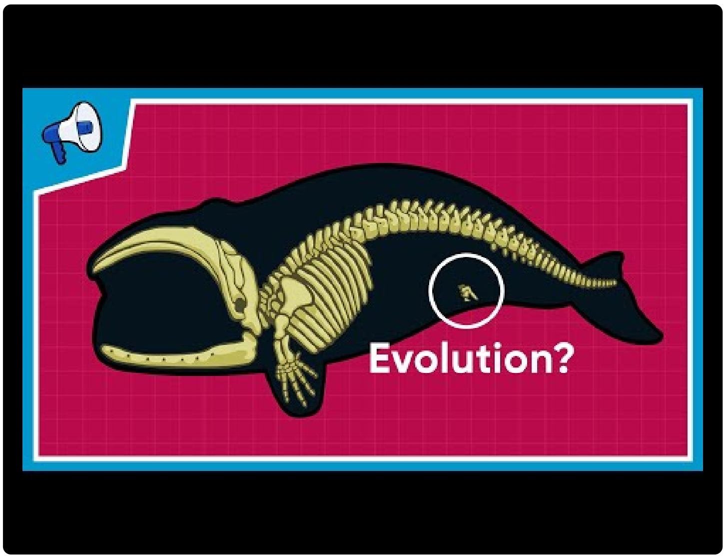
Evolution of the horse. Fossil evidence, depicted by the skeletal fragments, demonstrates evolutionary milestones in this process. Notice the 57 million year evolution of the horse leg bones and teeth. Especially obvious is the transformation of the leg bones from having four distinct digits to that of today's horse.

The oldest horse fossils show what the earliest horses were like. They were about the size of a fox, and they had four long toes. Other evidence shows they lived in wooded marshlands, where they probably ate soft leaves. Through time, the climate became drier, and grasslands slowly replaced the marshes. Later fossils show that horses changed as well.

- They became taller, which would help them see predator while they fed in tall grasses.

- They evolved a single large toe that eventually became a hoof. This would help them run swiftly and escape predators.
- Their molars (back teeth) became longer and covered with cement. This would allow them to grind tough grasses and grass seed without wearing out their teeth.

Similar fossil evidence demonstrates the evolution of the whale, moving from the land into the sea.



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Science Friday: Millions of Fossils Can't Be Wrong

What's in a tar pit? In this video by science Friday, Dr. John Harris describes how the La Brea Tar Pit has come to accumulate so many fossils.

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Summary

- Fossils provide a window into the past. They are evidence for evolution.
- Scientists who find and study fossils are called paleontologists.

Review

1. What is a fossil?
2. How do paleontologists learn about evolution?
3. Describe what fossils reveal about the evolution of the horse.

Report Content Errors

5.16 Comparative Anatomy

FlexBooks 2.0 > Biology For High School Diploma > Comparative Anatomy

Last Modified: Apr 18, 2022

What you will learn

- How comparative anatomy provides evidence for evolution
- How embryo, **vestigial structure**, and DNA are used to determine evolutionary relationships

---

[Figure 1]

Is this evidence of evolution?

Take a close look at this gorilla hand. The similarities to a human hand are remarkable. Comparing anatomy, and characterizing the similarities and differences, provides evidence of evolution.

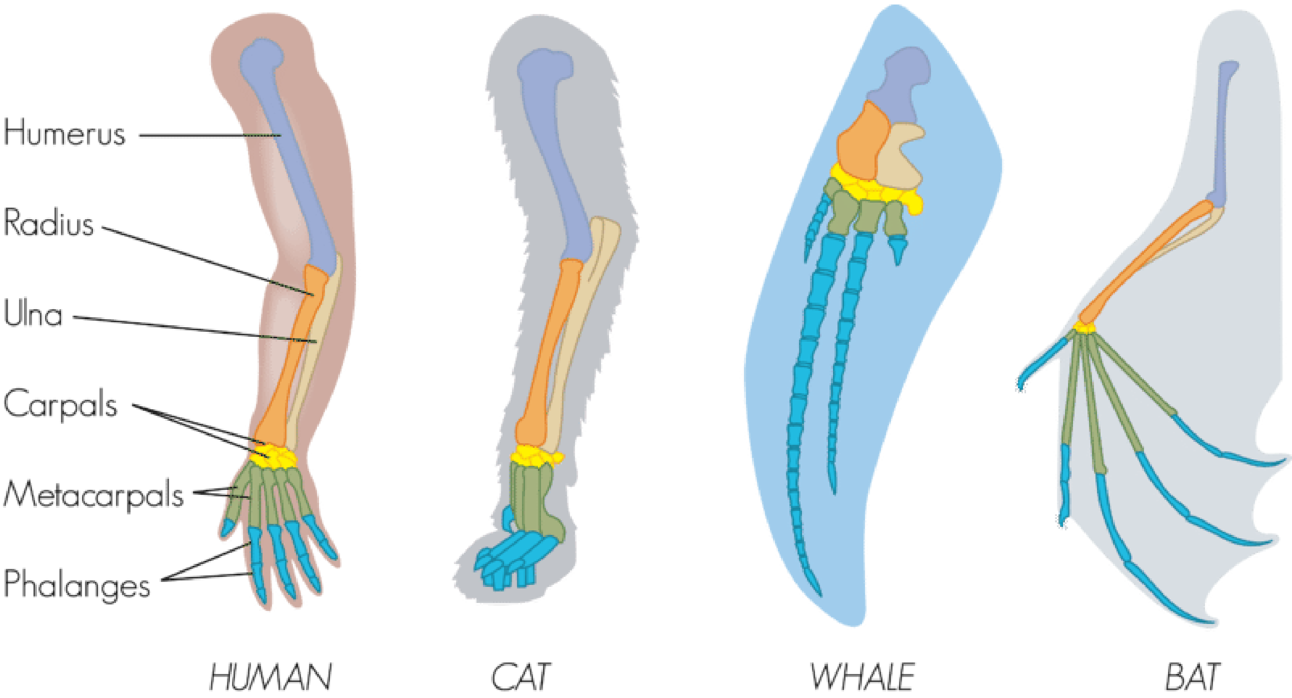
Evidence from Living Species

Just as Darwin did many years ago, today's scientists study living species to learn about evolution. They compare the anatomy, embryos, and DNA of modern organism to understand how they evolved.

Comparative Anatomy

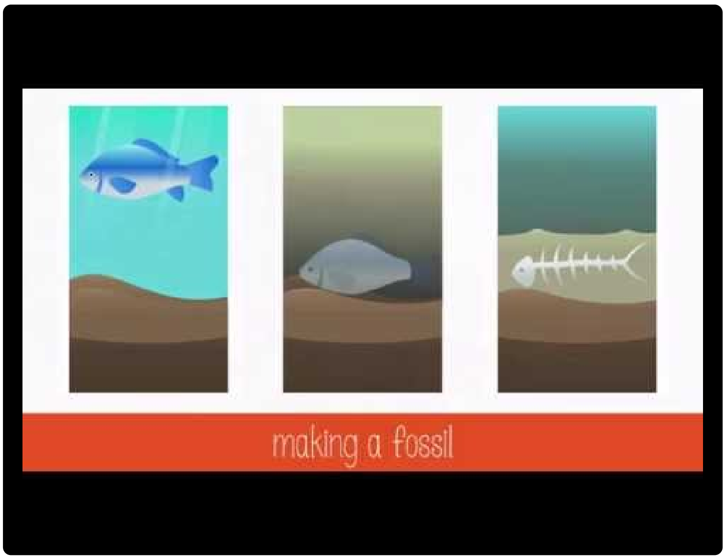
Comparative anatomy is the study of the similarities and differences in the structures of different species. Similar body parts may be homologies or analogies. Both provide evidence for evolution.

homologous structure are structures that are similar in related organisms because they were inherited from a common ancestor. These structures may or may not have the same function in the descendants. The **Figure** below shows the hands of several different mammal. They all have the same basic pattern of bone. They inherited this pattern from a common ancestor. However, their forelimbs now have different functions.



[Figure 2]

The forelimbs of all mammals have the same basic bone structure.



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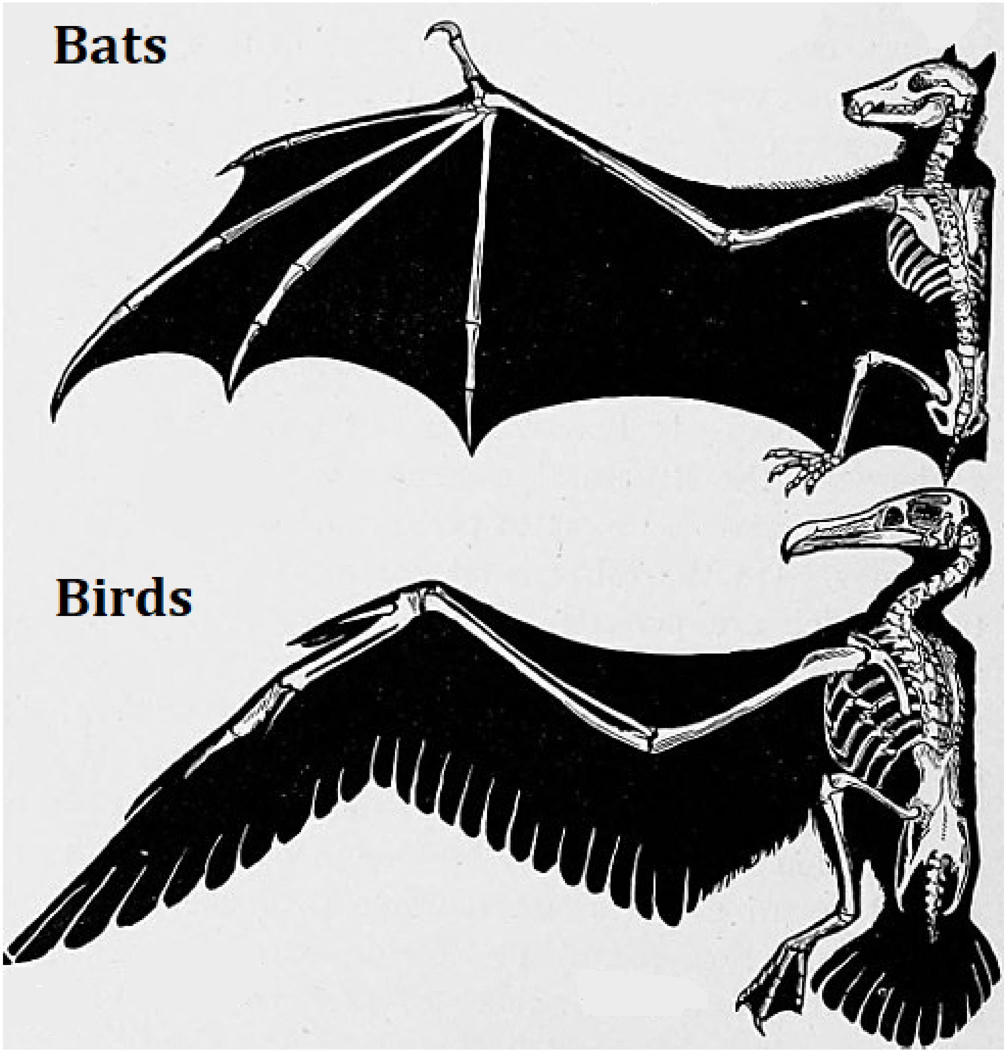
analogous structure are structures that are similar in unrelated organisms. The structures are similar because they evolved to do the same job, not because they were inherited from a common ancestor. For example, the wing of bats and bird, shown in the **Figure** below, look similar on the outside. They also have the same function. However, wings evolved independently in the two groups of animal. This is apparent when you compare the pattern of bones inside the wings.

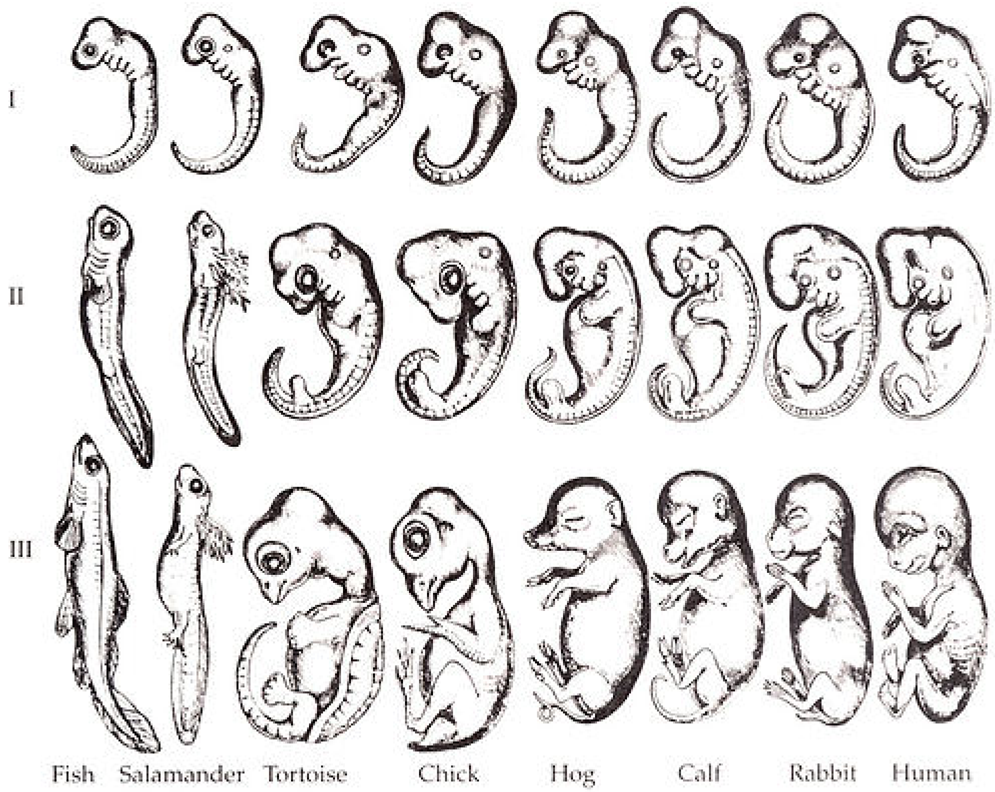


[Figure 3]

The wings of bats and birds serve the same function. Look closely at the bones inside the wings. The differences show they developed from different ancestors.

Comparative Embryology

comparative embryology is the study of the similarities and differences in the embryos of different species. Similarities in embryos are evidence of common ancestry. All vertebrate embryos, for example, have gill slits and tails (see the **Figure** below). Most vertebrates, except for fish, lose their gill slits by adulthood. Some of them also lose their tail. In humans, the tail is reduced to the tail bone. Thus, similarities organisms share as embryos may be gone by adulthood. This is why it is valuable to compare organisms in the embryonic stage.

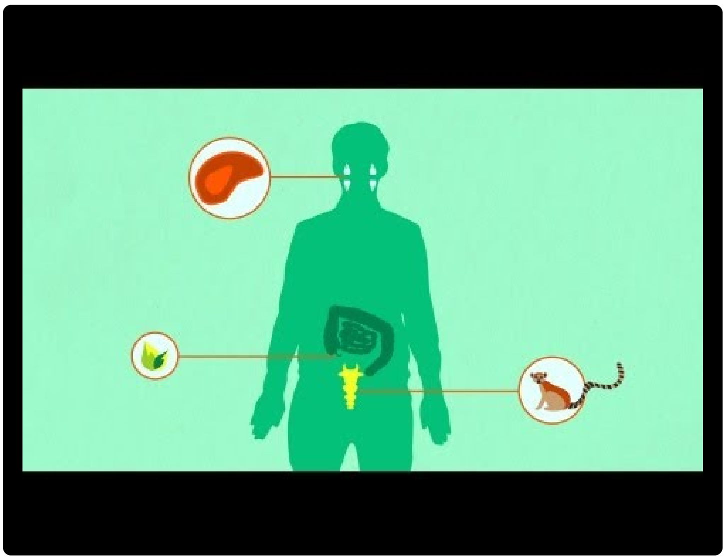


[Figure 4]

A comparison of the embryos of different vertebrates.

Vestigial Structures

Structures like the human tail bone and whale pelvis are called **vestigial structures**. Evolution has reduced their size because the structures are no longer used. The human appendix is another example of a vestigial structure. It is a tiny remnant of a once-larger organ. In a distant ancestor, it was needed to digest food. Why do you think structures that are no longer used shrink in size? Why might a full-sized, unused structure reduce an organism's fitness?



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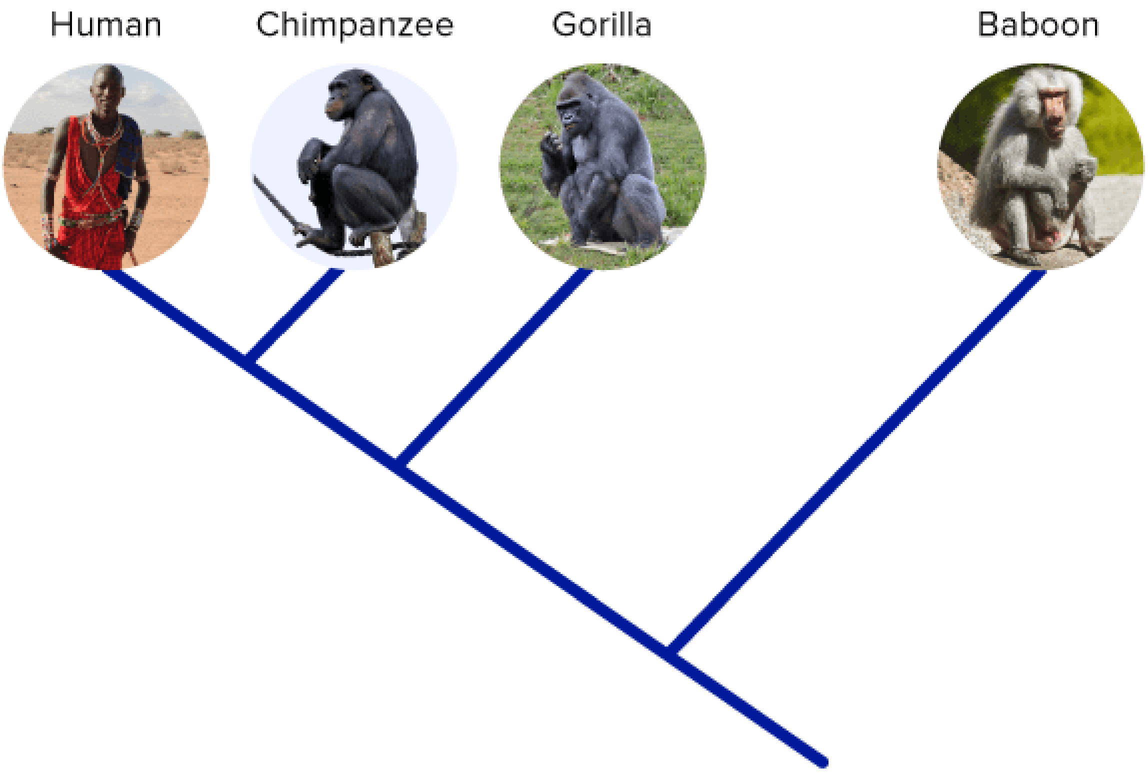
Comparing DNA

Darwin could compare only the anatomy and embryos of living things. Today, scientists can compare their DNA. Similar DNA sequences are the strongest evidence for evolution from a common ancestor. More similarities in the DNA sequence is evidence for a closer evolutionary relationship. Look at the cladogram in the **Figure** below. It shows how humans and apes are related based on their DNA sequences.



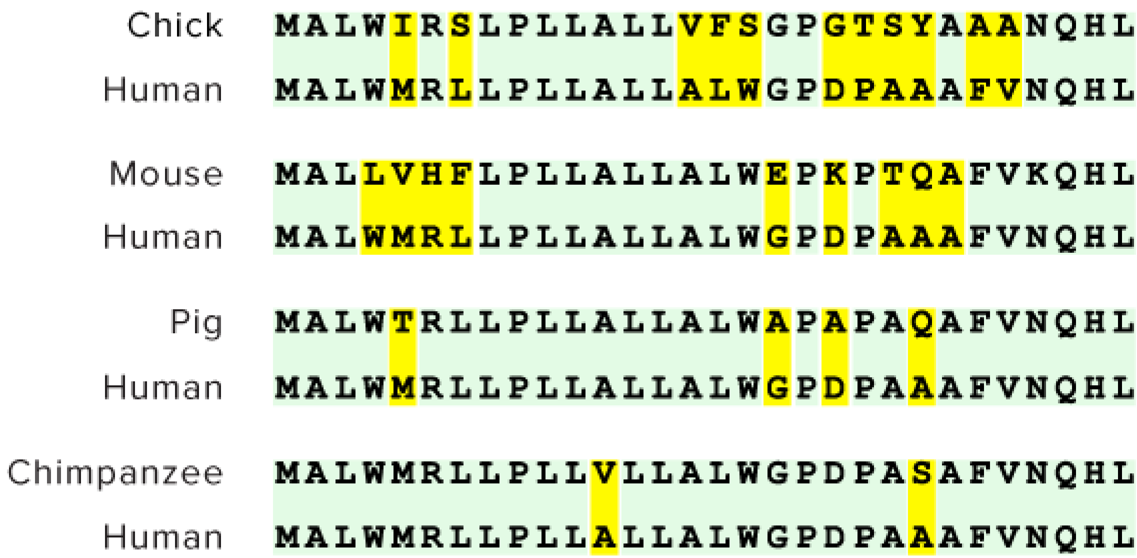
[Figure 5]

Cladogram of Humans and Apes. This cladogram is based on DNA comparisons. It shows how humans are related to apes by descent from common ancestors.

The same biochemical building blocks, such as amino acid and nucleotide, are found in all organisms, from bacterium to plants and animals. Recall that amino acids are the building blocks of protein, and nucleotides are the building blocks of DNA and RNA. DNA and RNA determine the development of all organisms. The similarities and differences between the genomes confirm patterns of evolution.

Which species is more closely related to humans?

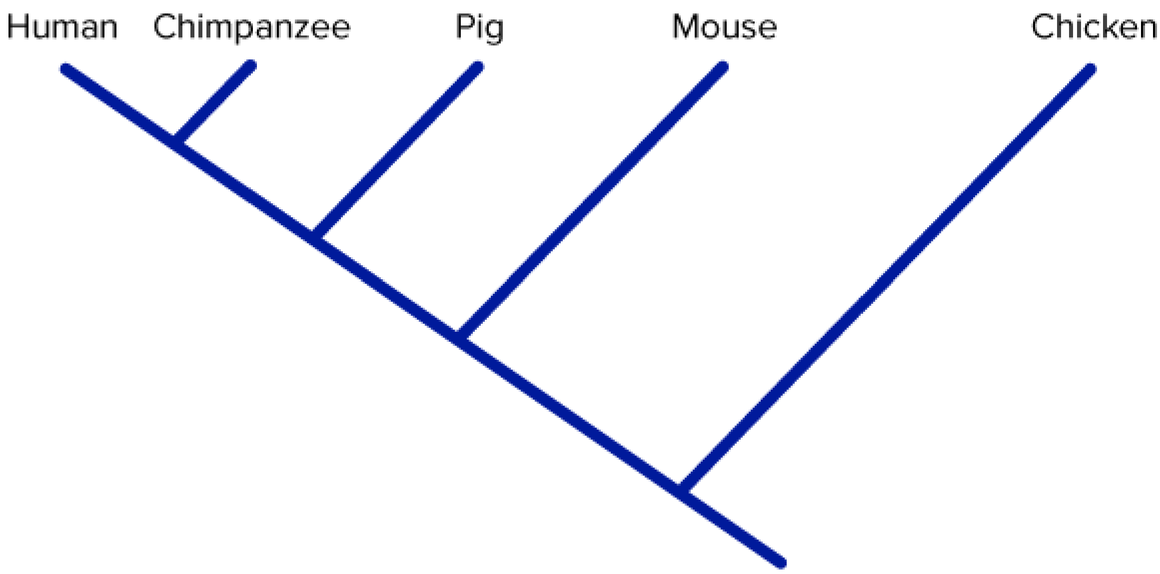
Compare the first 30 amino acids of the insulin precursor protein in the different organisms below to help infer how closely two species are related. Select one of the organisms to compare the amino acid sequence to humans. The green areas represent the similarities, and the yellow regions represent the differences in the amino acid sequences.



Based on your analysis of the information above:

A mouse is more closely related to humans than a ____________

A pig is more closely related to humans compared to a mouse. ____________



[Figure 6]

Cladogram based on an insulin precursor protein sequence comparison among different vertebrates.

Summary

- Scientists compare the anatomy, embryos, and DNA of living things to understand how they evolved.
- Evidence for evolution is provided by homologous structures. These are structures shared by related organisms that were inherited from a common ancestor.
- Other evidence for evolution is provided by analogous structures. These are structures that unrelated organisms share because they evolved to do the same job.
- Comparing DNA sequences provided some of the strongest evidence of evolutionary relationships.

Review

1. What are vestigial structures? Give an example.
2. Compare homologous and analogous structures.
3. Why do vertebrate embryos show similarities between organisms that do not appear in the adults?
4. Humans and apes have five fingers they can use to grasp objects. Do you think these are analogous or homologous structures? Explain.
5. What is the strongest evidence of evolution from a common ancestor?

Report Content Errors

5.17 Biogeography

FlexBooks 2.0 > Biology For High School Diploma > Biogeography

Last Modified: Apr 18, 2022

What you will learn

- How has geography influenced the evolution of plants and animal
- Examples of biogeography that provide evidence for evolution

---

[Figure 1]

Why would geography have anything to do with evolution?

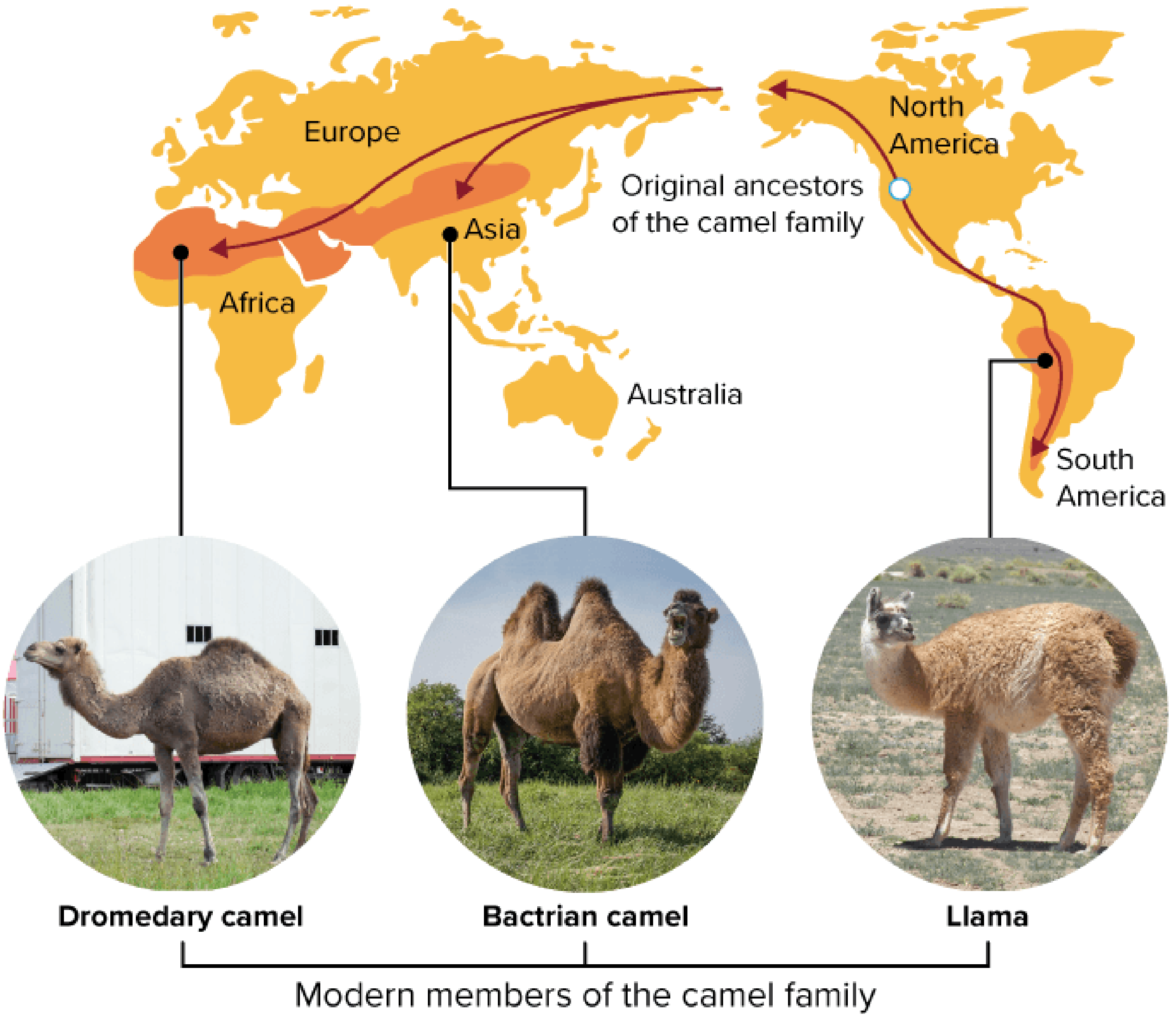
Similar to "how did the chicken cross the road?" but on a much grander scale. How did the animal cross Europe and into Asia? Or Asia into America? How did anything get into Australia?

Evidence from Biogeography

Biogeography is the study of how and why plants and animals live where they do. It provides more evidence for evolution. Let's consider the camel family as an example.

Biogeography of Camels: An Example

Today, the camel family includes different types of camels. They are shown in **Figure** below. All of today's camels are descended from the same camel ancestors. These ancestors lived in North America about a million years ago.



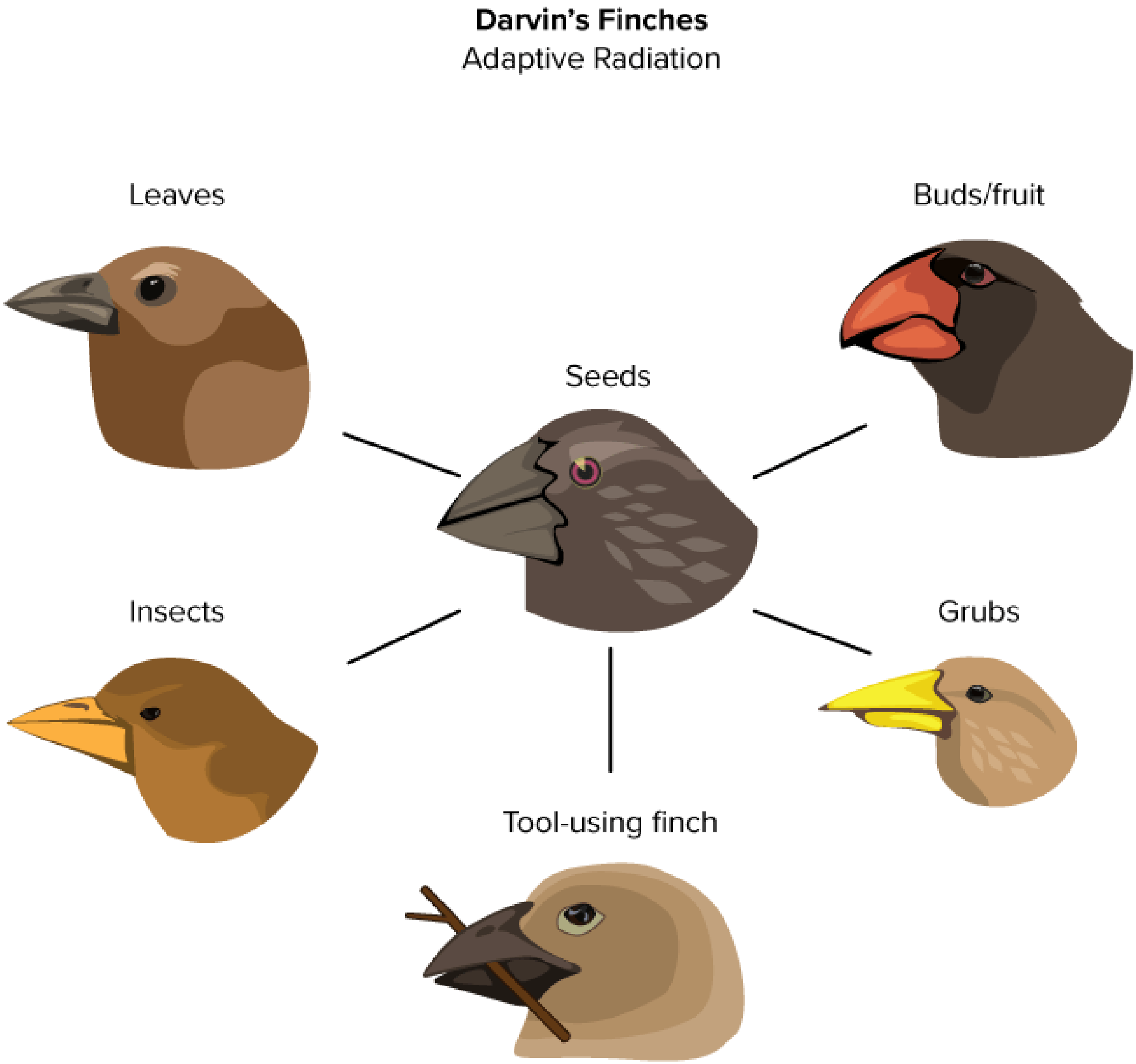
[Figure 2]

Camel Migrations and Present-Day Variation. Members of the camel family now live in different parts of the world. They differ from one another in a number of traits. However, they share basic similarities. This is because they all evolved from a common ancestor. What differences and similarities do you see?

Early North American camels migrated to other places. Some went to East Asia. They crossed a land bridge during the last ice age. A few of them made it all the way to Africa. Others went to South America. They crossed the Isthmus of Panama. Once camels reached these different places, they evolved independently. They evolved adaptation that suited them for the particular environment where they lived. Through natural selection, descendants of the original camel ancestors evolved the diversity they have today.

Island Biogeography

The biogeography of islands yields some of the best evidence for evolution. Consider the bird called finches that Darwin studied on the Galápagos Islands (see **Figure** below). All of the finches probably descended from one bird that arrived on the islands from South America. Until the first bird arrived, there had never been birds on the islands. The first bird was a seed eater. It evolved into many finch species. Each species was adapted for a different type of food. This is an example of **adaptive radiation**. This is the process by which a single species evolves into many new species to fill available niches.



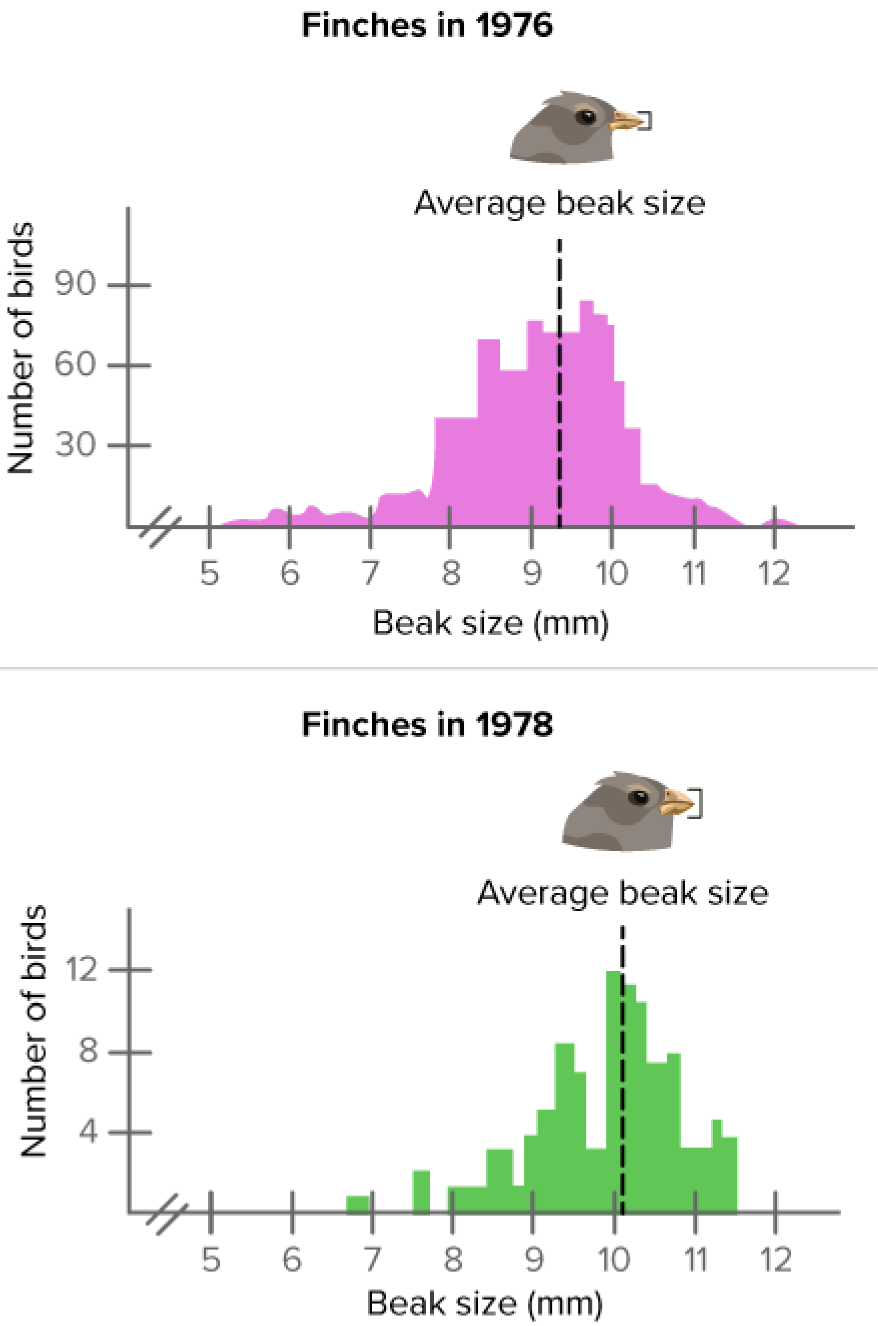
[Figure 3]

Galápagos finches differ in beak size and shape, depending on the type of food they eat.

Eyewitness to Evolution

In the 1970s, biologists Peter and Rosemary Grant went to the Galápagos Islands. They wanted to re-study Darwin's finches. They spent more than 30 years on the project. Their efforts paid off. They were able to observe evolution by natural selection actually taking place.

While the Grants were on the Galápagos, a drought occurred. As a result, fewer seeds were available for finches to eat. Birds with smaller beak could crack open and eat only the smaller seeds. Birds with bigger beaks could crack and eat seeds of all sizes. As a result, many of the small-beaked birds died in the drought. Birds with bigger beaks survived and reproduced (see **Figure** below). Within 2 years, the average beak size in the finch population increased. Evolution by natural selection had occurred.



[Figure 4]

Evolution of Beak Size in Galápagos Finches. The top graph shows the beak sizes of the entire finch population studied by the Grants in 1976. The bottom graph shows the beak sizes of the survivors in 1978. In just 2 years, beak size increased.

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Check your understanding!

PROGRESS 0 / 3

1. Which statement(s) are correct for Peter and Rosemary Grant's study on Darwin's finches done in the 1970s?

SELECT ALL THAT APPLY

a Birds with bigger beaks survived the drought and reproduced.

b Birds with smaller beak size survived the drought and reproduced.

c After two years of drought, the average beak size had increased.

d The Grant study could prove the evolution of finches by natural selection.

Check It

Hint

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Summary

- Biogeography is the study of how and why plants and animals live where they do. It also provides evidence for evolution.
- On island chains, such as the Galápagos, one species may evolve into many new species to fill available niches. This is called adaptive radiation.

Review

1. Define biogeography.
2. Describe an example of island biogeography that provides evidence of evolution.
3. Describe the effects of the drought on the Galápagos Islands observed by the Grants.

Report Content Errors

5.18 Population Genetics

FlexBooks 2.0 > Biology For High School Diploma > Population Genetics

Last Modified: May 02, 2022

What you will learn

- How genetic changes in population lead to **microevolution** and **macroevolution**
- What is a **gene pool**
- How changes in **allele frequency** result in evolution

[Figure 1]

Jeans vs. Genes. What's the difference?

Plenty. One you have for life, the other just lasts a few years. One is the basis for the passing of traits from one generation to the next. Some jeans you change frequently. But what happens when you change a gene's frequency? Essentially, evolution is a change in gene frequencies within a population.

Genes in Populations

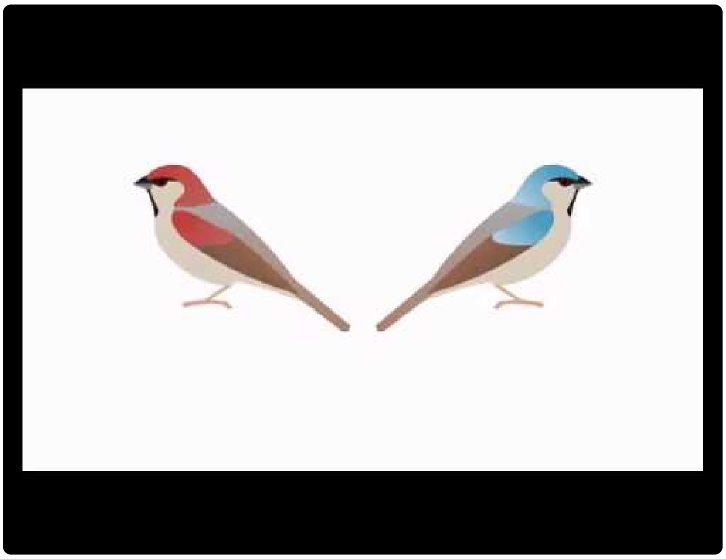
Darwin knew that heritable variations are needed for evolution to occur. However, he knew nothing about Mendel's laws of genetics. Mendel's laws were rediscovered in the early 1900s. Only then could scientists fully understand the process of evolution. We now know that variations of traits are heritable. These variations are determined by different **allele**. We also know that evolution is due to a change in alleles over time. How long a time? That depends on the scale of evolution.

- **Microevolution** occurs over a relatively short period of time within a population or species. The Grants observed this level of evolution in Darwin's finches.
- **Macroevolution** occurs over geologic time above the level of the species. The fossil record reflects this level of evolution. It results from microevolution taking place over many generations.

Remember that individuals do not evolve. Their **genes** do not change over time. The unit of evolution is the population. A **population** consists of organism of the same species that live in the same area. In terms of evolution, the population is assumed to be a relatively closed group. This means that most mating takes place within the population. The science that focuses on evolution within populations is **population genetics**. It is a combination of evolutionary theory and Mendelian genetics.

Gene Pool

The genetic makeup of an individual is the individual's **genotype**. A population consists of many genotypes. Altogether, they make up the population's gene pool. The **gene pool** consists of all the genes of all the members of the population. For each gene, the gene pool includes all the different alleles for the gene that exist in the population. For a given gene, the population is characterized by the frequency of the different alleles in the gene pool.



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Allele Frequencies

Allele frequency is how often an allele occurs in a gene pool relative to the other alleles for that gene. Look at the example in the **Table** below. The population in the table has 100 members. In a sexually reproducing species, each member of the population has two copies of each gene. Therefore, the total number of copies of each gene in the gene pool is 200. The gene in the example exists in the gene pool in two forms, alleles *A* and *a*. Knowing the genotypes of each population member, we can count the number of alleles of each type in the gene pool. The table shows how this is done.

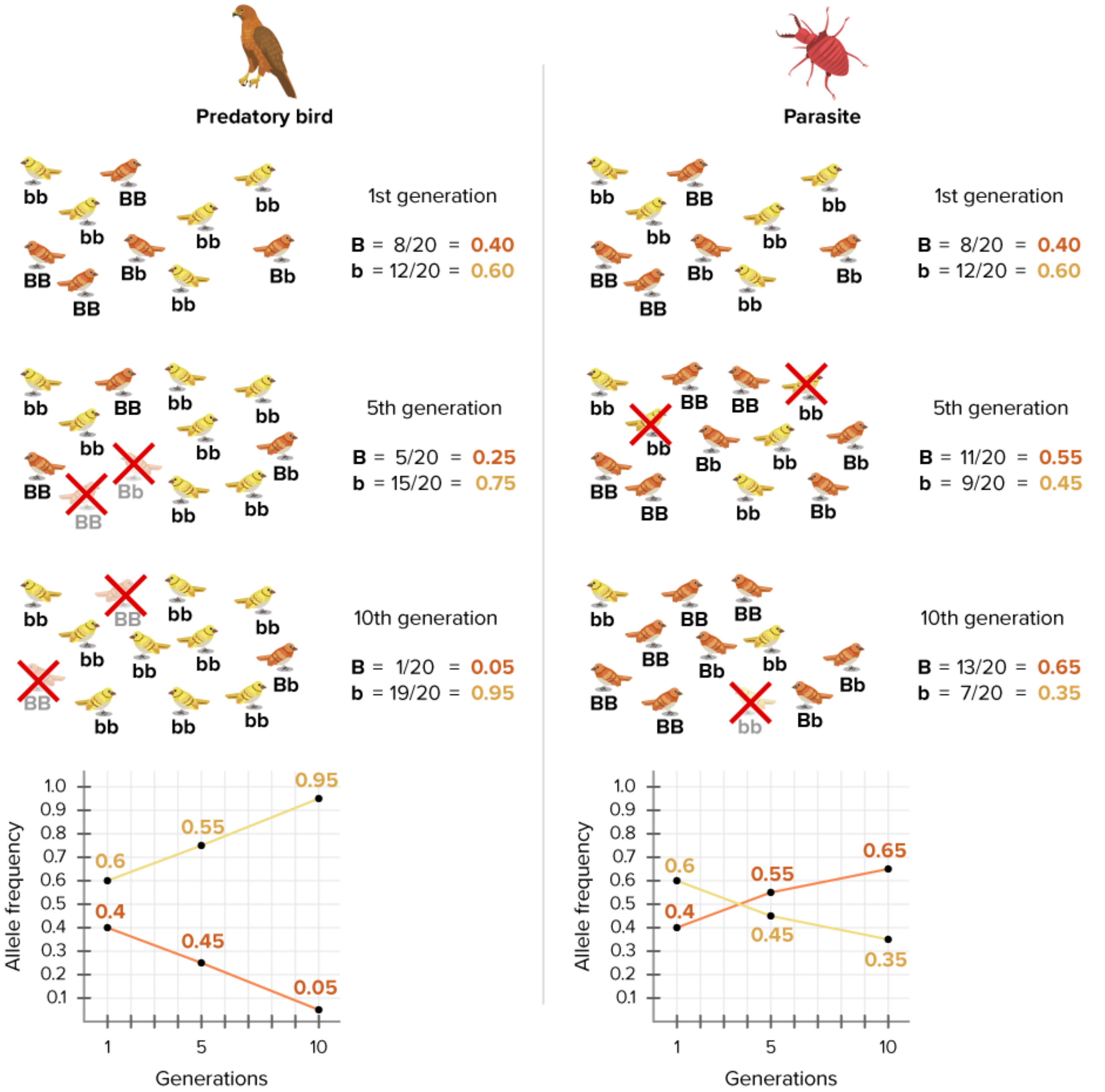
Genotype	Number of Individuals in the Population with that Genotype	Number of Allele *A* Contributed to the Gene Pool by that Genotype	Number of Allele *a* Contributed to the Gene Pool by that Genotype
AA	50	50 × 2 = 100	50 × 0 = 0
Aa	40	40 × 1 = 40	40 × 1 = 40
aa	10	10 × 0 = 0	10 × 2 = 20
Totals	100	140	60

Let the letter p stand for the frequency of allele A. Let the letter q stand for the frequency of allele a. We can calculate p and q as follows:

- p = number of A alleles/total number of alleles = 140/200 = 0.7
- q = number of a alleles/total number of alleles = 60/200 = 0.3
- Notice that $p + q = 1$.

Evolution occurs in a population when allele frequencies change over time. The example below shows how allele frequencies change in a population of sparrows over several generations due to external influences. It demonstrates the effect of a predatory bird that chooses brown-colored sparrows because they are easier to find in a given environment and a parasitic insect to which the yellow-colored sparrows are particularly vulnerable.

How do allele frequencies change in a population?



Check your understanding!

PROGRESS 0 / 3

1. An insecticide that was known to kill a specific type of beetle was suddenly found to be ineffective on a small group of beetles in a population, over a few generations. This was due to the resistance developed by this group as a result of a genetic mutation. This is an example of macroevolution.

TRUE

FALSE

Check It

Hint

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Summary

- Microevolution occurs over a short period of time in a population or species. Macroevolution occurs over geologic time above the level of the species.
- The population is the unit of evolution.
- A population's gene pool consists of all the genes of all the members of the population.
- For a given gene, the population is characterized by the frequency of different alleles in the gene pool.

Review

1. Compare microevolution to macroevolution.
2. Why are populations, rather than individuals, the units of evolution?
3. What is a gene pool?
4. Assume that a population of 50 individuals has the following numbers of genotypes for a gene with two alleles, *B* and *b*: *BB* = 30, *Bb* = 10, and *bb* = 10. Calculate the frequencies of the two alleles in the population's gene pool.

5.19 Hardy-Weinberg

FlexBooks 2.0 > Biology For High School Diploma > Hardy-Weinberg

Last Modified: Apr 18, 2022

What you will learn

- What is the **Hardy-Weinberg theorem**
- When is a population in Hardy-Weinberg equilibrium

[Figure 1]

Why is balance important?

To these individuals, the importance of maintaining balance is obvious. If balance, or equilibrium, is maintained within a population's gene, can evolution occur? No. But maintaining this type of balance today is difficult.

The Hardy-Weinberg Theorem

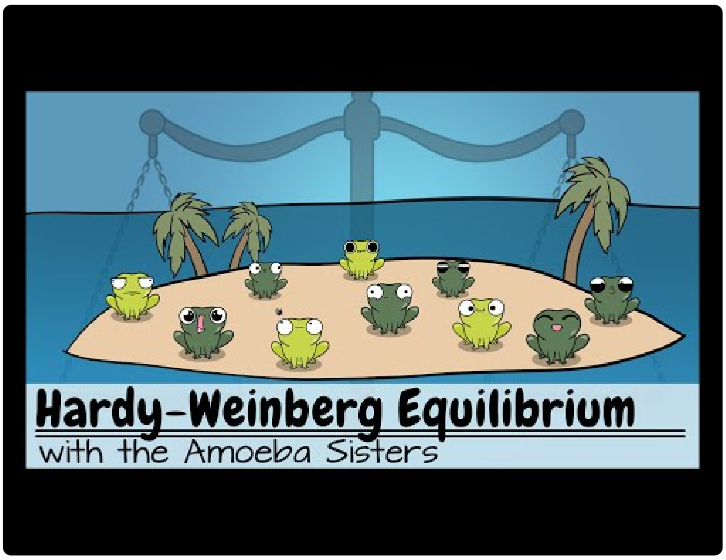
Godfrey Hardy was an English mathematician. Wilhelm Weinberg was a German doctor. Each worked alone to come up with the founding principle of population genetics. Today, that principle is called the **Hardy-Weinberg theorem**. It shows that allele frequency do not change in a population if certain conditions are met. Such a population is said to be in **Hardy-Weinberg equilibrium**. The conditions for equilibrium are:

1. No new **mutation** are occurring. Therefore, no new allele are being created.
2. There is no **migration**. In other words, no one is moving into or out of the population.
3. The population is very large.
4. mating is at random in the population. This means that individuals do not choose mates based on genotype.
5. There is no natural selection. Thus, all members of the population have an equal chance of reproducing and passing their genes to the next generation.

These five conditions rarely occur in nature. When one or more of the conditions does not exist, then evolution can occur. As a result, allele frequencies are constantly changing, and populations are constantly evolving. As mutations and natural selection occur frequently in nature, it is difficult for a population to be at genetic equilibrium. When all these conditions are met, allele frequencies stay the same. Genotype frequencies also remain constant. In addition, genotype frequencies can be expressed in terms of allele frequencies, as the **Table** below shows.

Hardy and Weinberg used mathematics to describe an equilibrium population (p = frequency of A, q = frequency of a, so $p + q = 1$): $p^2 + 2pq + q^2 = 1$. Using the genotype frequencies shown in **Table** below, if $p = 0.4$, what is the frequency of the AA genotype?

Genotype	Genotype Frequency
AA	p^2
Aa	$2pq$
aa	q^2



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Summary

- The Hardy-Weinberg theorem states that, if a population meets certain conditions, it will be in equilibrium.
- In an equilibrium population, allele and genotype frequencies do not change over time.
- The conditions that must be met are no mutation, no migration, very large population size, random mating, and no natural selection.

Review

1. Describe a Hardy-Weinberg equilibrium population. What conditions must it meet to remain in equilibrium?
2. Assume that a population is in Hardy-Weinberg equilibrium for a particular gene with two alleles, *A* and *a*. The frequency of *A* is p, and the frequency of *a* is q. Because these are the only two alleles for this gene, $p + q = 1.0$. If the frequency of homozygous recessive individuals (*aa*) is 0.04, what is the value of q? What is the value of p?
3. Use the values of p and q from question 2 to calculate the frequency of the heterozygote genotype (*Aa*).

Report Content Errors

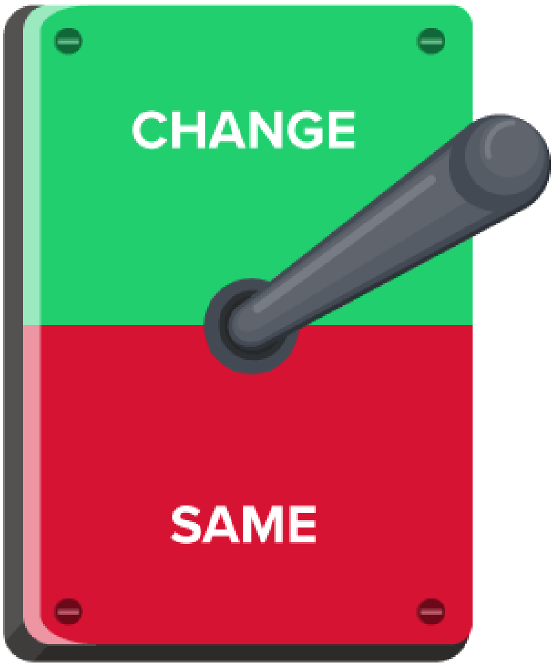
5.20 Forces of Evolution

FlexBooks 2.0 > Biology For High School Diploma > Forces of Evolution

Last Modified: Apr 25, 2022

What you will learn

- What are the forces of evolution
- What is **genetic drift** and how does it happen



[Figure 1]

How do a population's genes change?

Remember, without change, there cannot be evolution. Together, the forces that change a population's gene frequencies are the driving mechanisms behind evolution.

Forces of Evolution

The conditions for Hardy-Weinberg equilibrium are unlikely to be met in real population. The Hardy-Weinberg theorem also describes populations in which allele frequency are not changing. By definition, such populations are not evolving. How does the theorem help us understand evolution in the real world?

From the theorem, we can infer factors that cause allele frequencies to change. These factors are the "forces of evolution." There are four such forces: mutation, **gene flow**, genetic drift, and natural selection.

Mutation

Mutations create new genetic variations in a gene pool. It is how all new allele first arise. In sexually reproducing species, the mutations that matter for evolution are those that occur in gamete. Only these mutations can be passed to offspring. For any given gene, the chance of a mutation occurring in a given gamete is very low. Thus, mutations alone do not have much effect on allele frequencies. However, mutations provide the genetic variation needed for other forces of evolution to act.

Gene Flow

Gene flow occurs when individuals move into or out of a population. If the rate of migration is high, this can have a significant effect on allele frequencies. The allele frequencies of both the population they leave and the population they enter may change.

For example, wind or animal can carry pollen or seed from one plant population to another. In baboon troops or wolf packs, juvenile males may leave the group to find mates and establish separate populations. Human history includes countless migrations; gene flow continues to mix gene pools and cause microevolutionary changes.

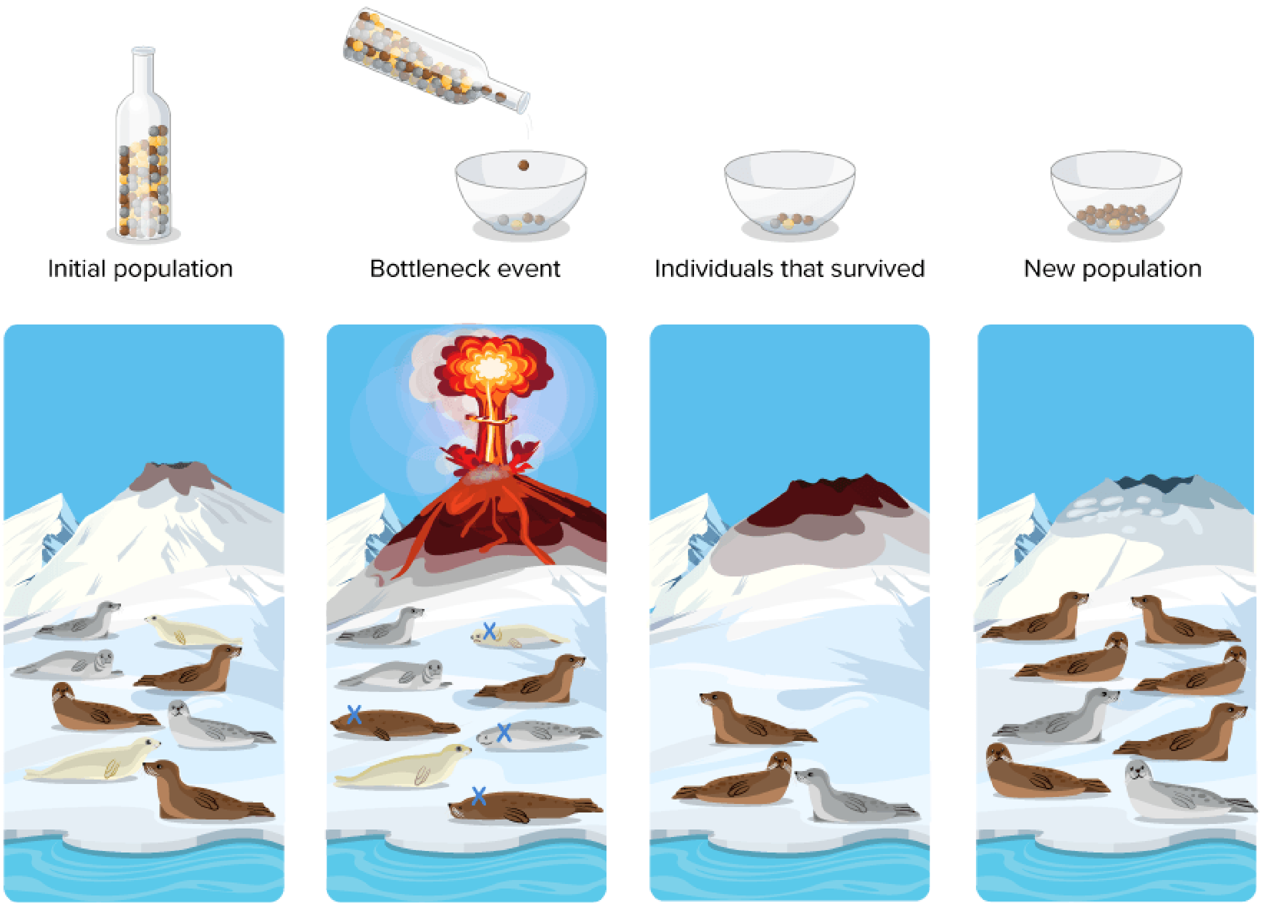
Genetic Drift

Genetic drift is a random change in allele frequencies that occurs in a small population. When a small number of parents produce just a few offspring, allele frequencies in the offspring may differ, by chance, from allele frequencies in the parents.

This is like tossing a coin. If you toss a coin just a few times, you may, by chance, get more or less than the expected 50 percent heads or tails. In a small population, you may also, by chance, get different allele frequencies than expected in the next generation. In this way, allele frequencies may drift over time.

There are two special conditions under which genetic drift occurs. They are called bottleneck effect and founder effect.

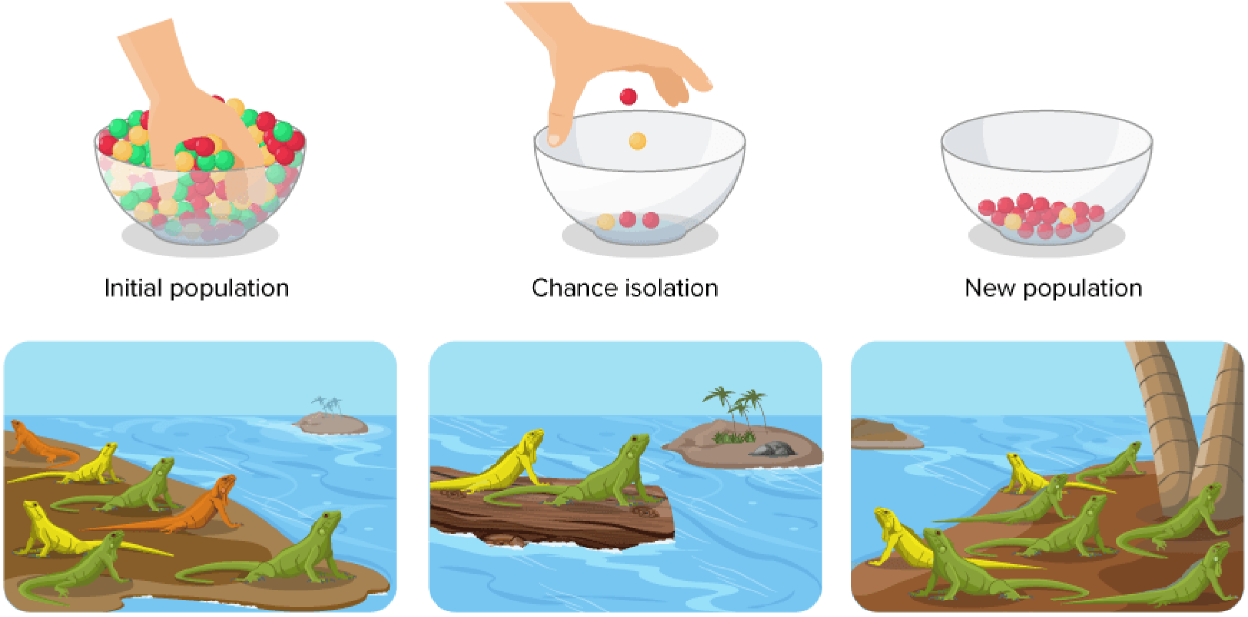
1. **Bottleneck effect** occurs when a population suddenly gets much smaller. This might happen because of a natural disaster such as a forest fire or a volcanic eruption (see the **Figure** below). By chance, allele frequencies of the survivors may be different from those of the original population.



[Figure 2]

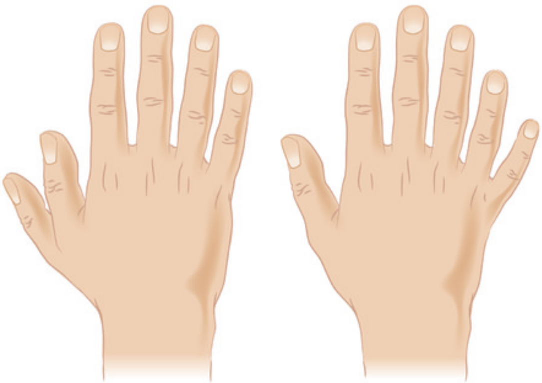
The bottleneck effect: The seal population on the island is reduced due to a volcanic eruption. The surviving individuals form the new population with different allele frequencies than the original population.

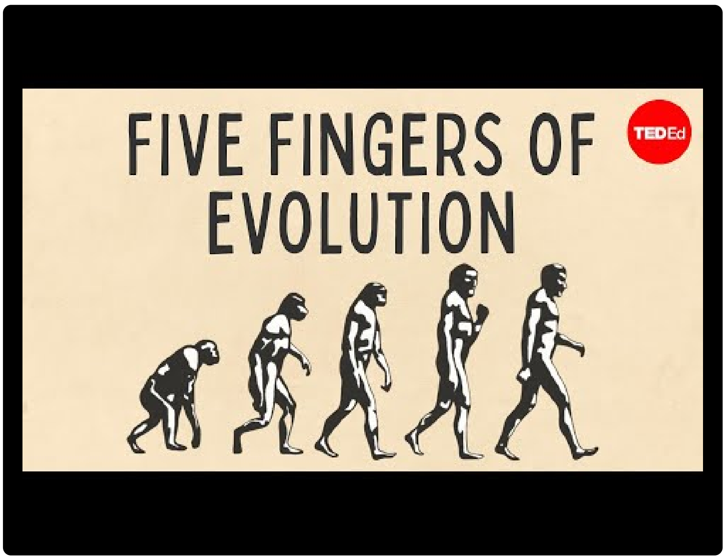
1. **Founder effect** occurs when a few individuals start, or found, a new population. By chance, allele frequencies of the founders may be different from allele frequencies of the population they left. An example is described in the **Figure** below.



[Figure 3]

The founder effect: A few lizards are isolated from the main population of lizards from a continent by chance and drift to a distant island. Their numbers gradually increase on the new island, but the allele frequencies of the new population are different compared to the original population.

<table>
<tr><th colspan="2">Founder Effect in the Amish Population</th></tr>
<tr><td>
[Figure 4]</td><td>Who Are the Amish?
There are almost 250,000 Amish people in the U.S. and Canada today. They live in small rural community, mainly in Ohio, Pennsylvania, and New York.
The present Amish population grew from 200 founders, who came to the U.S. from Germany and Switzerland in the mid-1700s.
Since then, the Amish have followed a simple lifestyle. For example, they do not own cars and instead travel by horse and buggy.
Amish people also rarely intermarry with people outside the Amish population.</td></tr>
<tr><td>
[Figure 5]</td><td>Founder Effect and the Amish Gene pool
One of the original 200 Amish founders carries a recessive allele for a rare condition. Called Ellis-van Creveld syndrome, the condition is a type of dwarfism. People with the syndrome have extra fingers and short limbs.
Today, the Amish population has far more cases of this syndrome than any other population in the world.</td></tr>
</table>



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Check your understanding!

PROGRESS 0 / 3

1. Modern horses have only single-toed hooves. However, their early ancestors had several toes which were lost over millions of years of evolution. Which force of evolution could have most likely resulted in this?

a gene flow

b genetic drift

c mutation

Check It

Hint

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Summary

- There are four forces of evolution: mutation, gene flow, genetic drift, and natural selection.
- Mutations create new genetic variations in a gene pool.
- Gene flow and genetic drift alter allele frequencies in a gene pool.

Review

1. Identify the four forces of evolution.
2. Why is mutation needed for evolution to occur, even though it usually has little effect on allele frequencies?
3. What is founder effect? Give an example.
4. Explain why genetic drift is most likely to occur in a small population.

5.21 Natural Selection

FlexBooks 2.0 > Biology For High School Diploma > Natural Selection

Last Modified: Apr 18, 2022

What you will learn

- What is natural selection and how does it affect allele frequency
- The three ways that natural selection affects the phenotype of polygenic trait

[Figure 1]

What is fitness?

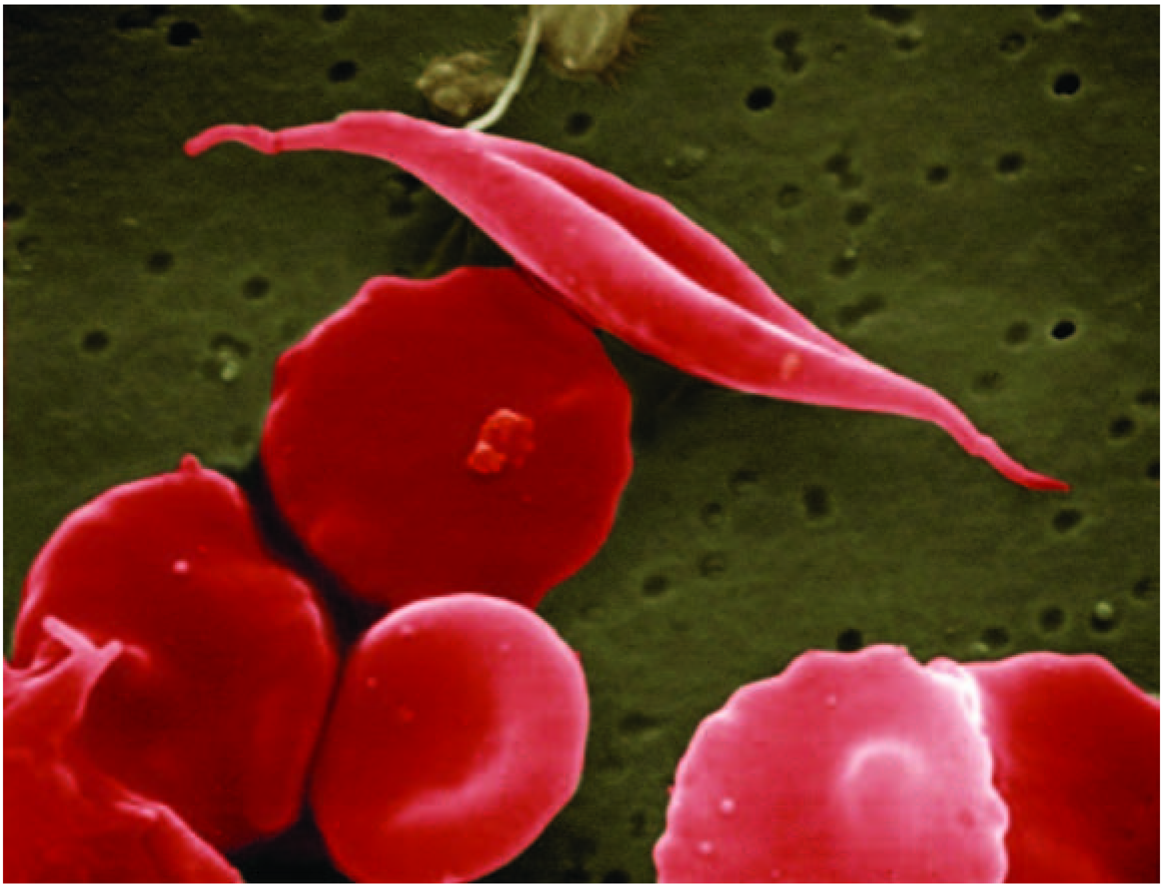
Does this type of fitness have anything to do with natural selection? Usually not. There are countless ways in which an organism can be more "fit," or better adapted to its habitat. And we probably do not know about most of these adaptation.

Natural Selection

Natural selection occurs when there are differences in fitness among members of a population. As a result, some individuals pass more gene to the next generation. This causes allele frequencies to change.

Sickle Cell and Natural Selection

The example of sickle-cell anemia is described in the **Figure** below and the **Table** below. It shows how natural selection can keep a harmful allele in a gene pool.



[Figure 2]

Sickle Cell and Natural Selection. Notice the normal-shaped red blood cell and the sickle-shaped cell.

Genotype	Phenotype	Fitness
AA	100% normal hemoglobin	Somewhat reduced fitness because of no resistance to malaria
AS	Enough normal hemoglobin to prevent sickle-cell anemia	Highest fitness because of resistance to malaria
SS	100% abnormal hemoglobin, causing sickle-cell anemia	Greatly reduced fitness because of sickle-cell anemia

Here's how natural selection can keep a harmful allele in a gene pool:

- The allele (*S*) for sickle-cell anemia is a harmful autosomal recessive. It is caused by a mutation in the normal allele (*A*) for hemoglobin (a protein on red blood cells). This genetic disorder results in sickle-shaped red blood cell that clog tiny blood vessel, causing pain and damaging organ and joint.
- Malaria is a deadly tropical disease caused by a parasite, *Plasmodium* protozoan. The parasites are spread by a mosquito vector. Parasites enter a host's blood through the bite of an infected mosquito. The parasites infect the host's red blood cells, causing symptoms such as fever, joint pain, anemia, and fatigue.
- heterozygote (*AS*) with the sickle-cell allele are resistant to malaria. Therefore, they are more likely to survive and reproduce. This keeps the *S* allele in the gene pool.

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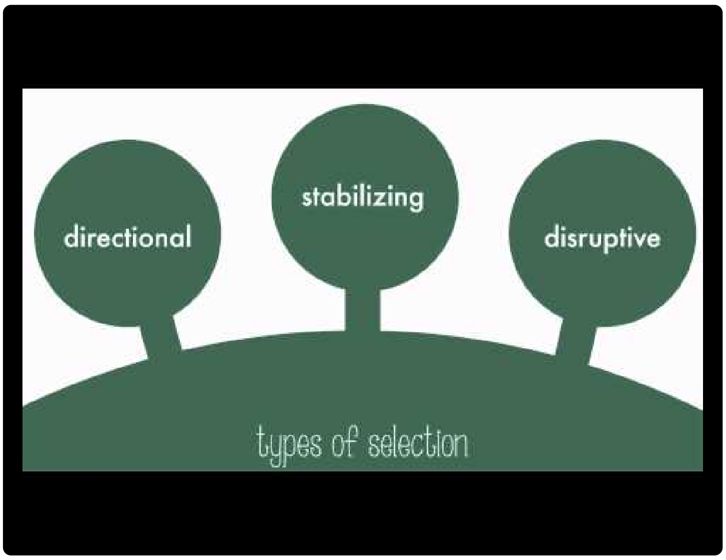
The sickle-cell example shows that fitness depends on phenotypes. It also shows that fitness may depend on the environment. What do you think might happen if malaria was eliminated in an African population with a relatively high frequency of the *S* allele? How might the fitness of the different genotype change? How might this affect the frequency of the *S* allele?

Natural Selection and Polygenic Traits

Sickle-cell trait is controlled by a single gene. Natural selection for polygenic traits is more complex, unless you just look at phenotypes. Three ways that natural selection can affect the phenotype of polygenic traits includes **stabilizing selection**, **directional selection**, and **disruptive selection**.



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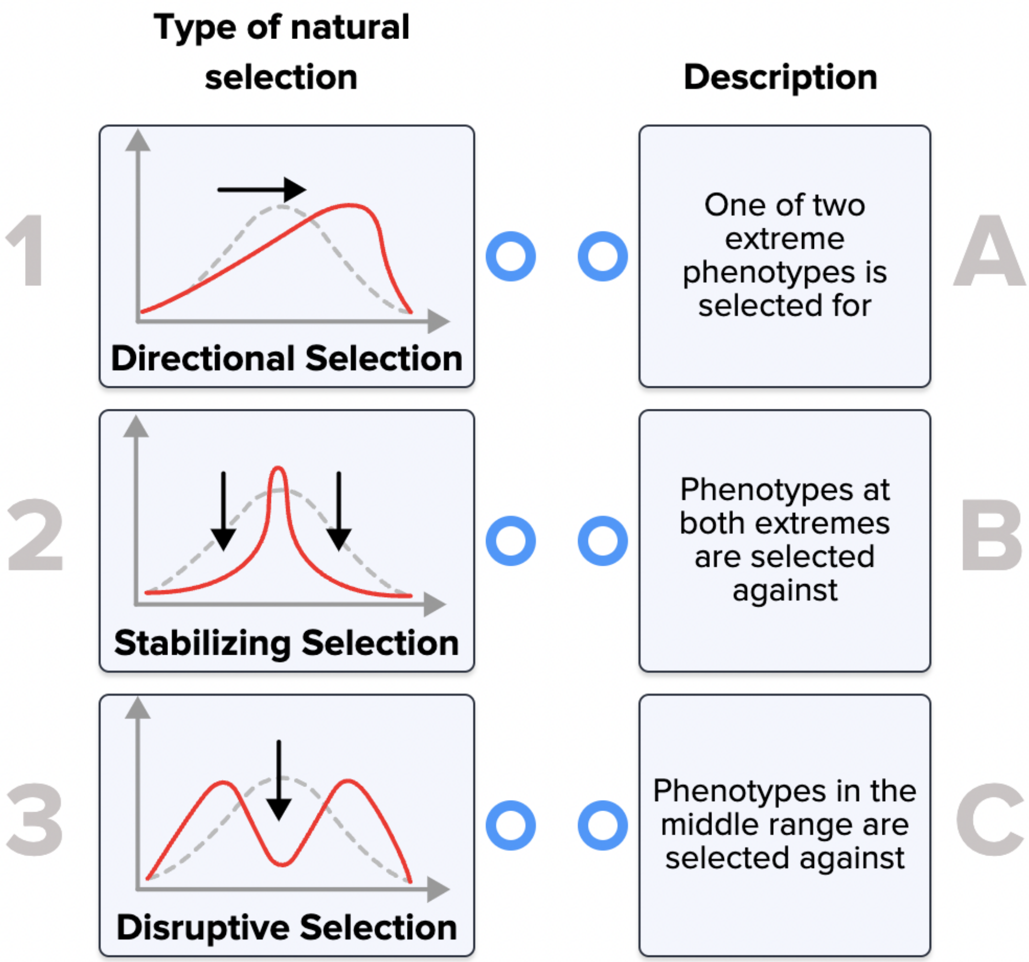
1. **Stabilizing selection** occurs when phenotypes at both extremes of the phenotypic distribution are selected against. This narrows the range of variation. An example is human birth weight. Babies that are very large or very small at birth are less likely to survive. This keeps birth weight within a relatively narrow range.
2. **Directional selection** occurs when one of two extreme phenotypes is selected for. This shifts the distribution toward that extreme. This is the type of natural selection that the Grants observed in the beak size of Galápagos finches.
3. **Disruptive selection** occurs when phenotypes in the middle of the range are selected against. This results in two overlapping phenotypes, one at each end of the distribution. An example is **sexual dimorphism**. This refers to differences between the phenotypes of males and females of the same species. In humans, for example, males and females have different heights and body shapes.



Answers: 1-A, 2-B, 3-C

Check your understanding!

PROGRESS 0 / 3

1.
Which of the statement (s) are correct for stabilizing selection?

SELECT ALL THAT APPLY

a Stabilizing selection selects against individuals with extreme traits and favors individuals with average traits.

b Stabilizing selection drives the population towards average traits.

c The phenotypic distribution of traits under stabilizing selection shows a narrow bell-shaped curve.

d Stabilizing selection favors individuals with extreme traits and selects against individuals with average traits.

Check It

Hint

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Summary

- Natural selection occurs when there are differences in fitness among members of a population.
- Sickle-cell anemia shows how natural selection can keep a harmful allele in a gene pool.
- Natural selection for a polygenic trait changes the distribution of phenotypes. It may have a stabilizing, directional, or disruptive effect on the phenotype distribution.

Review

1. What is natural selection and what are its effects on allele frequencies?
2. Describe three types of natural selection for a polygenic trait.
3. How does the recessive sickle-cell allele stay in the gene pool?

Report Content Errors

5.22 Origin of Species

FlexBooks 2.0 > Biology For High School Diploma > Origin of Species

Last Modified: Apr 18, 2022

What you will learn

- How new **species** evolve through **speciation**
- Allopatric and **sympatric speciation**

[Figure 1]

How can a river influence evolution?

Imagine a group of small organism, such as mice, that become separated by a mighty river. This group has now become isolated and formed two separate groups. The groups are obviously no longer able to breed together. Over many generations, each group will evolve separately, eventually forming two completely new species of mice.

Origin of Species

macroevolution is evolution over geologic time above the level of the species. One of the main topics in macroevolution is how new species arise. The process by which a new species evolves is called **speciation**. How does speciation occur? How does one species evolve into two or more new species?

To understand how a new species forms, it's important to review what a species is. A **species** is a group of organisms that can breed and produce fertile offspring together in nature. For a new species to arise, some members of the species must become reproductively isolated from the rest of the species. This means they can no longer interbreed with other members of the species. How does this happen? Usually, they become geographically isolated first.

Allopatric Speciation

Assume that some members of a species become geographically separated from the rest of the species. If they remain separated long enough, they may evolve genetic differences. If the differences prevent them from interbreeding with members of the original species, they have evolved into a new species. Speciation that occurs in this way is called **allopatric speciation**. An example is described in the **Table** below.

 [Figure 2]	• Kaibab squirrels are found only on the north rim of the Grand Canyon, on the Kaibab plateau. • Kaibab squirrels became geometrically isolated from Albert's squirrels, which are found on the south rim of the canyon. • In isolation, Kaibab squirrels evolved distinct characteristics, such as a completely white tail. • Kaibab squirrels are currently classified as a sub-species of Albert's squirrels. • Kaibab squirrels may eventually become different enough to be classified as a separate species.
 [Figure 3]	• Albert's squirrels occupy a larger area on the south rim of the Grand Canyon. • Albert's squirrels are the original species from which Kaibab squirrels diverged.

Sympatric Speciation

Less often, a new species arises without geographic separation. This is called **sympatric speciation**. The following example shows one way this can occur.

1. Hawthorn flies lay egg in hawthorn trees. The eggs hatch into larva that feed on hawthorn fruit. Both the flies and trees are native to the U.S.
2. Apple trees were introduced to the U.S. and often grow near hawthorn trees. Some hawthorn flies started to lay eggs in nearby apple trees. When the eggs hatched, the larvae fed on apples.
3. Over time, the two fly populations—those that fed on hawthorn trees and those that preferred apple trees—evolved reproductive isolation. Now they are reproductively isolated because they breed at different times. Their breeding season matches the season when the apple or hawthorn fruits mature.
4. Because they rarely interbreed, the two population of flies are evolving other genetic differences. They appear to be in the process of becoming separate species.


[Figure 4]

Hawthorn fly


[Figure 5]

Hawthorn tree


[Figure 6]

Apple tree

Check your understanding!

PROGRESS 0 / 3

1. The Siberian ibex (a mountain goat) and the Himalayan ibex were thought to belong to the same species. However, they are now known to be two different species. What might have resulted in the origin of the Himalayan ibex?

a sympatric speciation

b a random mutation

c allopatric speciation

Check It

Hint

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Summary

- New species arise in the process of speciation.
- Allopatric speciation occurs when some members of a species become geographically separated. They then evolve genetic differences. If the differences prevent them from interbreeding with the original species, a new species has evolved.
- Sympatric speciation occurs without geographic separation, such as changes in behavior and different breeding seasons.

Review

1. Define speciation.
2. Describe how allopatric speciation occurs.
3. Why is sympatric speciation less likely to occur than allopatric speciation?

Report Content Errors

5.23 Coevolution

FlexBooks 2.0 > Biology For High School Diploma > Coevolution

Last Modified: Apr 18, 2022

What you will learn

- How does coevolution occur
- Examples of coevolution

[Figure 1]

How can a predator, such as a wolf, influence evolution?

Wolves hunt caribou, chasing them down to capture them. The slower caribou are more likely to become lunch or dinner, leaving the faster individuals to reproduce. The resulting faster offspring will be even more difficult for the wolves to catch, and only the fastest wolves - or perhaps the wolves who are genetically capable of developing methods to hunt very fast prey - will get enough food to survive. This is coevolution in action.

Coevolution

Evolution occurs in response to a change in the environment. Environmental change often involves other species of organism. In fact, species in symbiotic relationships tend to evolve together. This is called **coevolution**. As one species changes, the other species must also change in order to adapt.

Coevolution occurs in flowering plants and the species that pollinate them. The flower and bird in the **Figure** below are a good example. They have evolved matching structures.

[Figure 2]

Results of Coevolution in a Flower and Its Pollinator. The very long mouth part of this hummingbird has coevolved with the tubular flower it pollinates. Only this species of bird can reach the nectar deep in the flower. What might happen to the flower if the bird species went extinct?

In coevolution, relationships may be positive for one species or both, or may be an evolutionary arms race between predator and prey. Flowering plants depend on insects for pollination, so have evolved colors, shapes, scents, and even food supplies that are attractive to certain insect species. Insects, in turn, have evolved mouthparts, senses, and flight patterns that allow them to respond to and benefit from specific floral "offerings," shown in the **Figure** below.

[Figure 3]

Impressive proboscis and vivid colors! Hawk moths and the zinnias influence each other's evolution, because the flower depends on the moth for pollination, and the moth feeds on the flower.

The **endosymbiotic theory** describes a special form of co-evolution: mitochondrion and chloroplast evolve within eukaryote cell, yet because these organelle have their own DNA sequence, different from that of the nucleus in the "host" cell, the organelle and host cell evolve in tandem – each influences the evolution of the other.

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Science Friday: Sex, Lies and Orchids

Orchids utilize a wide variety of techniques to manipulate other species into becoming their pollinator. In this video by science Friday, curator Marc Hachadourian describes some of these deceptive methods.

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Summary

- Coevolution occurs when species evolve together.
- Coevolution often happens in species that have symbiotic relationships. Examples include flowering plants and their pollinators.

Review

1. Define coevolution.

2. Apply the concepts of fitness and natural selection to explain the coevolution of insects and flowering plants.

Report Content Errors

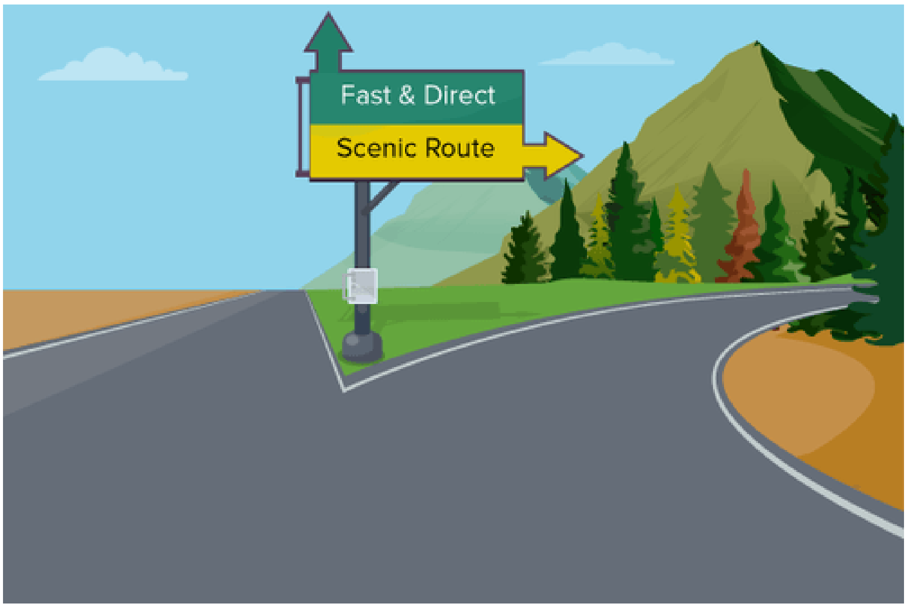
5.24 Macroevolution

FlexBooks 2.0 > Biology For High School Diploma > Macroevolution

Last Modified: Apr 18, 2022

What you will learn

- How macroevolution happens through **gradualism** and punctuated equilibrium



[Figure 1]

Fast or slow?

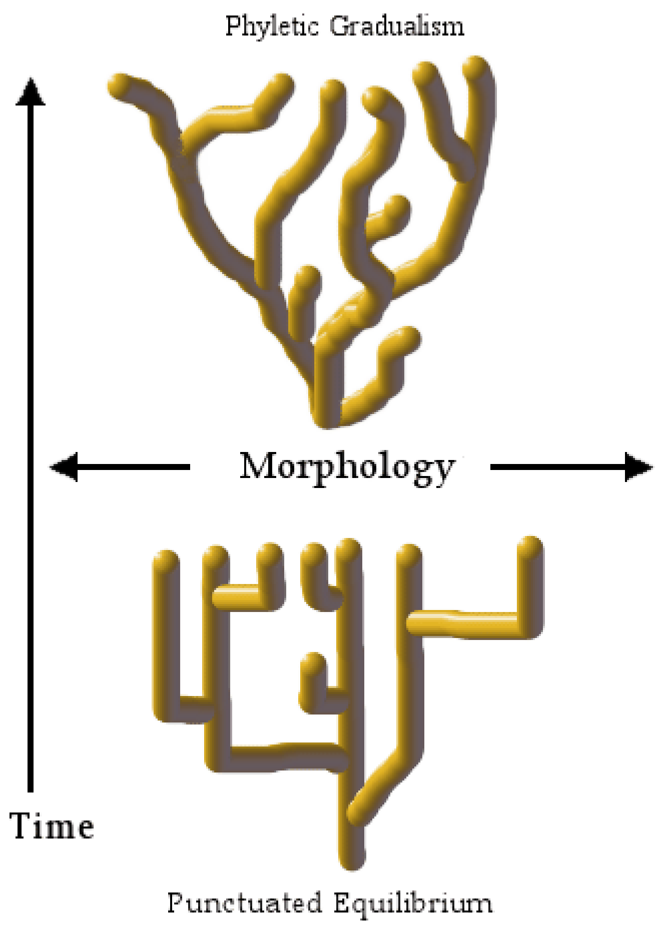
Which is better, the direct route or the scenic route? Each has its advantages, depending on the situation. And that describes evolution. It can be fast or slow, depending on the situation.

Timing of Macroevolution

Is evolution slow and steady? Or does it occur in fits and starts? It may depend on what else is going on, such as changes in climate and geologic conditions.

- When geologic and climatic conditions are stable, evolution may occur gradually. This is how Darwin thought evolution occurred. This model of the timing of evolution is called **gradualism**.
- When geologic and climatic conditions are changing, evolution may occur more quickly. Thus, long periods of little change may be interrupted by bursts of rapid change. This

model of the timing of evolution is called **punctuated equilibrium**. It is better supported by the fossil record than is gradualism. This model suggests that niches left open by sudden geologic and climatic changes may be rapidly filled by bursts of evolution.



[Figure 2]

Two theories of evolutionary change - gradualism vs. punctuated equilibrium - are still debated. The former proposes continuous change, while the latter suggests that species remain constant for long periods of time and that change, when it occurs, is rapid.

Summary

- Darwin thought that evolution occurs gradually. This model of evolution is called gradualism.
- The fossil record better supports the model of punctuated equilibrium. In this model, long periods of little change are interrupted by bursts of rapid change.

Review

1. What is gradualism? When is it most likely to apply?

2. Describe the timing of evolutionary change according to the punctuated equilibrium model.
3. Which model of evolution would be predicted to follow the extinction of the dinosaurs? Why?

Report Content Errors

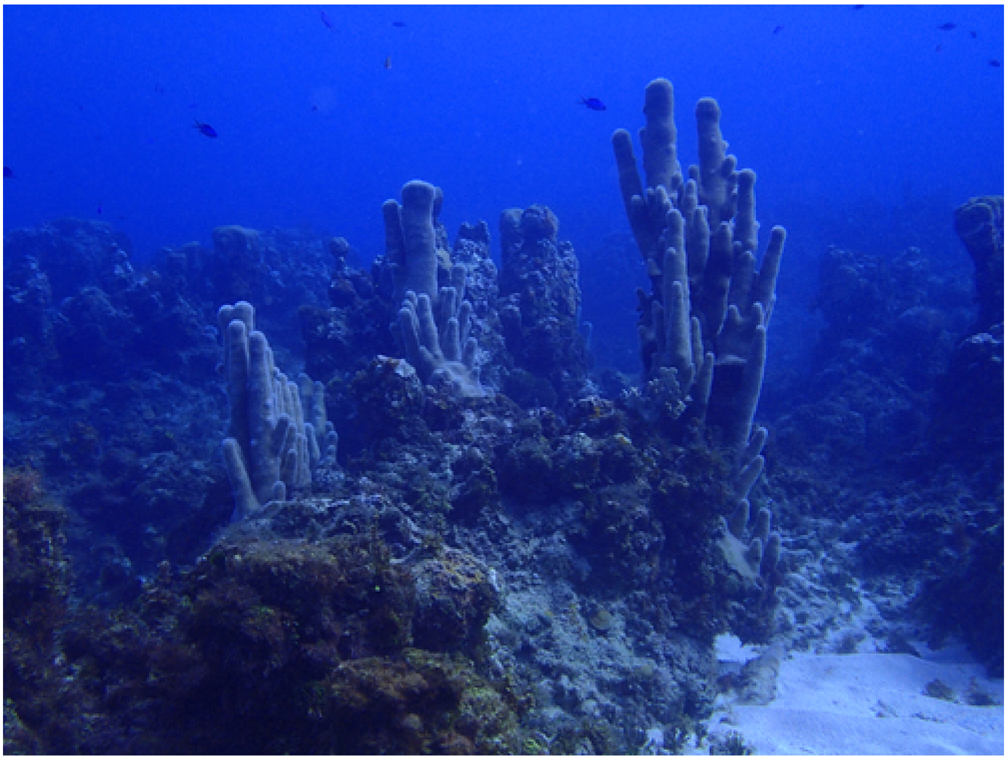
5.25 Animal Evolution

FlexBooks 2.0 > Biology For High School Diploma > Animal Evolution

Last Modified: Apr 25, 2022

What you will learn

- How did the invertebrate and vertebrate animal evolve
- What were the important adaptation in the evolution of animals



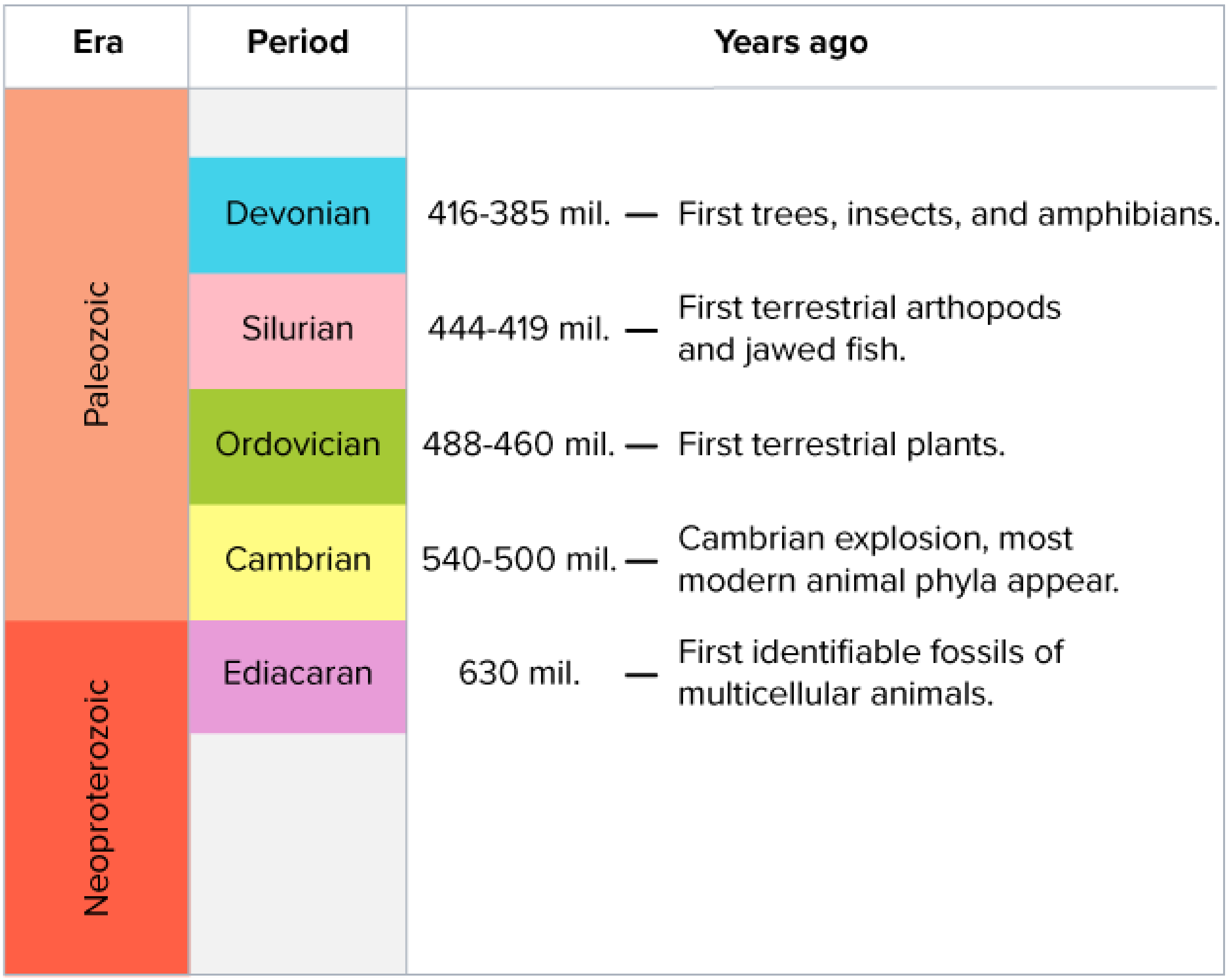
[Figure 1]

What are these? Are these organisms plants, fungi, protists, or animals?

This colony of tube sponges resembles the pipes of a musical instrument. These sponges are actually animals, although they are the simplest animals on Earth. Sponges are frequently used as shelter for small crabs, shrimps, and other invertebrates.

Major Trends in Animal Evolution

The oldest animal fossil are about 630 million years old. By 500 million years ago, most modern phyla of animals had evolved. The **Figure** below shows when some of the major events in animal evolution took place.

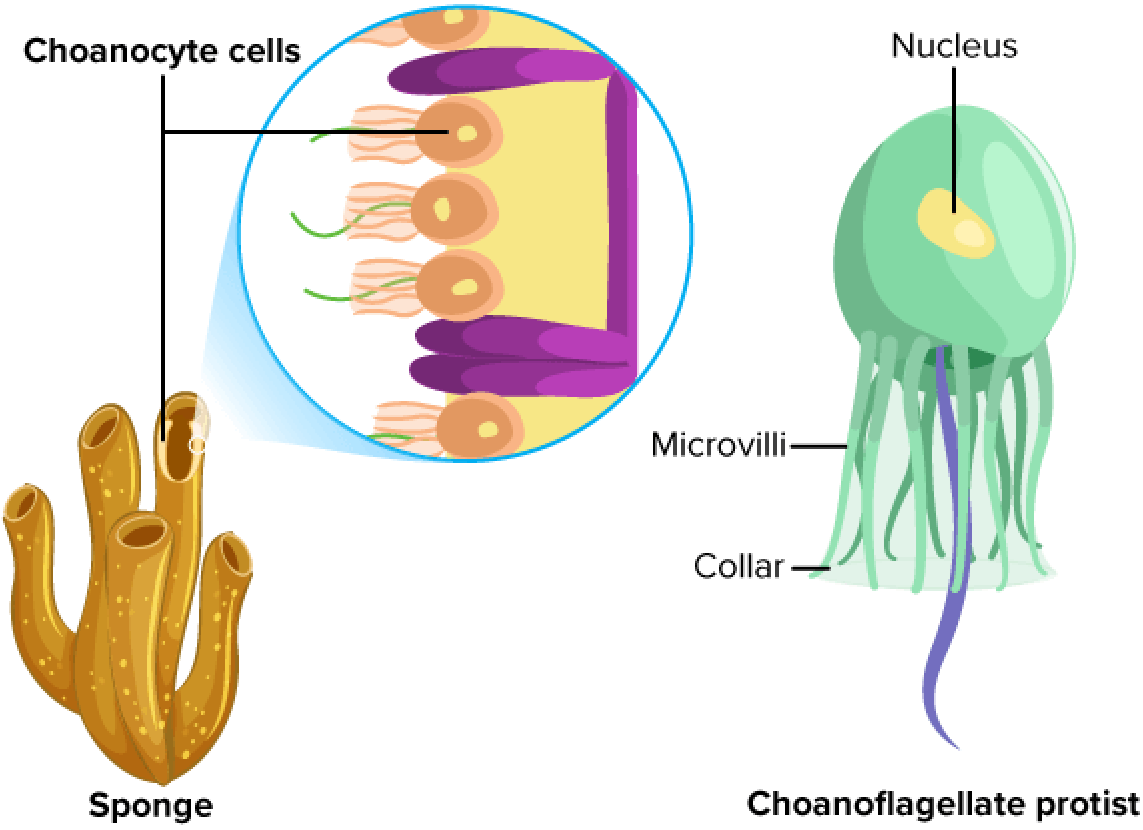


[Figure 2]

Partial Geologic Time Scale. This portion of the geologic time scale shows major events in animal evolution.

Animal Origins

Who were the ancestors of the earliest animals? They may have been marine protist that lived in colonies. Scientists think that cell of some protist colonies became specialized for different jobs. After a while, the specialized cells came to need each other for survival. Thus, the first multicellular animal evolved. Look at the cells in the **Figure** below. One type of sponge cell, the **choanocyte**, looks a lot like the protist cell. How does this support the hypothesis that animals evolved from protists?



[Figure 3]

Choanoflagellate Protist and Choanocyte Cells in Sponges. Sponge choanocytes look a lot like choanoflagellate protists.

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Evolution of Invertebrates

Many important animal adaptations evolved in invertebrates. Without these adaptations, vertebrates would not have been able to evolve. They include:

- tissue, organ, and organ system.
- A symmetrical body.
- A brain and sensory organs.
- A fluid-filled body cavity.
- A complete digestive system.
- A body divided into segments.

Moving from Water to Land

When you think of the first animals to colonize the land, you may think of amphibian. It's true that ancestors of amphibians were the first vertebrates to move to land. However, the very first animals to go ashore were invertebrates, most likely arthropod.

The move to land required new adaptations. For example, animals needed a way to keep their body from drying out. They also needed a way to support their body on dry land without the buoyancy of water. One way early arthropods solved these problems was by evolving an **exoskeleton.** This is a non-bony skeleton that forms on the outside of the body. It supports the body and helps retain water. The ability to breath oxygen without gill was another necessary adaptation.

Evolution of Chordates

Another major step in animal evolution was the evolution of a **notochord**. A **notochord** is a rigid rod that runs the length of the body. It supports the body and gives it shape (see **Figure** below). It also provides a place for muscles to anchor, and counterbalances them when they contract. Animals with a notochord are called **chordate**. They also have a hollow nerve cord that runs along the top of the body. Gill slits and a tail are two other chordate features. Many modern chordates have some of these structures only as embryo.

[Figure 4]

This tunicate is a primitive, deep-sea chordate. It is using its notochord to support its head, while it waits to snatch up prey in its big mouth.

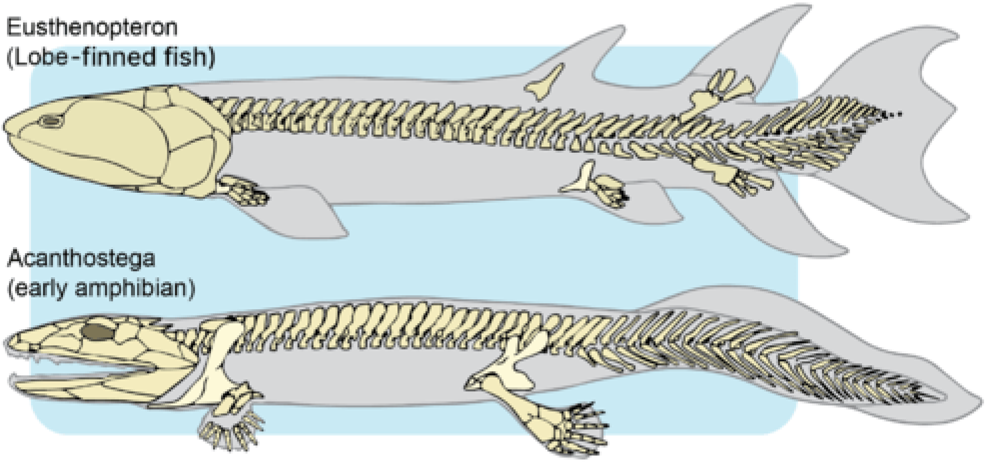
Evolution of Vertebrates

Vertebrates evolved from primitive chordates. This occurred about 550 million years ago. The earliest vertebrates may have been jawless fish, like the **hagfish** in the **Figure** below. Vertebrates evolved a backbone to replace the notochord after the embryo stage. They also evolved a **cranium**, or bony skull, to enclose and protect the brain.

[Figure 5]

Hagfish are very simple vertebrates.

As early vertebrates evolved, they became more complex. Around 365 million years ago, they finally made the transition from water to land. The first vertebrates to live on land were amphibians. They evolved from lobe-finned fish. You can compare a lobe-finned fish and an amphibian in the **Figure** below.



[Figure 6]

From Lobe-Finned Fish to Early Amphibian. Lobe-finned fish evolved into the earliest amphibians. A lobe-finned fish could breathe air for brief periods of time. It could also use its fins to walk on land for short distances. What similarities do you see between the lobe-finned fish and the amphibian?

Evolution of Amniotes

Amphibians were the first animals to have true lung and limbs for life on land. However, they still had to return to water to reproduce. That's because their egg lacked a waterproof covering and would dry out on land. The first fully terrestrial vertebrates were **amniote**. **Amniotes** are animals that produce eggs with internal membranes. The membranes let gases but not water pass through. Therefore, in an amniotic egg, an embryo can breathe without drying out. Amniotic eggs were the first eggs that could be laid on land.

The earliest amniotes evolved about 350 million years ago. Within a few million years, two important amniote groups evolved: synapsids and sauropsida. **Synapsids** evolved into mammal. The **sauropsids** gave rise to reptile, dinosaur, and bird.

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Summary

- The earliest animals evolved from colonial protists more than 600 million years ago.
- Many important animal adaptations evolved in invertebrates, including tissues and a brain.
- The first animals to live on land were invertebrates.
- Amphibians were the first vertebrates to live on land.
- Amniotes were the first animals that could reproduce on land.

Review

1. List three traits that evolved in invertebrate animals.
2. Assume that a new species of animal has been discovered. It is an egg-laying animal that lives and reproduces on land. Explain what you know about its eggs without ever seeing them.
3. Relate similarities between choanoflagellates and choanocytes to animal origins.
4. What was important about the evolution of an exoskeleton?

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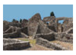
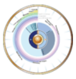
	**Credit:** Jebulon **Source:** https://commons.wikimedia.org/w/index.php?curid=44313039 **License:** CC0
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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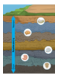
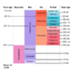
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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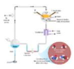	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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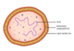	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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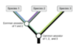	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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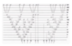
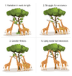
	**Credit:** Charles Darwin, 1859 **Source:** http://commons.wikimedia.org/wiki/File:Darwins_tree_of_life_1859.gif **License:** Public Domain
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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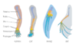	**Credit:** Christopher AuYeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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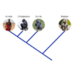
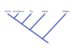
	**Credit:** Cladogram - CK-12 Foundation; Human - Patricia Michelberger; Chimpanzee - JuergenHanke; Gorilla - Plympton_Academy; Baboon - Alexas_Fotos **Source:** Cladogram - CK-12 Foundation; Human - https://pixabay.com/photos/massai-east-africa-kenya-1116673/; Chimpanzee - https://pixabay.com/photos/chimpanzee-ape-primate-zoo-3473177/; Gorilla - https://pixabay.com/photos/gorilla-zoo-animal-ape-sitting-2295023/; Baboon - https://pixabay.com/photos/baboon-ape-animal-primate-mammal-6989455/ **License:** Cladogram - CK-12 Curriculum Materials License; Human, Chimpanzee, Gorilla, Baboon - Pixabay License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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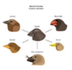
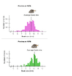
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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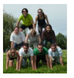	**Credit:** Monica Gotta **Source:** https://commons.wikimedia.org/wiki/File:MG-team.JPG **License:** Public Domain
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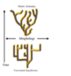	**Credit:** User:Mchavez/Wikipedia **Source:** http://commons.wikimedia.org/wiki/File:Punctuatedequilibrium.png **License:** Public Domain
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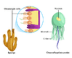	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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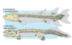	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation, text modified by CK-12 **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

CHAPTER 6

Ecology

Chapter Outline

6.1 Ecosystems

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[Figure 1]

What lives in the forest?

Take a close look at this ecosystem. Obviously there are deer and many types of plants. But there are organism that live there that cannot be seen in the picture. Many other animal, such as rabbits, mice, and countless insects. There are also bacterium and fungus. Add in the nonliving aspects of the area, such as the water, and you have an ecosystem.

The Ecosystem

ecology is the study of how living things interact with each other and with their environment. It is a major branch of biology, but has areas of overlap with geography, geology, climatology, and other sciences. The study of ecology begins with two fundamental concepts in ecology: the ecosystem and their organisms.

Organisms are individual living things. Despite their tremendous diversity, all organisms have the same basic needs: energy and matter. These must be obtained from the environment. Therefore, organisms are not closed systems. They depend on and are influenced by their environment. The environment includes two types of factors: abiotic and biotic.

1. **abiotic factor** are the nonliving aspects of the environment. They include factors such as sunlight, soil, temperature, and water.
2. **Biotic factors** are the living aspects of the environment. They consist of other organisms, including members of the same and different species.

An **ecosystem** is a unit of nature and the focus of study in ecology. It consists of all the biotic and abiotic factors in an area and their interactions. Ecosystems can vary in size. A lake could be considered an ecosystem. So could a dead log on a forest floor. Both the lake and log contain a variety of species that interact with each other and with abiotic factors. Another example of an ecosystem is pictured in the **Figure** below.

[Figure 2]

A desert ecosystem. What are some of the biotic and abiotic factors in this desert ecosystem?

When it comes to energy, ecosystems are not closed. They need constant inputs of energy. Most ecosystems get energy from sunlight, which enters the ecosystem through photosynthesis. This energy then flows through the ecosystem, passed from producer to consumers. Plants are producers in many ecosystems. Energy flows from plants to the herbivore that eat the plants, and then to carnivore that eat the herbivores. The flow of energy depicts interactions of organisms within an ecosystem. A small minority get energy from chemical compounds. Unlike energy, matter is not constantly added to ecosystems. Instead, it is recycled. Water and element such as carbon and nitrogen are used over and over again. The flow of energy and the recycling of nutrient and water are examples of the interactions between organisms and the interactions between the biotic and abiotic factors of an ecosystem.

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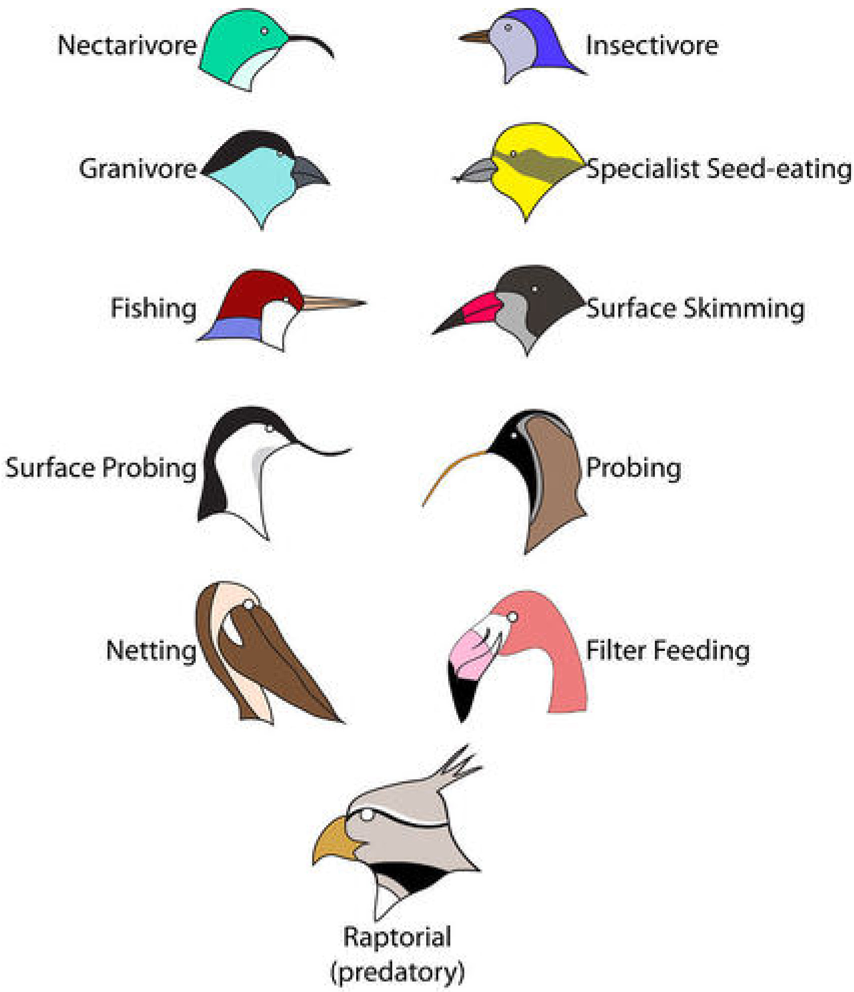
Niche

One of the most important concepts associated with the ecosystem is the **niche**. A **niche** refers to the role of a species in its ecosystem. It includes all the ways that the species interacts with the biotic and abiotic factors of the environment. Two important aspects of a species' niche are the food it eats and how the food is obtained. Look at the **Figure** below. It shows pictures of bird that occupy different niches. Each species eats a different type of food and obtains the food in a different way.



[Figure 3]

Bird Niches. Each of these species of birds has a beak that suits it for its niche. For example, the long slender beak of the nectarivore allows it to sip liquid nectar from flowers. The short sturdy beak of the granivore allows it to crush hard, tough grains.

Habitat

The **habitat** is the physical environment in which a species lives and to which it is adapted. A habitat's features are determined mainly by abiotic factors such as temperature and rainfall. These factors also influence the traits of the organisms that live there.

Competitive Exclusion Principle

A given habitat may contain many different species, but each species must have a different niche. Two different species cannot occupy the same niche in the same place for very long. This is known as the **competitive exclusion principle**. If two species were to occupy the same niche, what do you think would happen? They would compete with one another for the same food and other resources in the environment. Eventually, one species would be likely to outcompete and replace the other. In order for two species within the same area to coexist, they may adapt by developing different specializations. This is known as **character displacement**. An example of character displacement is when different birds adapt to eating different types of food. They can develop different types of bills. Therefore, competition for resources within and between species plays an important role in evolution through natural selection.

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Summary

- Ecology is the study of how living things interact with each other and with their environment.
- The environment includes abiotic (nonliving) and biotic (living) factors.
- An ecosystem consists of all the biotic and abiotic factors in an area and their interactions.
- A niche refers to the role of a species in its ecosystem.
- A habitat is the physical environment in which a species lives and to which it is adapted.
- Two different species cannot occupy the same niche in the same place for very long.

Review

1. Define ecology.
2. Define biotic and abiotic factors of the environment. Give an example of each.
3. How do ecologists define the term ecosystem? What makes up an ecosystem?
4. State the competitive exclusion principle.
5. Compare and contrast the ecosystem concepts of niche and habitat.

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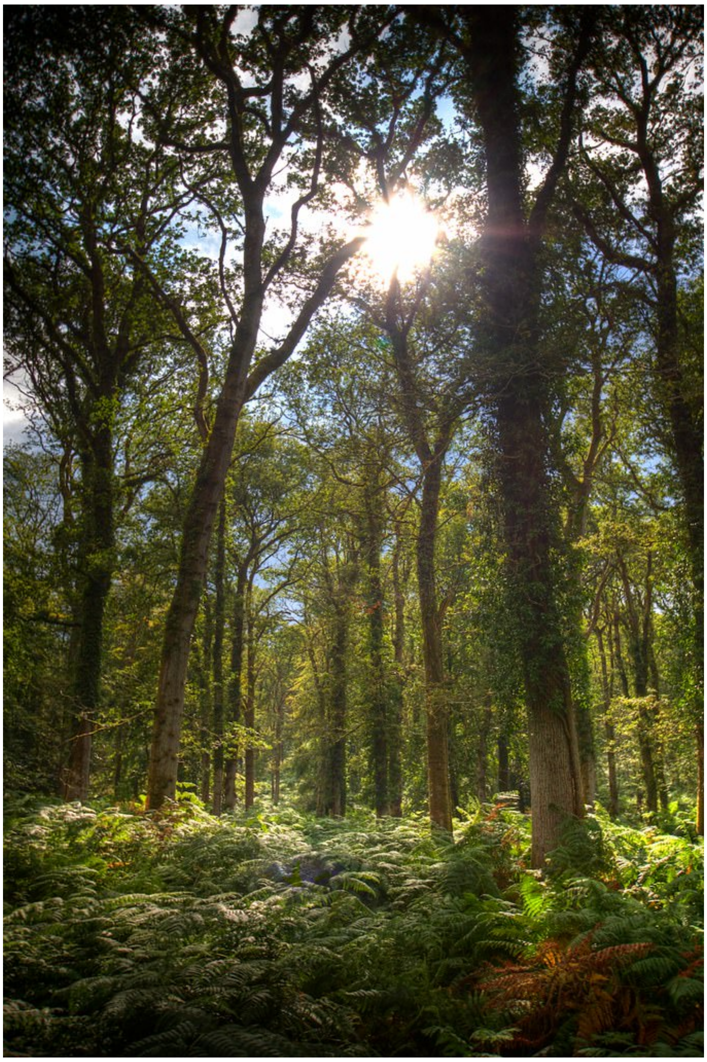
6.2 Energy Flow

FlexBooks 2.0 > Biology For High School Diploma > Energy Flow

Last Modified: May 02, 2022



[Figure 1]

What is happening inside each leaf and blade of grass?

photosynthesis. Maybe the most important biochemical reaction of Earth. As sunlight shines down on this forest, the sunlight is being absorbed, and the energy from that sunlight is being transformed into chemical energy. That chemical energy is then distributed to all other living organism in the ecosystem.

Flow of Energy

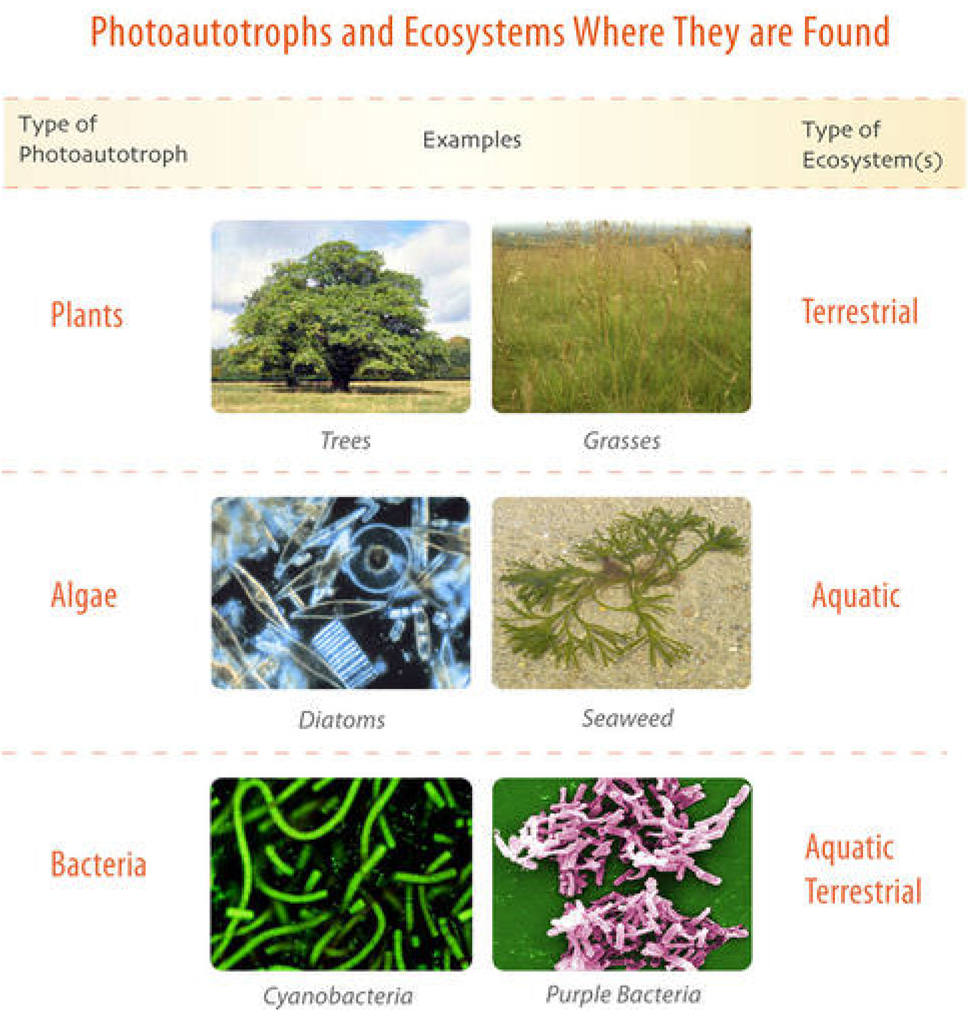
To survive, ecosystems need a constant influx of energy. Energy enters ecosystems in the form of sunlight or chemical compounds. Some organisms use this energy to make food.

Other organisms get energy by eating the food.

Producers

producer are organisms that produce food for themselves and other organisms. They use energy and simple inorganic molecules to make organic compound. The stability of producers is vital to ecosystems because all organisms need organic molecule. Producers are also called **autotroph**. There are two basic types of autotrophs: photoautotroph and chemoautotroph.

1. **Photoautotrophs** use energy from sunlight to make food by photosynthesis. They include plants, alga, and certain bacterium (see **Figure** below).
2. **Chemoautotrophs** use energy from chemical compounds to make food by chemosynthesis. They include some bacteria and also archaea. Archaea are microorganisms that resemble bacteria.



[Figure 2]

Different types of photoautotrophs are important in different ecosystems.

Consumers

Consumers are organisms that depend on other organisms for food. They take in organic molecules by essentially “eating” other living things. They include all animal and fungus. (Fungi don't really “eat”; they absorb nutrient from other organisms.) They also include many bacteria and even a few plants, such as the pitcher plant shown in **Figure** below. Consumers are also called heterotroph. Heterotrophs are classified by what they eat:

- **herbivore** consume producers such as plants or algae. They are a necessary link between producers and other consumers. Examples include deer, rabbits, and mice.
- **carnivore** consume animals. Examples include lions, polar bears, hawks, frog, salmon, and spiders. Carnivores that are unable to digest plants and must eat only animals are called obligate carnivores. Other carnivores can digest plants but do not commonly eat them.
- **omnivore** consume both plants and animals. They include humans, pigs, brown bears, gulls, crows, and some species of fish.

[Figure 3]

Pitcher Plant. Virtually all plants are producers. This pitcher plant is an exception. It consumes insects. It traps them in a sticky substance in its “pitcher.” Then it secretes enzymes that break down the insects and release nutrients. Which type of consumer is a pitcher plant?

Decomposers

When organisms die, they leave behind energy and matter in their remains. **decomposer** break down the remains and other wastes and release simple inorganic molecules back to the environment. Producers can then use the molecules to make new organic compounds. The stability of decomposers is essential to every ecosystem. Decomposers are classified by the type of organic matter they break down:

- **scavenger** consume the soft tissue of dead animals. Examples of scavengers include vultures, raccoons, and blowflies.
- **detritivore** consume **detritus**—the dead leaves, animal feces, and other organic debris that collects on the soil or at the bottom of a body of water. On land, detritivores include

earthworm, millipedes, and dung beetles (see **Figure** below). In water, detritivores include "bottom feeders" such as sea cucumbers and catfish.

- **saprotroph** are the final step in decomposition. They feed on any remaining organic matter that is left after other decomposers do their work. Saprotrophs include fungi, bacteria and single-celled protozoan. Fungi are the only organisms that can decompose wood.

[Figure 4]

Dung Beetle. This dung beetle is rolling a ball of feces to its nest to feed its young.

KQED: Banana Slugs: The Ultimate Recyclers

One of the most beloved and iconic native species within the old growth redwood forests of California is the Pacific Banana Slug. These slimy friends of the forest are the ultimate recyclers. Feeding on fallen leaves, mushroom or even dead animals, they play a pivotal role in replenishing the soil. QUEST goes to Henry Cowell Redwoods State Park near Santa Cruz, California on a hunt to find *Ariolimax dolichophallus*, a bright yellow slug with a very big personality.

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Summary

- Ecosystems require constant inputs of energy from sunlight or chemicals.
- Producers use energy and inorganic molecules to make food.
- Consumers take in food by eating producers or other living things.
- Decomposers break down dead organisms and other organic wastes and release inorganic molecules back to the environment.

Review

1. Identify three different types of consumers. Name an example of each type.
2. What are photoautotrophs? Give an example of one.
3. What can you infer about an ecosystem that depends on chemoautotrophs for food?
4. What is the role of decomposers?
5. What do scavengers do? Give an example of a scavenger.

Report Content Errors

6.3 Food Chain

FlexBooks 2.0 > Biology For High School Diploma > Food Chain

Last Modified: May 04, 2020

[Figure 1]

Who eats whom?

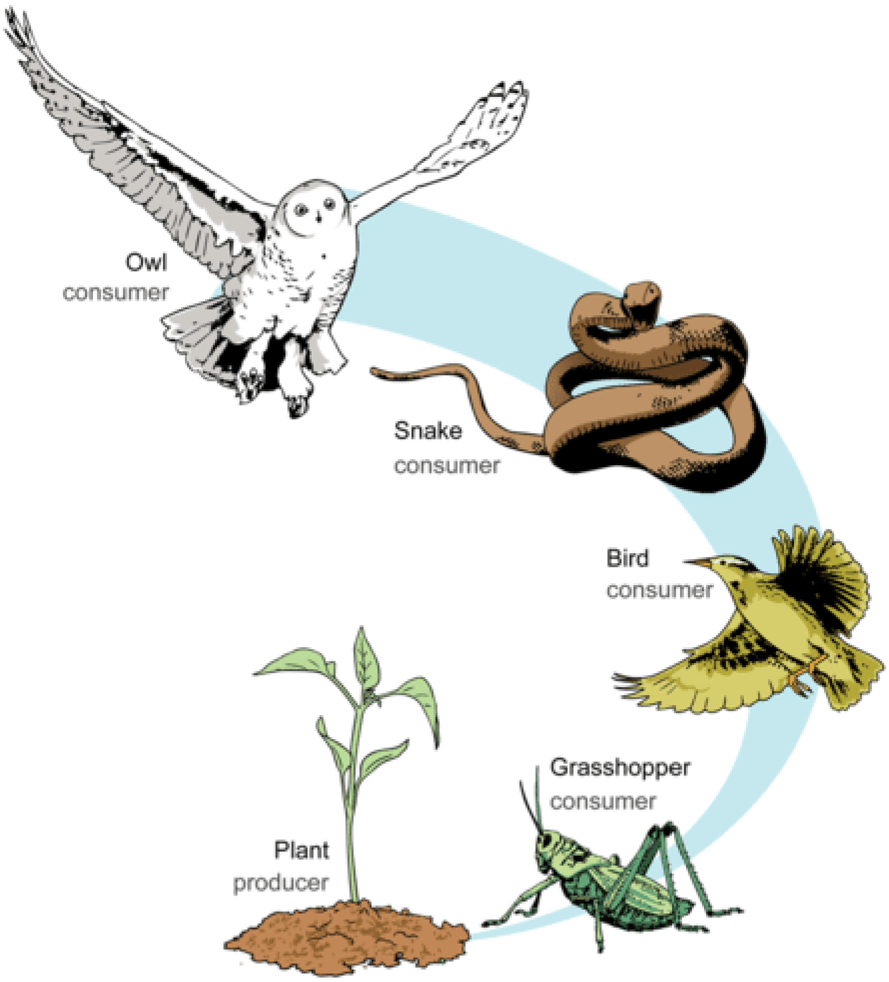
Describing the flow of energy within an ecosystem essentially answers this question. To survive, one must eat. Why? To get energy. Food chains and webs describe the transfer of energy within an ecosystem, from one organism to another. In other words, they show who eats whom.

Food Chains and Food Webs

Food chains and **food web** are diagrams that represent feeding relationships. Essentially, they show who eats whom. In this way, they model how energy and matter move through ecosystems.

Food Chains

A **food chain** represents a single pathway by which energy and matter flow through an ecosystem. An example is shown in **Figure** below. Food chains are generally simpler than what really happens in nature. Most organisms consume—and are consumed by—more than one species.

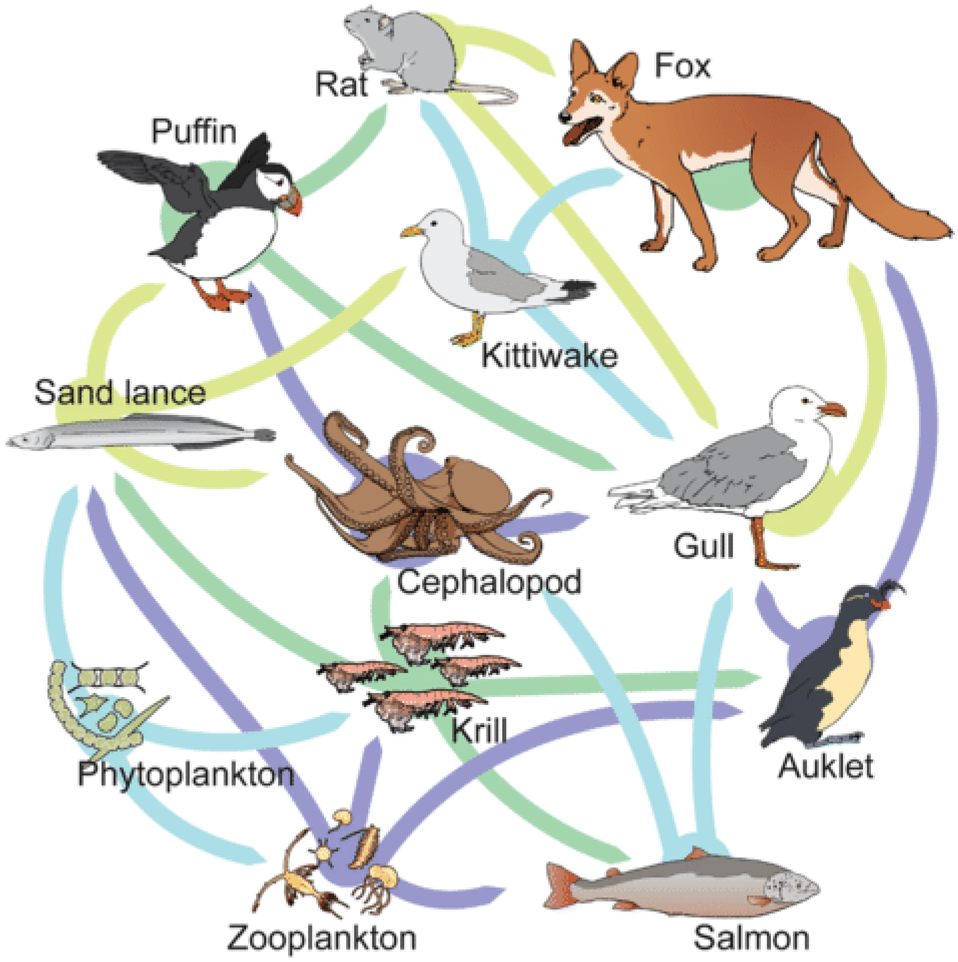


[Figure 2]

This food chain includes producers and consumers. How could you add decomposers to the food chain?

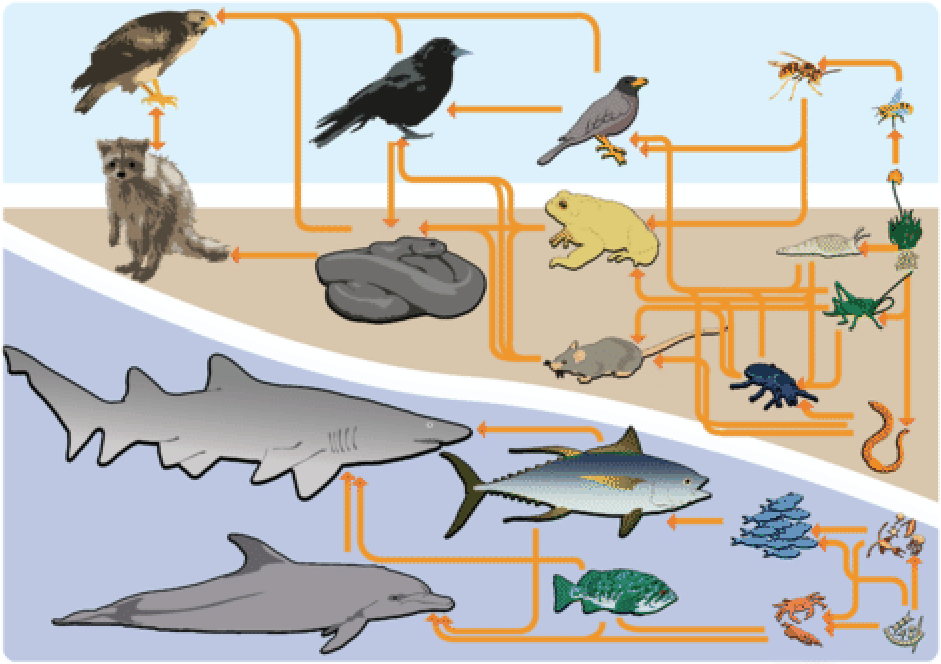
Food Webs

A **food web** represents multiple pathways through which energy and matter flow through an ecosystem. It includes many intersecting food chains. It demonstrates that most organisms eat, and are eaten, by more than one species. Examples are shown in the **Figures** below.



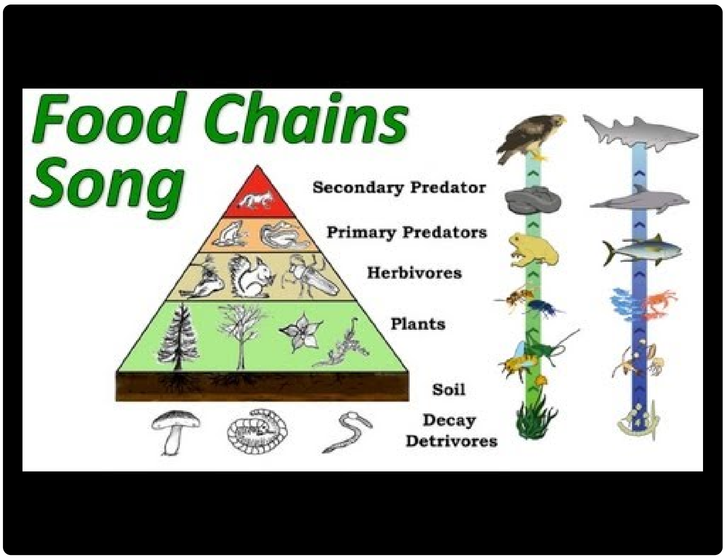
[Figure 3]

Food Web. This food web consists of several different food chains. Which organisms are producers in all of the food chains included in the food web?



[Figure 4]

Examples of food webs.



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Science Friday: Can Underwater Parks Protect Coral?

Coral community are incredibly important for marine life. In this video by science Friday, Marine scientists John Bruno and Elizabeth Selig describe the effects of local Marine

Protection Areas on preserving coral.

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Summary

- Food chains and food webs are diagrams that represent feeding relationships.
- Food chains and webs model how energy and matter move through ecosystems.

Review

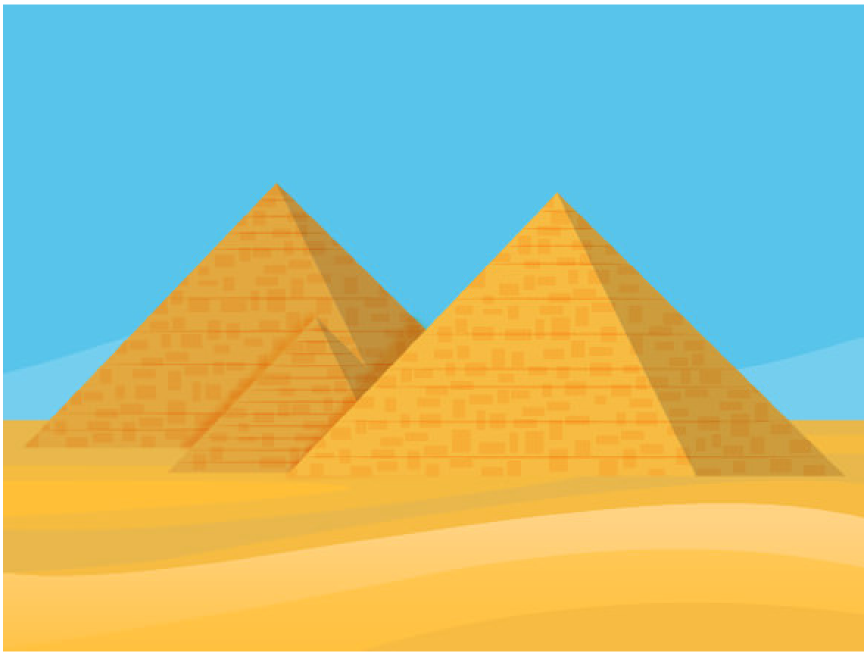
1. What is a food chain?
2. Describe the role of decomposers in food webs.
3. Why is a food web more realistic than a food chain?
4. Draw a terrestrial food chain that includes four feeding levels.

Report Content Errors

6.4 Trophic Level

FlexBooks 2.0 > Biology For High School Diploma > Trophic Level

Last Modified: Aug 01, 2018



[Figure 1]

Why are pyramids important in ecology?

The classic example of a pyramid is shown here. But the pyramid structure can also represent the decrease in a measured substance from the lowest level on up. In ecology, pyramids model the use of energy from the producer through the ecosystem.

Trophic Levels

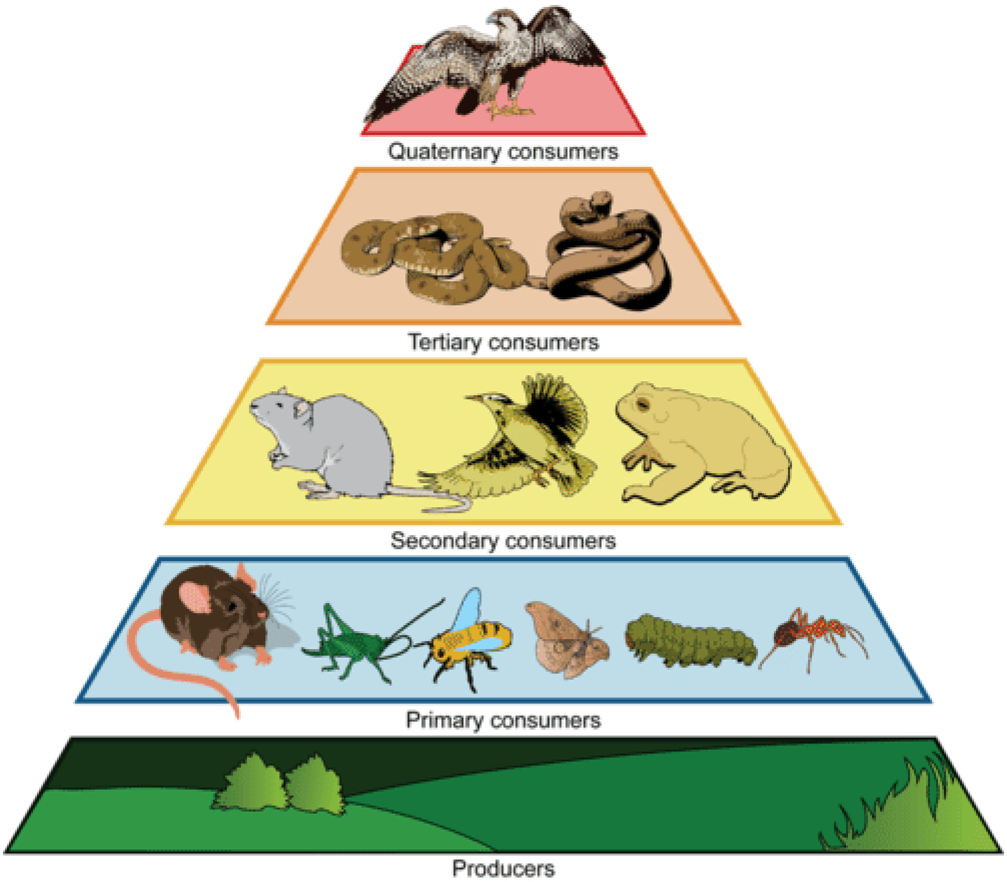
The feeding positions in a food chain or web are called **trophic levels**. The different trophic levels are defined in the **Table** below. Examples are also given in the table. All food chains and webs have at least two or three trophic levels. Generally, there are a maximum of four trophic levels.

Trophic Level	Where It Gets Food	Example
1st Trophic Level: Producer	Makes its own food	Plants make food
2nd Trophic Level: Primary Consumer	Consumes producers	Mice eat plant seed
3rd Trophic Level: Secondary Consumer	Consumes primary consumers	Snakes eat mice
4th Trophic Level: Tertiary Consumer	Consumes secondary consumers	Hawks eat snakes

Many consumers feed at more than one trophic level. Humans, for example, are primary consumers when they eat plants such as vegetables. They are secondary consumers when they eat cows. They are tertiary consumers when they eat salmon.

Trophic Levels and Energy

Energy is passed up a food chain or web from lower to higher trophic levels. However, generally only about 10 percent of the energy at one level is available to the next level. This is represented by the **ecological pyramid** in **Figure** below. What happens to the other 90 percent of energy? It is used for metabolic processes or given off to the environment as heat. This loss of energy explains why there are rarely more than four trophic levels in a food chain or web. Sometimes there may be a fifth trophic level, but usually there's not enough energy left to support any additional levels.



[Figure 2]

Ecological Pyramid. This pyramid shows how energy and biomass decrease from lower to higher trophic levels. Assume that producers in this pyramid have 1,000,000 kilocalories of energy. How much energy is available to primary consumers?

Ecological pyramids can demonstrate the decrease in energy, **biomass** or numbers within an ecosystem.

Trophic Levels and Biomass

With less energy at higher trophic levels, there are usually fewer organism as well. Organisms tend to be larger in size at higher trophic levels, but their smaller numbers result in less biomass. **Biomass** is the total mass of organisms at a trophic level. The decrease in biomass from lower to higher levels is also represented by **Figure** above.

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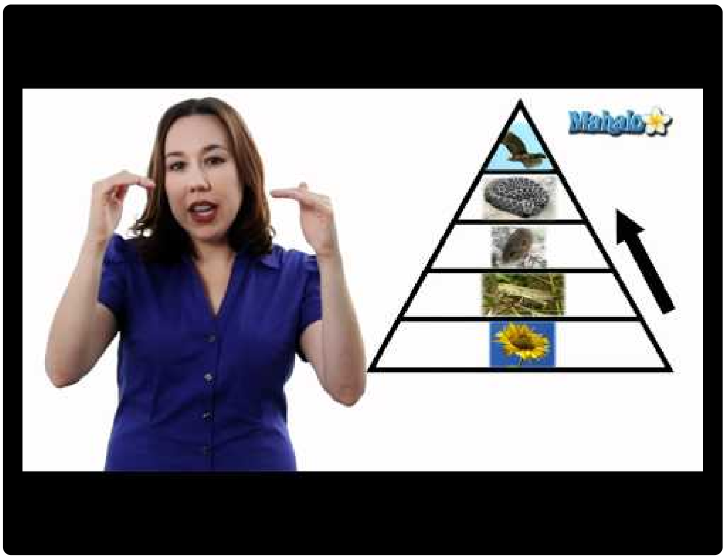

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Summary

- The different feeding positions in a food chain or web are called trophic levels.
- Generally, there are no more than four trophic levels because energy and biomass decrease from lower to higher levels.

Review

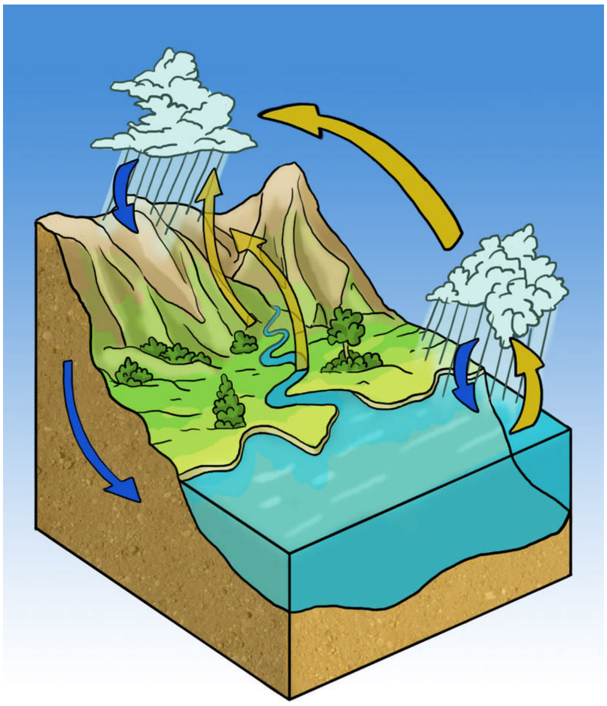
1. What is a trophic level?
2. What do energy pyramids depict?
3. Explain how energy limits the number of trophic levels in a food chain or web.
4. Draw a terrestrial food chain that includes four trophic levels. Identify the trophic level of each organism in the food chain.

Report Content Errors

6.5 Water Cycle

FlexBooks 2.0 > Biology For High School Diploma > Water Cycle

Last Modified: Oct 19, 2020



[Figure 1]

Where does the water come from that is needed by your cells?

Unlike energy, matter is not lost as it passes through an ecosystem. Instead, matter, including water, is recycled. This recycling involves specific interactions between the biotic and abiotic factor in an ecosystem. Chances are, the water you drank this morning has been around for millions of years, or more.

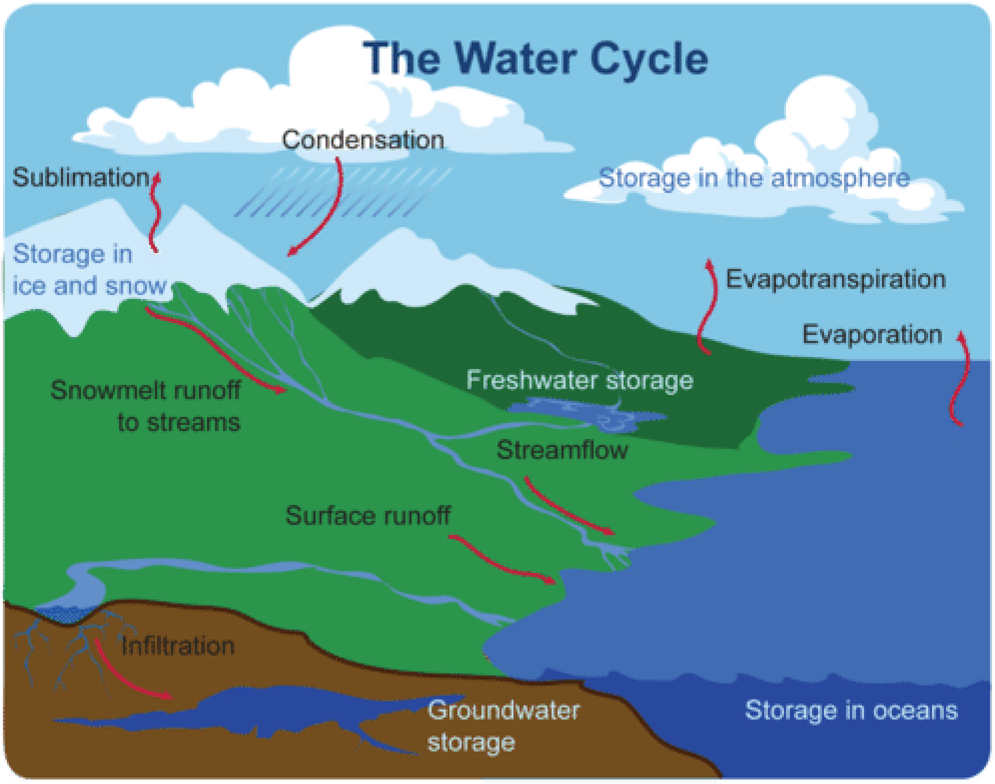
The Water Cycle

The chemical element and water that are needed by organism continuously recycle in ecosystems. They pass through biotic and abiotic components of the biosphere. That's why their cycles are called **biogeochemical cycle**. For example, a chemical might move from organisms (*bio*) to the atmosphere or ocean (*geo*) and back to organisms again. Elements or water may be held for various periods of time in different parts of a cycle.

- Part of a cycle that holds an element or water for a short period of time is called an **exchange pool**. For example, the atmosphere is an exchange pool for water. It usually holds water (in the form of water vapor) for just a few days.

- Part of a cycle that holds an element or water for a long period of time is called a **reservoir**. The ocean is a reservoir for water. The deep ocean may hold water for thousands of years.

Water on Earth is billions of years old. However, individual water molecules keep moving through the water cycle. The **water cycle** is a global cycle. It takes place on, above, and below Earth's surface, as shown in **Figure** below.



[Figure 2]

Like other biogeochemical cycles, there is no beginning or end to the water cycle. It just keeps repeating.

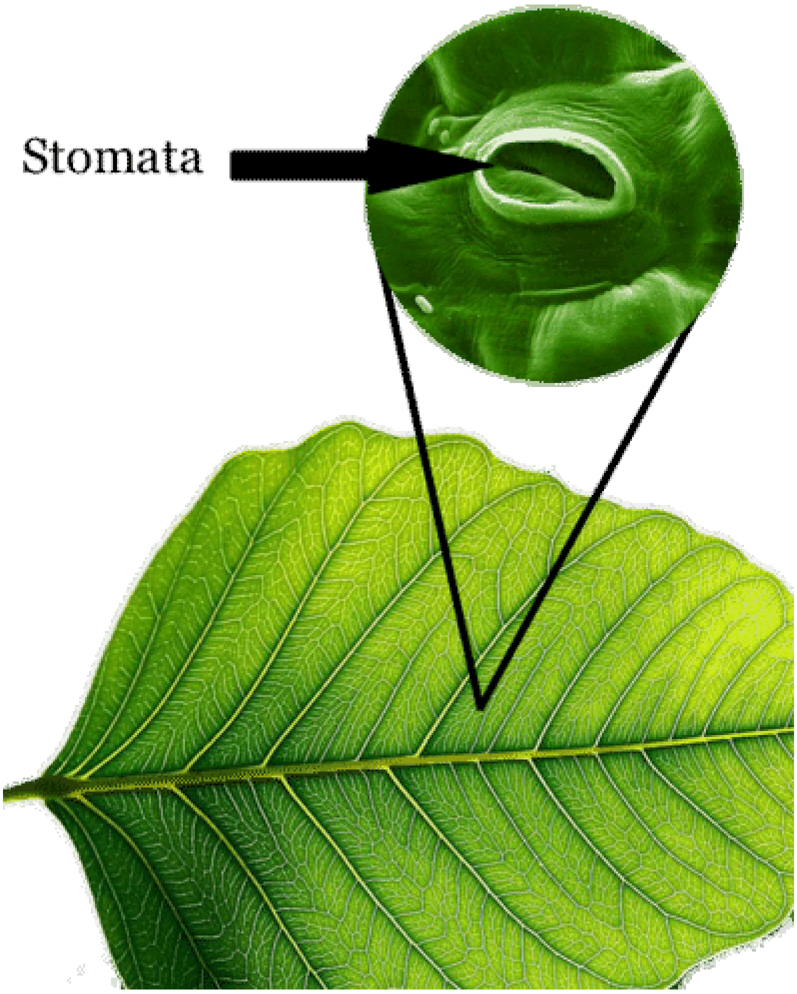
During the water cycle, water occurs in three different states: gas (water vapor), liquid (water), and solid (ice). Many processes are involved as water changes state in the water cycle.

Evaporation, Sublimation, and Transpiration

Water changes to a gas by three different processes:

1. **evaporation** occurs when water on the surface changes to water vapor. The sun heats the water and gives water molecules enough energy to escape into the atmosphere.
2. **sublimation** occurs when ice and snow change directly to water vapor. This also happens because of heat from the sun.

3. **transpiration** occurs when plants release water vapor through leaf pores called stoma (see **Figure** below).



[Figure 3]

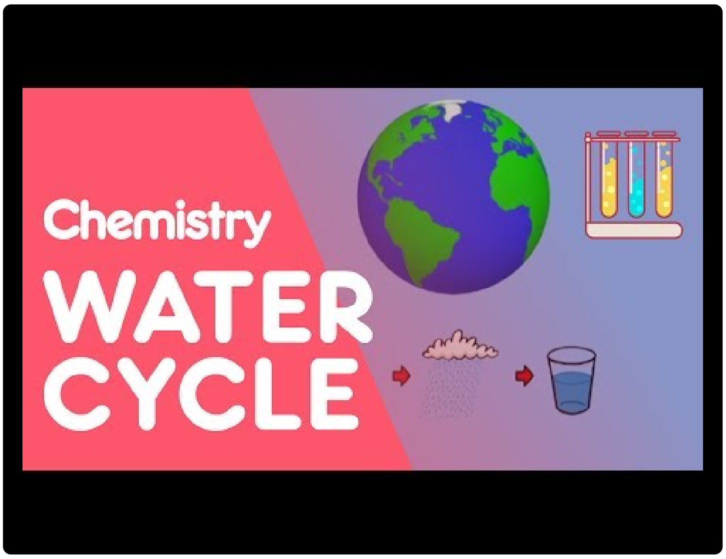
Plant leaves have many tiny stomata. They release water vapor into the air.

Condensation and Precipitation

Rising air currents carry water vapor into the atmosphere. As the water vapor rises in the atmosphere, it cools and condenses. **condensation** is the process in which water vapor changes to tiny droplets of liquid water. The water droplets may form clouds. If the droplets get big enough, they fall as **precipitation**—rain, snow, sleet, hail, or freezing rain. Most precipitation falls into the ocean. Eventually, this water evaporates again and repeats the water cycle. Some frozen precipitation becomes part of ice caps and glaciers. These masses of ice can store frozen water for hundreds of years or longer.

Groundwater and Runoff

Precipitation that falls on land may flow over the surface of the ground. This water is called **runoff**. It may eventually flow into a body of water. Some precipitation that falls on land may soak into the ground, becoming **groundwater**. Groundwater may seep out of the ground at a spring or into a body of water such as the ocean. Some groundwater may be taken up by plant roots. Some may flow deeper underground to an **aquifer**. This is an underground layer of rock that stores water, sometimes for thousands of years.



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Science Friday: Forecasting the Meltdown: The Aerial Snow Observatory

75% of Southern California's water supply comes from the snowpack in the Sierra Nevada Mountain Range. This video by science Friday explains how NASA uses the Airborne Snow Observatory that uses specialized instrumentation to carefully measure the water content.

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Summary

- Chemical elements and water are recycled through biogeochemical cycles. The cycles include both biotic and abiotic parts of ecosystems.
- The water cycle takes place on, above, and below Earth's surface. In the cycle, water occurs as water vapor, liquid water, and ice. Many processes are involved as water changes state in the cycle.
- The atmosphere is an exchange pool for water. Ice masses, aquifers, and the deep ocean are water reservoirs.

Review

1. What is a biogeochemical cycle? Name an example.
2. Identify and define two processes by which water naturally changes from a solid or liquid to a gas.
3. Define exchange pool and reservoir, and identify an example of each in the water cycle.
4. Assume you are a molecule of water. Describe one way you could go through the water cycle, starting as water vapor in the atmosphere.

Report Content Errors

6.6 Carbon Cycle

FlexBooks 2.0 > Biology For High School Diploma > Carbon Cycle

Last Modified: May 04, 2020

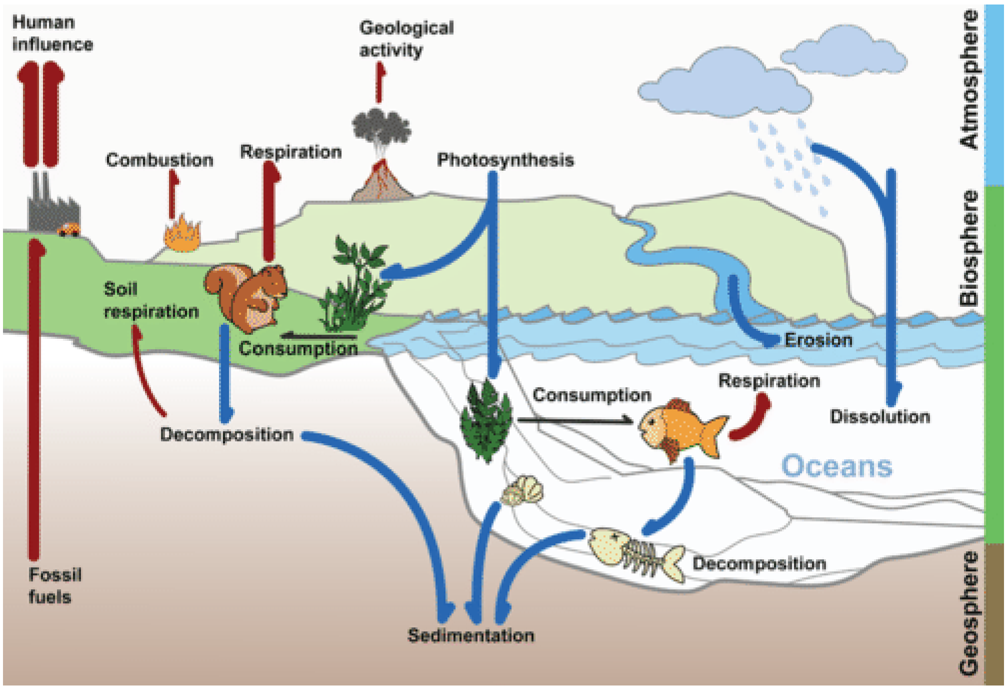
[Figure 1]

How could releasing this much pollution into the atmosphere not be a poor idea?

Burning fossil fuel, such as oil, releases carbon into the atmosphere. This carbon must be cycled - removed from the atmosphere - back into living organism, or it stays in the atmosphere. Increased carbon in the atmosphere contributes to the greenhouse effect on Earth.

The Carbon Cycle

Flowing water can slowly dissolve carbon in sedimentary rock. Most of this carbon ends up in the ocean. The deep ocean can store carbon for thousands of years or more. Sedimentary rock and the ocean are major reservoir of stored carbon. Carbon is also stored for varying lengths of time in the atmosphere, in living organisms, and as fossil fuel deposits. These are all parts of the **carbon cycle**, which is shown in **Figure** below.



[Figure 2]

The Carbon Cycle. Carbon moves from one reservoir to another in the carbon cycle. What role do organisms play in this cycle?

Why is recycling carbon important? Recall that carbon is the cornerstone of organic compound, the compounds necessary for life. But do organisms make their own carbon? Do they have the gene that encode protein necessary to make carbon? No. In fact, there are no such genes. Carbon must be recycled from other living organisms, from carbon in the atmosphere, and from carbon in other parts of the biosphere.

Carbon in the Atmosphere

Though carbon can be found in ocean water, rocks and sediment and other parts of the biosphere, the atmosphere may be the most recognizable reservoir of carbon. Carbon occurs in various forms in different parts of the carbon cycle. Some of the different forms in which carbon appears are described in **Table** below. KEY: C = Carbon, O = Oxygen, H = Hydrogen

Form of Carbon	Chemical Formula	State	Main Reservoir
Carbon Dioxide	CO_2	Gas	Atmosphere
Carbonic Acid	H_2CO_3	Liquid	Ocean
Bicarbonate ion	HCO_3^-	Liquid(dissolved ion)	Ocean
Organic Compounds	*Examples:* $C_6H_{12}O_6$ (Glucose), CH_4 (Methane)	Solid Gas	Biosphere Organic Sediments (fossil Fuels)
Other Carbon Compounds	*Examples:* $CaCO_3$ (calcium Carbonate), $CaMg(CO_3)_2$ (Calcium Magnesium Carbonate)	Solid Solid	Sedimentary Rock, Shells, Sedimentary Rock

Carbon in Carbon Dioxide

Carbon cycles quickly between organisms and the atmosphere. In the atmosphere, carbon exists primarily as carbon dioxide (CO_2). Carbon dioxide cycles through the atmosphere by several different processes, including those listed below.

- Living organisms release carbon dioxide as a byproduct of **cellular respiration**.
- **photosynthesis** removes carbon dioxide from the atmosphere and uses it to make organic compounds.
- Carbon dioxide is given off when dead organisms and other organic materials decompose.
- Burning organic material, such as fossil fuels, releases carbon dioxide.
- Carbon cycles far more slowly through geological processes such as **sedimentation**. Carbon may be stored in sedimentary rock for millions of years.
- When volcanoes erupt, they give off carbon dioxide that is stored in the mantle.
- Carbon dioxide is released when limestone is heated during the production of cement.
- Ocean water releases dissolved carbon dioxide into the atmosphere when water temperature rises.
- Carbon dioxide is also removed when ocean water cools and dissolves more carbon dioxide from the air.

Because of human activities, there is more carbon dioxide in the atmosphere today than in the past hundreds of thousands of years. Burning fossil fuels has released great quantities of carbon dioxide into the atmosphere. Cutting forests and clearing land has also increased carbon dioxide into the atmosphere because these activities reduce the number of autotrophic organisms that use up carbon dioxide in photosynthesis. In addition, clearing often involves burning, which releases carbon dioxide that was previously stored in autotroph.

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Summary

- Carbon must be recycled through living organisms or it stays in the atmosphere.
- Carbon cycles quickly between organisms and the atmosphere.
- Due to human activities, there is more carbon dioxide in the atmosphere today than in the past hundreds of thousands of years.

Review

1. What is the role of the carbon cycle?
2. Why is cycling carbon important?
3. Describe a major method that carbon is cycled.
4. How have human activities increased atmospheric carbon dioxide levels?

6.7 Nitrogen Cycle

FlexBooks 2.0 > Biology For High School Diploma > Nitrogen Cycle

Last Modified: Nov 23, 2021

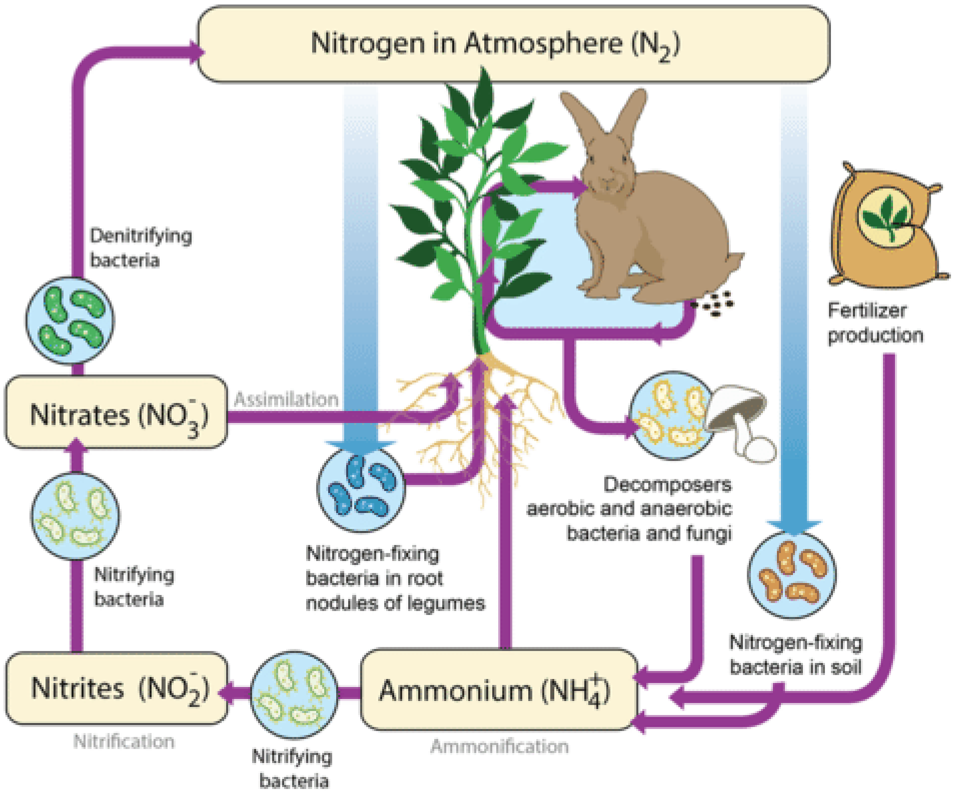
[Figure 1]

Alfalfa, clover, peas, beans, lentils, lupins, mesquite, carob, soy, and peanuts. What are these?

Legumes. Legume plants have the ability to fix atmospheric nitrogen, due to a mutualistic symbiotic relationship with bacterium found in root nodules of these plants.

The Nitrogen Cycle

Nitrogen makes up 78 percent of Earth's atmosphere. It's also an important part of living things. Nitrogen is found in protein, nucleic acid, and chlorophyll. The **nitrogen cycle** moves nitrogen through the abiotic and biotic parts of ecosystem. **Figure** below shows how nitrogen cycles through a terrestrial ecosystem. Nitrogen passes through a similar cycle in aquatic ecosystems.

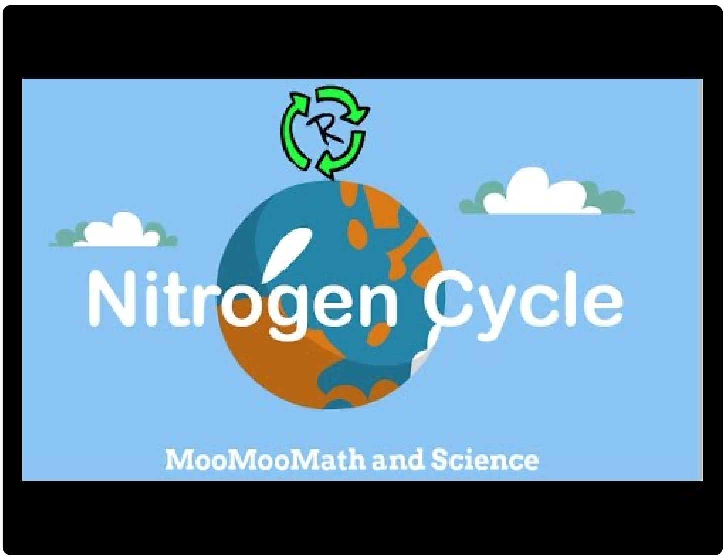


[Figure 2]

Nitrogen Cycle in a Terrestrial Ecosystem. Nitrogen cycles between the atmosphere and living things.

Even though nitrogen gas makes up most of Earth's atmosphere, plants cannot use this nitrogen gas to make organic compound for themselves and other organism. The two nitrogen atoms in a molecule of nitrogen gas are held together by a very stable triple bond. This bond must be broken for the nitrogen to be used. The nitrogen gas must be changed to a form called nitrates, which plants can absorb through their roots. The process of changing nitrogen gas to nitrates is called **nitrogen fixation**. It is carried out by nitrogen-fixing bacteria. The bacteria live in soil and roots of legumes, such as peas.

When plants and other organisms die, decomposer break down their remains. In the process, they release nitrogen in the form of ammonium ion. This process is called **ammonification.** Nitrifying bacteria change the ammonium ions into nitrites and nitrates. Some of the nitrates are used by plants. The process of converting ammonium ions to nitrites or nitrates is called **nitrification.** Still other bacteria, called denitrifying bacteria, convert some of the nitrates in soil back into nitrogen gas in a process called **denitrification.** The process is the opposite of nitrogen fixation. Denitrification returns nitrogen gas back to the atmosphere, where it can continue the nitrogen cycle.



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Summary

- The nitrogen cycle moves nitrogen back and forth between the atmosphere and organisms.
- Bacteria change nitrogen gas from the atmosphere to nitrogen compounds that plants can absorb.
- Other bacteria change nitrogen compounds back to nitrogen gas, which re-enters the atmosphere.

Review

1. Why can't plants use nitrogen gas directly?
2. What is nitrogen fixation?
3. Explain why bacteria are essential parts of the nitrogen cycle.
4. What is ammonification?

Report Content Errors

6.8 Biomes and Climate

FlexBooks 2.0 > Biology For High School Diploma > Biomes and Climate

Last Modified: Aug 10, 2021

[Figure 1]

What do temperature, wind, and rain, have in common?

They are all part of **climate**, the statistical summary of temperature, humidity, atmospheric pressure, wind, rainfall, other meteorological measurements in a given region over long periods. In other words, is it dry or wet, hot or cold, or humid? And it is these abiotic factor that help determine the nature of a biome.

Terrestrial Biomes

If you look at the two pictures in **Figure** below, you will see very few similarities. The picture on the left shows a desert in Africa. The picture on the right shows a rainforest in Australia. The desert doesn't have any visible plants, whereas the rainforest is densely packed with trees. What explains these differences?

[Figure 2]

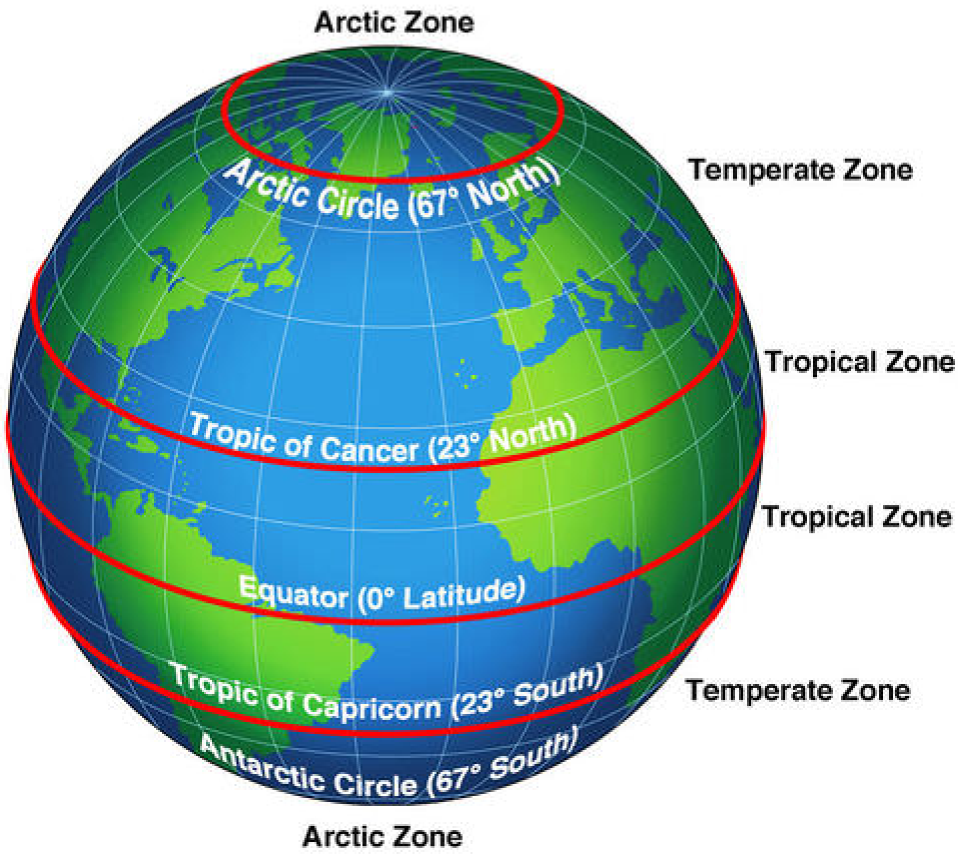
Sahara Desert in northern Africa (left). Rainforest in northeastern Australia (right). Two very different biomes are pictured here. A biome is a group of similar ecosystems with the same general abiotic factors and primary producers. Both are found at roughly the same distance from the equator.

terrestrial biome include all the land areas on Earth where organism live. The distinguishing features of terrestrial biomes are determined mainly by climate. Terrestrial biomes include tundras, temperate forests and grasslands, chaparral, temperate and tropical deserts, and tropical forests and grasslands.

Terrestrial Biomes and Climate

Climate is the average weather in an area over a long period of time. **Weather** refers to the conditions of the atmosphere from day to day. Climate is generally described in terms of temperature and moisture.

Temperature falls from the equator to the poles. Therefore, major temperature zones are based on **latitude**. They include tropical, temperate, and arctic zones (see **Figure** below). However, other factors besides latitude may also influence temperature. For example, land near the ocean may have cooler summers and warmer winters than land farther inland. This is because water gains and loses heat more slowly than does land, and the water temperature influences the temperature on the coast. Temperature also falls from lower to higher altitudes. That's why tropical zone mountain tops may be capped with snow.



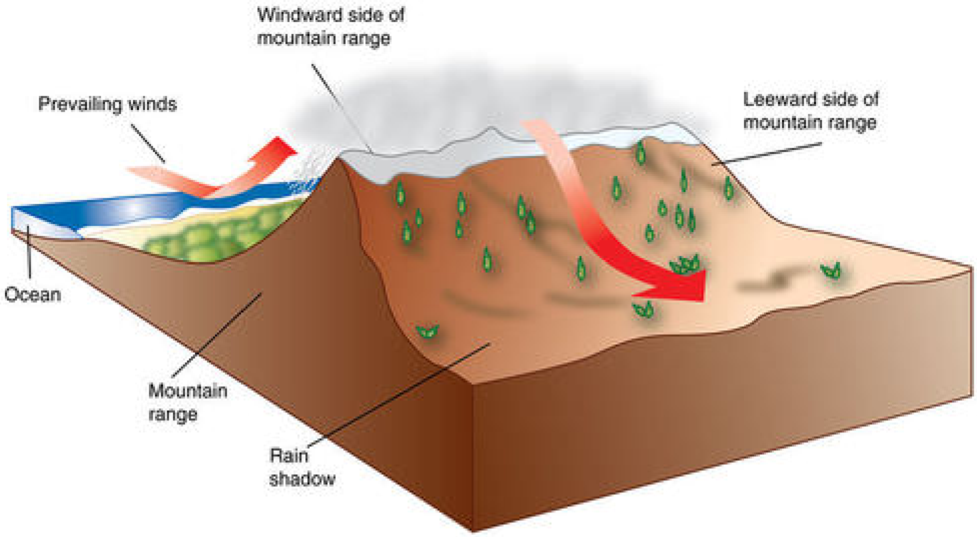
[Figure 3]

Temperature zones are based on latitude. What temperature zone do you live in?

In terms of moisture, climates can be classified as arid (dry), semi-arid, humid (wet), or semi-humid. The amount of moisture depends on both precipitation and evaporation. Precipitation increases moisture. Evaporation decreases moisture.

- The global pattern of precipitation is influenced by movement of air masses. For example, there is a global belt of dry air masses and low precipitation at about 30° N and 30° S latitude.
- Precipitation is also influenced by temperature. Warm air can hold more moisture than cold air, so tropical areas receive more rainfall than other parts of the world.
- Nearness to the ocean and mountain ranges may also influence the amount of precipitation an area receives. This is explained in **Figure** below.
- Evaporation of moisture is greatest where it is hot and sunny. Therefore, cold climates with low precipitation may not be as dry as warm climates with the same amount of precipitation.
- Moist air from the ocean rises up over the mountain range.
- As the air rises, it cools and its water vapor condenses. Precipitation falls on the windward side of the mountain range.

- The air is dry when it reaches the leeward side of the mountain range, so there is little precipitation there. This creates a "rain shadow."



[Figure 4]

This diagram shows how precipitation is affected by the ocean and a mountain range.

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Climate and Plant Growth

Plants are the major producer in terrestrial biomes. They have five basic needs: air, warmth, sunlight, water, and nutrient. How well these needs are met in a given location depends on the **growing season** and soil quality, both of which are determined mainly by climate.

- The **growing season** is the period of time each year when it is warm and wet enough for plants to grow. The growing season may last all year in a hot, wet climate but just a few months in a cooler or drier climate.
- Plants grow best in soil that contains plenty of nutrients and organic matter. Both are added to soil when plant litter and dead organisms decompose. Decomposition occurs too slowly in cold climates and too quickly in hot, wet climates for nutrients and organic matter to accumulate. Temperate climates usually have the best soil for plant growth.

Climate and Biodiversity

Because climate determines plant growth, it also influences the number and variety of other organisms in a terrestrial biome. **biodiversity** generally increases from the poles to the equator. It is also usually greater in more humid climates. This is apparent from the desert and rainforest biomes pictured in **Figure** above.

Climate and Adaptations

Organisms evolve adaptation that help them survive in the climate of the biome where they live. For example, in biomes with arid climates, plants may have special tissue for storing water (see **Figure** below). The desert animal pictured in **Figure** below also have adaptations for a dry climate.

[Figure 5]

The aloe plant on the left stores water in its large, hollow leaves. The cactus plant on the right stores water in its stout, barrel-shaped stems.

[Figure 6]

The Gila monster's fat tail is an adaptation to its dry climate. It serves as a storage depot for water. The kangaroo rat has very efficient kidneys. They produce concentrated urine, thus reducing the amount of water lost from the body.

In biomes with cold climates, plants may adapt by becoming dormant during the coldest part of the year. **dormancy** is a state in which a plant slows down cellular activities and may shed its leaves. Animals also adapt to cold temperatures. One way is with insulation in the form of fur and fat. This is how the polar bears in **Figure** below stay warm.

[Figure 7]

Thick fur and a layer of blubber keep polar bears warm in their Arctic ecosystem. Why do you think their fur is white? Why might it be an adaptation in an Arctic biome?

Summary

- Terrestrial biomes are determined mainly by climate.

- Climate influences plant growth, biodiversity, and adaptations of land organisms.

Review

1. What is climate? How does it differ from weather?

2. What is a rain shadow?

3. What is a growing season? How does climate influence plant growth?

4. Describe the relationship between climate and biodiversity.

5. Compare the data for Seattle and Denver in **Table** below. Seattle is farther north than Denver. Why is Seattle warmer?

City, State	Latitude (°N)	Altitude (ft above sea level)	Location (relative to ocean)	Average Low Temperature in January (°F)
Seattle, Washington	48	429	Coastal	33
Denver, Colorado	41	5183	Interior	15

Report Content Errors

6.9 Terrestrial Biomes

FlexBooks 2.0 > Biology For High School Diploma > Terrestrial Biomes

Last Modified: Oct 27, 2020

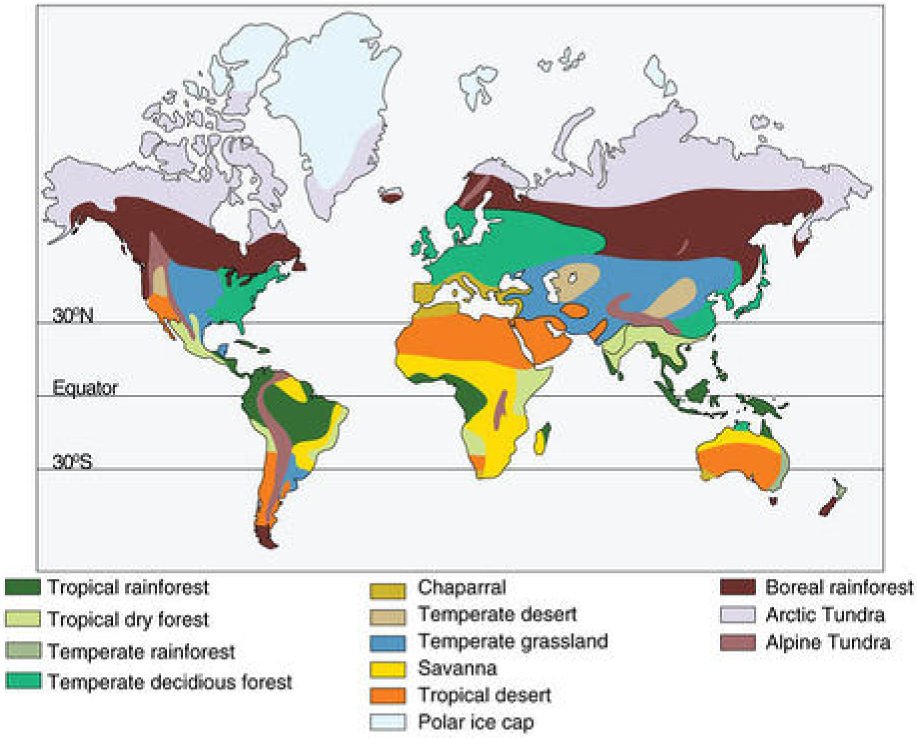
[Figure 1]

Forest vs. desert. What explains these differences?

If you look at these two pictures, you will see very few similarities. The picture on the left shows a desert in Africa. The picture on the right shows a rainforest in Australia. The desert doesn't have any visible plants, whereas the rainforest is densely packed with trees. Do they have different climates? Does one get more rain than the other?

Survey of Terrestrial Biomes

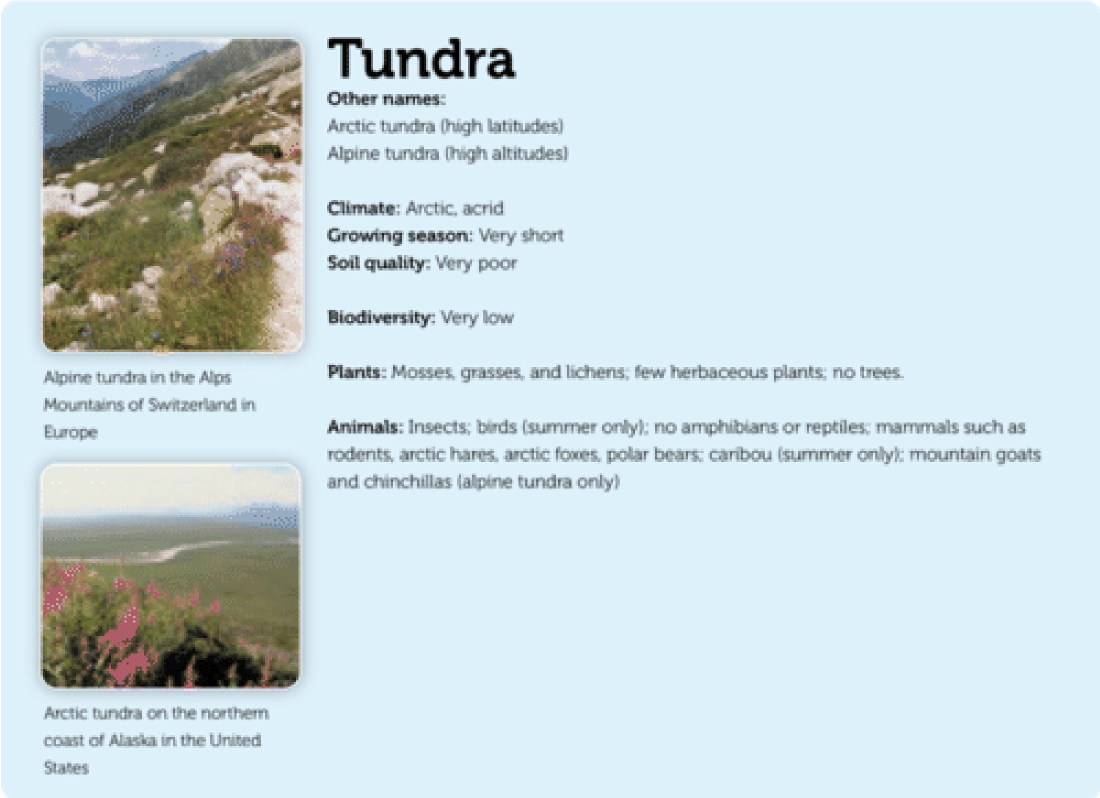
Terrestrial **biome** are classified by the **climate** and their **biodiversity**, especially the types of **primary producer**. The world map in **Figure** below shows where 13 major terrestrial biome are found.



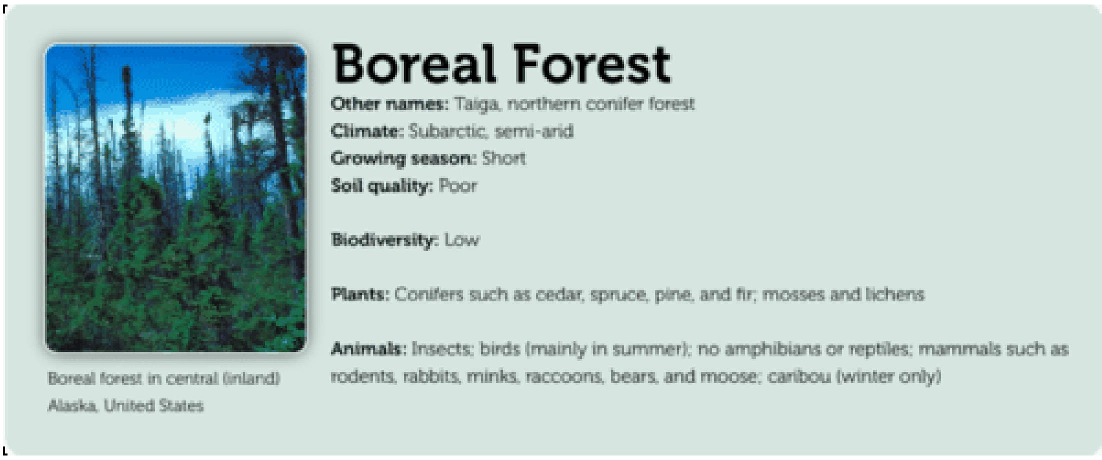
[Figure 2]

Worldwide Distribution of Terrestrial Biomes. This map shows the locations of Earth's major terrestrial biomes.

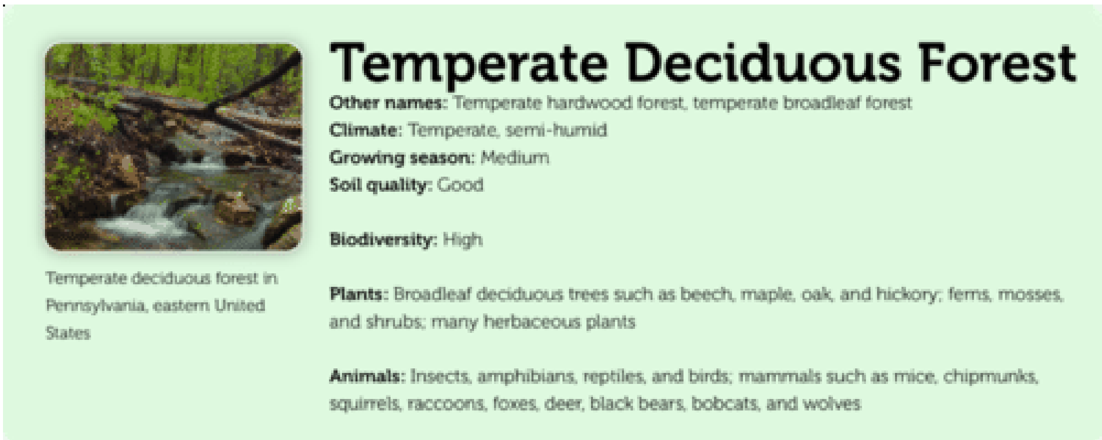
The following figures summarize the basic features of major terrestrial biomes. As you read about each biome, think about how its biodiversity and types of plants and animal relate to its climate. For example, why do you think there are no amphibian or reptile in tundra biomes? (Hint: Amphibians and reptiles cannot maintain a constant body temperature. Instead, they have about the same temperature as their surroundings.)



[Figure 3]



[Figure 4]



[Figure 5]

Temperate grassland in Nebraska, midwestern United States

Temperate Grassland

Other names: Prairie, outback, pampa, steppe
Climate: Temperate, semi-arid
Growing season: Medium
Soil quality: Excellent

Biodiversity: Medium-high

Plants: Grasses; other herbaceous plants; no trees

Animals: Invertebrates such as worms and insects; amphibians, reptiles, and birds; mammals such as mice, prairie dogs, rabbits, foxes, wolves, coyotes, bison, and antelope; kangaroo (only in Australia)

[Figure 6]

Chaparral in southern California, United States

Chaparral

Other names: Mediterranean scrub forest
Climate: Temperate, semi-arid
Growing season: Medium
Soil quality: Poor

Biodiversity: Low-medium

Plants: Shrubs and small trees such as scrub oak and scrub pine

Animals: Insects, reptiles, and birds; mammals such as rodents and deer

[Figure 7]

Desert in southern California, United States

Desert

Climate: Temperate or tropical, arid
Growing season: Varies
Soil quality: Very poor

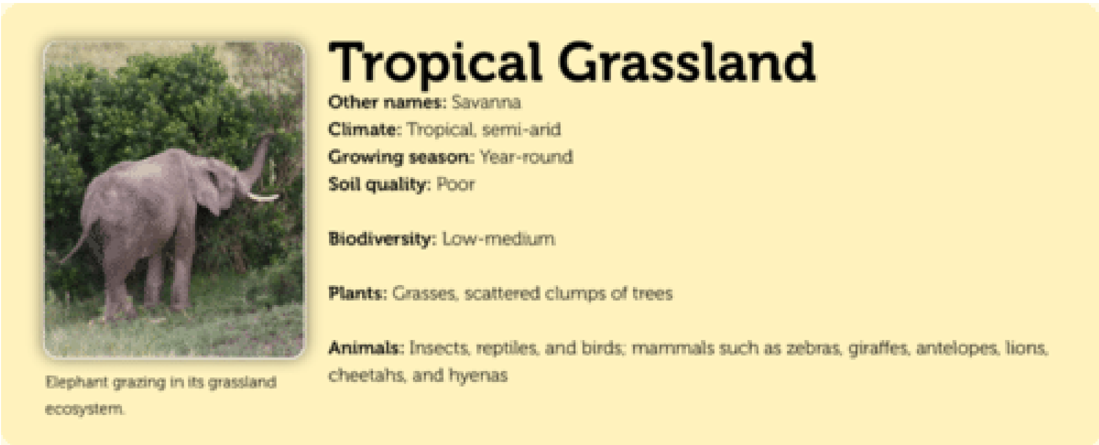
Biodiversity: None-low

Plants: Plants adapted to dryness, such as cacti, sagebrush, and mesquite; virtually no plants if extremely arid

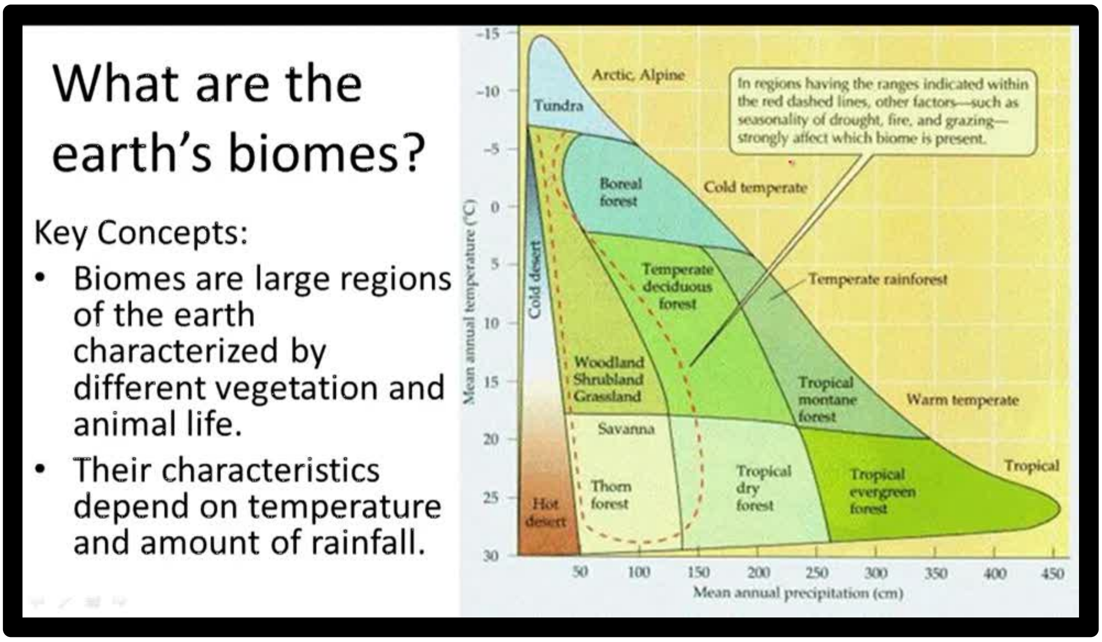
Animals: Insects, reptiles, and birds; mammals such as rodents and coyotes

[Figure 8]

[Figure 9]



[Figure 10]



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Science Friday: Superbloom: How Death Valley Springs to Life

A massive seed bank of desert wildflowers lies beneath Death Valley. This video by science Friday shows that when heavy winter rains soak deep into the soil, these hidden wonders spring to life, in an event called a "superbloom".

https://flexbooks.ck12.org/flx/render/embeddedobject/194572

Summary

- Terrestrial biomes include tundras, temperate forests and grasslands, chaparral, temperate and tropical deserts, and tropical forests and grasslands.

Review

1. Identify two types of tundra and where they are found.
2. What terrestrial biome has the highest biodiversity? the lowest?
3. In which biome are you most likely to find grasses, zebras, and lions?
4. If you were to design a well-adapted desert animal, what adaptations would you give it to help it survive in its desert biome?

Report Content Errors

6.10 Aquatic Biomes

FlexBooks 2.0 > Biology For High School Diploma > Aquatic Biomes

Last Modified: Apr 15, 2020

[Figure 1]

Do aquatic ecosystems need sunlight?

Of course. The sunlight - in part - allows the diversity of life seen in this ecosystem. If the available sunlight was less, could this ecosystem still thrive? Maybe, but the ecosystem would probably be very different. Sunlight, of course, is necessary for photosynthesis, which brings energy into an ecosystem. So, the availability of that sunlight has a direct impact on the productivity and biodiversity of aquatic ecosystems.

Aquatic Biomes

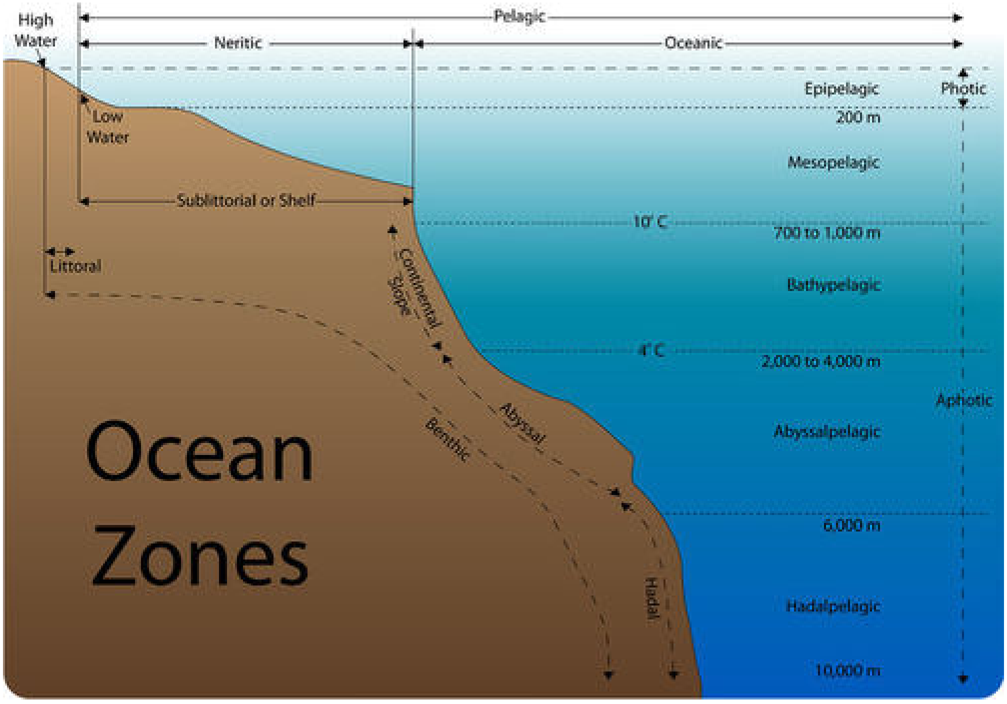
Terrestrial organism are generally limited by temperature and moisture. Therefore, terrestrial biome are defined in terms of these abiotic factor. Most aquatic organisms do not have to deal with extremes of temperature or moisture. Instead, their main limiting factor are the availability of sunlight and the concentration of dissolved oxygen and nutrient in the water. These factors vary from place to place in a body of water and are used to define **aquatic biome**.

Aquatic Biomes and Sunlight

In large bodies of standing water, including the ocean and lakes, the water can be divided into zones based on the amount of sunlight it receives:

1. The **photic zone** extends to a maximum depth of 200 meters (656 feet) below the surface of the water. This is where enough sunlight penetrates for photosynthesis to occur. alga and other photosynthetic organisms can make food and support food web.
2. The **aphotic zone** is water deeper than 200 meters. This is where too little sunlight penetrates for photosynthesis to occur. As a result, food must be made by chemosynthesis or else drift down from the water above.

These and other aquatic zones in the ocean are identified in **Figure** below.



[Figure 2]

The ocean is divided into many different zones, depending on distance from shore and depth of water.

Aquatic Biomes and Dissolved Substances

Water in lakes and the ocean also varies in the amount of dissolved oxygen and nutrients it contains:

1. Water near the surface of lakes and the ocean usually has more dissolved oxygen than does deeper water. This is because surface water absorbs oxygen from the air above it.
2. Water near shore generally has more dissolved nutrients than water farther from shore. This is because most nutrients enter the water from land. They are carried by runoff, streams, and rivers that empty into a body of water.
3. Water near the bottom of lakes and the ocean may contain more nutrients than water closer to the surface. When aquatic organisms die, they sink to the bottom. decomposer

near the bottom of the water break down the dead organisms and release their nutrients back into the water.

Marine Biomes

Anglerfish live in the ocean. Aquatic biomes in the ocean are called **marine biome**. Organisms that live in marine biomes must be adapted to the salt in the water. For example, many have organ for excreting excess salt. Two ocean zones are particularly challenging to marine organisms: the **intertidal zone** and the deep ocean.

The **intertidal zone** is the narrow strip along the coastline that is covered by water at high tide and exposed to air at low tide (see **Figure** below). There are plenty of nutrients and sunlight in the intertidal zone. However, the water is constantly moving in and out, and the temperature keeps changing. These conditions require adaptation in the organisms that live there, such as the barnacles in **Figure** below.

[Figure 3]

These pictures show the intertidal zone of the Bay of Fundy, on the Atlantic coast in Maine. Can you identify the intertidal zone from the pictures?

[Figure 4]

Barnacles secrete a cement-like substance that anchors them to rocks in the intertidal zone.

Organisms that live deep in the ocean must be able to withstand extreme water pressure, very cold water, and complete darkness. However, even here, thriving community of living things can be found. Organisms cluster around hydrothermal vents in the ocean floor. The vents release hot water containing chemicals that would be toxic to most other living things. The producer among them are single-celled chemoautotroph. They make food using energy stored in the chemicals.

Monitoring Marine Protected Areas

Is overfishing an important issue? What would happen if fish population dwindled? Marine Protected Areas are no-fishing zones that have recently been established up and down the California coast, in the hope of allowing fish to breed, grow large, and replenish state waters. Scientists monitor these areas to determine if this process is working.

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Further Reading

Chemosynthesis

Summary

- Aquatic biomes are determined mainly by sunlight and concentrations of dissolved oxygen and nutrients in the water.
- Marine biomes are found in the salt water of the ocean.

Review

1. How are aquatic biomes defined?
2. What is the photic zone of the ocean?
3. Where does food come from in the aphotic zone?

Report Content Errors

6.11 Freshwater and Wetland Biomes

FlexBooks 2.0 > Biology For High School Diploma > Freshwater and Wetland Biomes

Last Modified: Aug 01, 2018

[Figure 1]

What may be the most biologically diverse type of ecosystem?

These are **wetland** marshes in Delaware. Notice the abundance of vegetation mixed with the water. And of course, where there are plants, there are animal. Wetlands are considered the most biologically diverse of all ecosystem. Plant life found in wetlands includes mangrove, water lilies, cattails, black spruce, cypress, and many others. Animal life includes many different amphibian, reptile, bird, insects, and mammal.

Freshwater Biomes

freshwater biome have water that contains little or no salt. They include standing and running freshwater biomes. Standing freshwater biomes include ponds and lakes. Lakes are generally bigger and deeper than ponds. Some of the water in lakes is in the aphotic zone, where there is too little sunlight for photosynthesis. Plankton and plants, such as the duckweed in **Figure** below, are the primary producer in standing freshwater biomes.

[Figure 2]

The pond on the left has a thick mat of duckweed plants. They cover the surface of the water and use sunlight for photosynthesis. The cattails on the right grow along a stream bed. They have tough, slender leaves that can withstand moving water.

Running freshwater biomes include streams and rivers. Rivers are usually larger than streams. Streams may start with runoff or water seeping out of a spring. The water runs downhill and joins other running water to become a stream. A stream may flow into a river that empties into a lake or the ocean. Running water is better able to dissolve oxygen and nutrient than standing water. However, the moving water is a challenge to many living things. alga and plants, such as the cattails in **Figure** above, are the primary producers in running water biome.

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Wetlands

A **wetland** is an area that is saturated with water or covered by water for at least one season of the year. The water may be freshwater or salt water. Wetlands are extremely important biomes for several reasons:

- They store excess water from floods.
- They slow down runoff and help prevent erosion.
- They remove excess nutrients from runoff before it empties into rivers or lakes.
- They provide a unique habitat that certain community of plants need to survive.
- They provide a safe, lush habitat for many species of animals, so they have high biodiversity.

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KQED: San Francisco Bay: A Unique Estuary

An **estuary** is a partly enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the ocean. Estuaries can be thought of as the most biologically productive regions on Earth, with very high biodiversity. Estuaries are zones where land and sea come together, and where fresh and salt water meet.

The San Francisco Bay is one of the great estuaries of the world.

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Science Friday: Poop and Paddle: An Eco-Friendly Floating Toilet

How do wetlands filter water? In this video by science Friday, inventor Adam Katzman describes how his toilet-boat converts human waste into cattails and clean water.

https://flexbooks.ck12.org/flx/render/embeddedobject/194516

Summary

- Freshwater biomes include standing water and running water biomes.
- Wetlands are extremely important biomes. They may have freshwater or salt water.

Review

1. Describe a freshwater biome.
2. Define a wetland.
3. Why do wetlands have high biodiversity?
4. A developer wants to extend a golf course into a wetland. Outline environmental arguments you could make against this plan.

Report Content Errors

6.12 Aquatic Organisms

FlexBooks 2.0 > Biology For High School Diploma > Aquatic Organisms

Last Modified: Jun 22, 2020

[Figure 1]

What is this? Plant or animal?

It is actually the Yellow Christmas tree worm. These animal are colorful, and can be red, orange, yellow, blue, and white. The Christmas tree worm lives on tropical coral reefs throughout the world. The Christmas tree worm's plumes are used for feeding and respiration. These worms use their plumes to catch plankton and other small particles passing in the water. cilia then pass the food to the worm's mouth.

Aquatic Organisms

Aquatic organism generally fall into three broad groups: plankton, nekton, and benthos. They vary in how they move and where they live.

1. **Plankton** are tiny aquatic organisms that cannot move on their own. They live in the photic zone. They include **phytoplankton** and **zooplankton**. **Phytoplankton** are bacterium and alga that use sunlight to make food. **Zooplankton** are tiny animals that feed on phytoplankton.
2. **Nekton** are aquatic animals that can move on their own by "swimming" through the water. They may live in the photic or aphotic zone. They feed on plankton or other nekton. Examples of nekton include fish and shrimp.
3. **Benthos** are aquatic organisms that crawl in sediments at the bottom of a body of water. Many are decomposer. Benthos include sponges, clams, and anglerfish like the one in **Figure** below. How has this fish adapted to a life in the dark?

[Figure 2]

Anglerfish. This anglerfish lives between 1000 and 4000 meters below sea level. No sunlight penetrates to this depth. The rod-like structure on its face has a glow-in-the-dark tip. It is covered with microorganisms that give off their own light. The fish wiggles the structure like a worm to attract prey. In the darkness, only the rod-like worm is visible.

KQED: Studying Aquatic Animals

Oceans cover more than 70 percent of our planet, yet they are some of the least explored regions on Earth. Who better to unlock the mysteries of the ocean than marine animals themselves? Marine scientists have been tagging and tracking sharks, leatherback turtles, and other sea life to learn more about marine ecosystem. Through the Tagging of Pacific predator program (TOPP), scientists hope to assess and explain the migration routes, ecosystems, and diversity of our oceans' species.

Beginning in 2000, scientists from the National Oceanic and Atmospheric Administration, Stanford University, and the University of California, Santa Cruz combined to form TOPP. As part of TOPP, researchers attach satellite tags to elephant seals, white sharks, giant leatherback turtles, bluefin tuna, swordfish, and other marine animals. The tags collect information, such as how deep each animal dives, the levels of ambient light (to help determine an animal's location), and interior and exterior body temperature. Some tags also collect information about the temperature, salinity, and depth of the water surrounding an animal to help scientists identify ocean currents. The tags send the data to a satellite, which in turn sends the data the scientists. They use this information to create maps of migration patterns and discover new information about different marine ecosystems. The information collected by TOPP offers rare insights into the lives of marine animals. Without TOPP, that information would otherwise remain unknown. With TOPP, scientists are developing a working knowledge of the particular migration routes animals take, as well as the locations of popular breeding grounds and the environmental dangers faced by different species. TOPP has shed light on how we can better protect the leatherback turtle and other endangered species.

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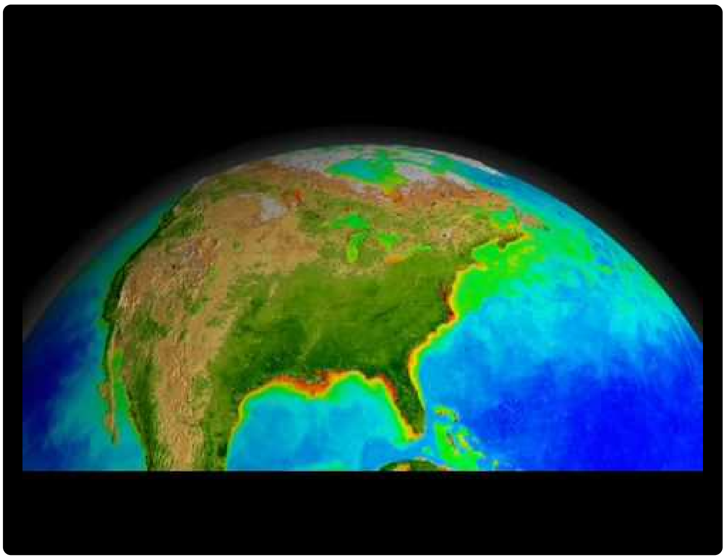
Summary

- Aquatic organisms are either plankton, nekton, or benthos.

Review

1. Compare plankton, nekton, and benthos.
2. Give an example of plankton, nekton, and benthos.
3. What are phytoplankton and zooplankton?

Resources



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Report Content Errors

6.13 Predation

FlexBooks 2.0 > Biology For High School Diploma > Predation

Last Modified: Mar 24, 2020

[Figure 1]

What may be the most common way different species interact?

biome as different as deserts and wetland share something very important. All biomes have population of interacting species. Species interact in the same basic ways in all biomes. For example, all biomes have some species that **prey** on others for food.

Predation

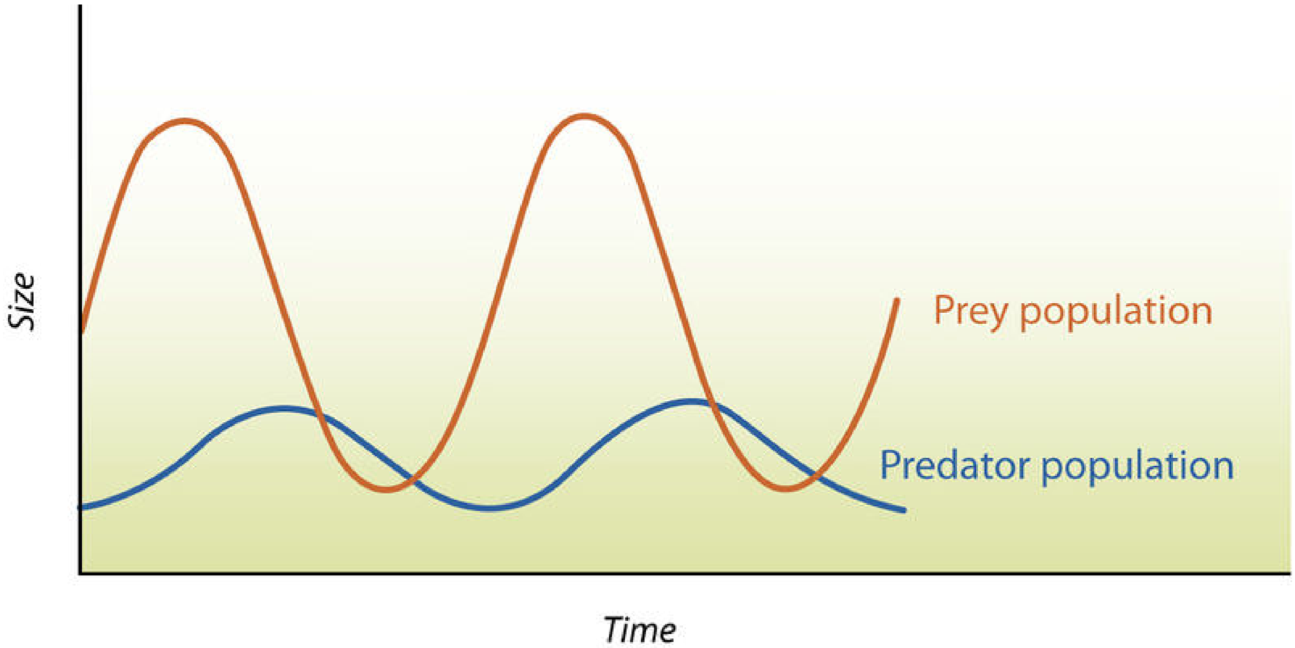
Predation is a relationship in which members of one species (the **predator**) consume members of another species (the **prey**). The lionesses and zebra in **Figure** below are classic examples of predators and prey. In addition to the lionesses, there is another predator in this figure. Can you spot it? The other predator is the zebra. Like the lionesses, it consumes prey species, in this case species of grass. However, unlike the lionesses, the zebra does not kill its prey. Predator-prey relationships such as these account for most energy transfers in food chain and food web.

[Figure 2]

Predators and Their Prey. These lionesses feed on the carcass of a zebra.

Predation and Population

A **predator-prey relationship** tends to keep the populations of both species in balance. This is shown by the graph in **Figure** below. As the prey population increases, there is more food for predators. So, after a slight lag, the predator population increases as well. As the number of predators increases, more prey are captured. As a result, the prey population starts to decrease. What happens to the predator population then?



[Figure 3]

Predator-Prey Population Dynamics. As the prey population increases, why does the predator population also increase?

In the predator-prey example, one factor limits the growth of the other factor. As the prey population deceases, the predator population begins to decrease as well. The prey population is a limiting factor. A **limiting factor** limits the growth or development of an organism, population, or process.

Keystone Species

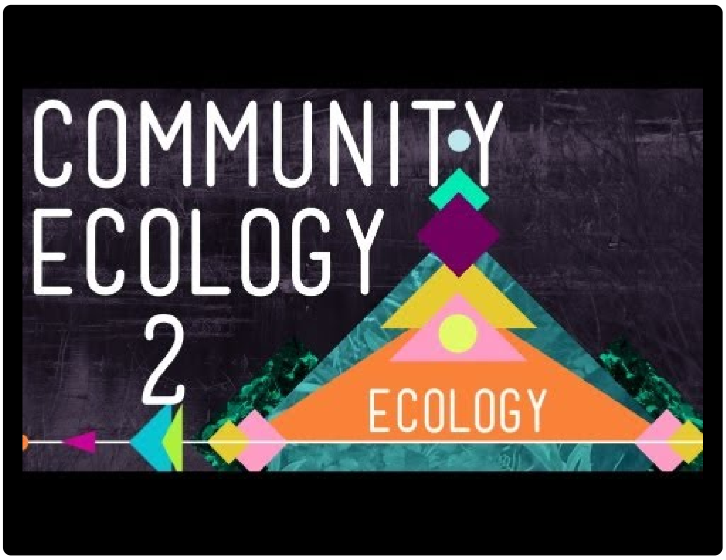
Some predator species are known as **keystone species**. A **keystone species** is one that plays an especially important role in its community. Major changes in the numbers of a keystone species affect the populations of many other species in the community. For example, some sea star species are keystone species in coral reef communities. The sea stars prey on mussels and sea urchins, which have no other natural predators. If sea stars were removed from a coral reef community, mussel and sea urchin populations would have explosive growth. This, in turn, would drive out most other species. In the end, the coral reef community would be destroyed.

Adaptations to Predation

Both predators and prey have adaptation to predation that evolve through natural selection. Predator adaptations help them capture prey. Prey adaptations help them avoid predators. A common adaptation in both predator and prey is **camouflage**. Several examples are shown in **Figure** below. Camouflage in prey helps them hide from predators. Camouflage in predators helps them sneak up on prey.

[Figure 4]

Camouflage in Predator and Prey Species. Can you see the crab in the photo on the left? It is camouflaged with the sand. The preying mantis in the middle photo looks just like the dead leaves in the background. Can you tell where one zebra ends and another one begins? This may confuse a predator and give the zebras a chance to run away.



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Science Friday: Can Underwater Parks Protect Coral?

Coral communities are incredibly important for marine life. In this video by science Friday, Marine scientists John Bruno and Elizabeth Selig describe the effects of local Marine Protection Areas on preserving coral.

https://flexbooks.ck12.org/flx/render/embeddedobject/194517

Summary

- Predation is a relationship in which members of one species (the predator) consume members of another species (the prey).
- A predator-prey relationship keeps the populations of both species in balance.

Review

1. Describe the relationship between a predator population and the population of its prey.
2. What is a keystone species? Give an example.
3. What is a limiting factor?
4. What is the role of camouflage in prey and predator?

Report Content Errors

6.14 Competition

FlexBooks 2.0 > Biology For High School Diploma > Competition

Last Modified: Aug 01, 2018

[Figure 1]

Does there have to be a winner?

When animal compete? Yes. Animals, or other organism, will compete when both want the same thing. One must "lose" so the winner can have the resource. But competition doesn't necessarily involve physical altercations.

Competition

Competition is a relationship between organisms that strive for the same resources in the same place. The resources might be food, water, or space. There are two different types of competition:

1. **intraspecific competition** occurs between members of the same species. For example, two male bird of the same species might compete for mates in the same area. This type of competition is a basic factor in natural selection. It leads to the evolution of better adaptation within a species.
2. **interspecific competition** occurs between members of different species. For example, predator of different species might compete for the same prey.

Interspecific Competition and Extinction

Interspecific competition often leads to **extinction**. The species that is less well adapted may get fewer of the resources that both species need. As a result, members of that species are less likely to survive, and the species may go extinct.

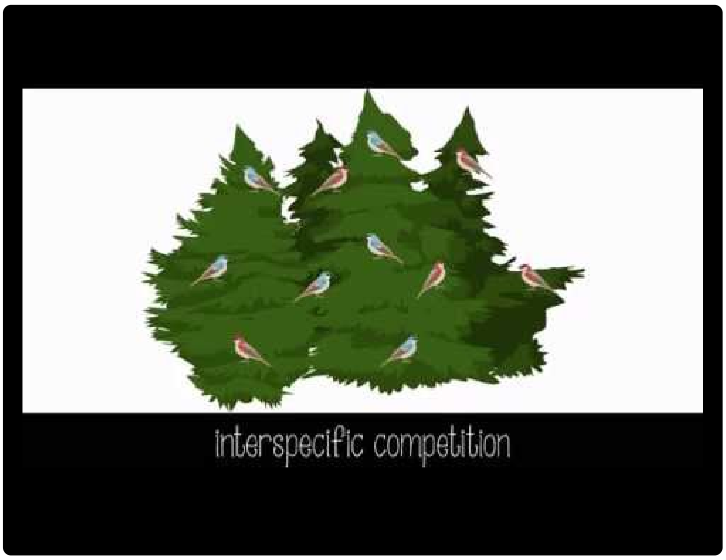
Interspecific Competition and Specialization

Instead of extinction, interspecific competition may lead to greater **specialization**. **Specialization** occurs when competing species evolve different adaptations. For example, they may evolve adaptations that allow them to use different food sources. **Figure** below describes an example.

[Figure 2]

Specialization lets different species of anole lizards live in the same area without competing.

Watch the beginning of the following video to learn more about competition.



https://flexbooks.ck12.org/flx/render/embeddedobject/187108

Summary

- Competition is a relationship between organisms that strive for the same resources in the same place.
- Intraspecific competition occurs between members of the same species. It improves the species' adaptations.
- Interspecific competition occurs between members of different species. It may lead to one species going extinct or both becoming more specialized.

Review

1. What is competition?
2. Describe the evolutionary effects of intraspecific and interspecific competition.

Report Content Errors

6.15 Symbiosis

FlexBooks 2.0 > Biology For High School Diploma > Symbiosis

Last Modified: Feb 25, 2021

[Figure 1]

Do interactions between species always result in harm?

A commensal shrimp sits on another sea organism, a sea slug. As a commensal shrimp, it neither brings a benefit nor has a negative effect on its **host**.

Symbiotic Relationships

Symbiosis is a close relationship between two species in which at least one species benefits. For the other species, the relationship may be positive, negative, or neutral. There are three basic types of symbiosis: **mutualism**, **commensalism**, and **parasitism**.

Mutualism

Mutualism is a symbiotic relationship in which both species benefit. An example of mutualism involves goby fish and shrimp (see the **Figure** below). The nearly blind shrimp and the fish spend most of their time together. The shrimp maintains a burrow in the sand in which both the fish and shrimp live. When a predator comes near, the fish touches the shrimp with its tail as a warning. Then, both fish and shrimp retreat to the burrow until the predator is gone. From their relationship, the shrimp gets a warning of approaching danger. The fish gets a safe retreat and a place to lay its egg.

[Figure 2]

The multicolored shrimp in the front and the green goby fish behind it have a mutualistic relationship.

coevolution often occurs in species involved in mutualistic relationships. Many examples are provided by flowering plants and the species that pollinate them. Plants have evolved flower with traits that promote pollination by particular species. pollinator species, in turn, have evolved traits that help them obtain pollen or nectar from certain species of flowers. The flowering plants and the pollinators, such as a bird or insect, both benefit from the relationship.

Commensalism

Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. One species typically uses the other for a purpose other than food. For example, mites attach themselves to larger flying insects to get a "free ride." Hermit crabs use the shells of dead snails for homes. Another example of commensalism involves a whale and barnacles (see the **Figure** below). The barnacles attach to the whale to gain greater access to food and a secure place to live. The whale is unaffected by the relationship.

[Figure 3]

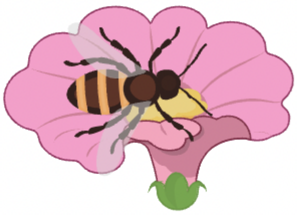
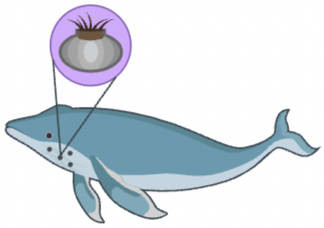
Whale and barnacles.

Parasitism

Parasitism is a symbiotic relationship in which one species (the **parasite**) benefits while the other species (the **host**) is harmed. Many species of animal are parasites, at least during some stage of their life. Most species are also hosts to one or more parasites.

Some parasites live on the surface of their host. Others live inside their host. They may enter the host through a break in the skin or in food or water. For example, roundworms are parasites of mammal, including humans, cats, and dogs. The worms produce huge numbers of eggs, which are passed in the host's feces to the environment. Other individuals may be infected by swallowing the eggs in contaminated food or water.

Some parasites kill their host, but most do not. It's easy to see why. If a parasite kills its host, the parasite is also likely to die. Instead, parasites usually cause relatively minor damage to their host.

	**Mutualism**	**both species benefit**
	**Commensalism**	**one species benefits, the other species is unaffected**
	**Parasitism**	**one species benefits, the other species is harmed**

Science Friday: Invasion of the Zombees: A Bee Horror Film

What would cause bees to suddenly drop dead? In this video by science Friday, Lila Higgins discusses the parasite this is quietly causing these bees to die.

https://flexbooks.ck12.org/flx/render/embeddedobject/194518

Summary

- Symbiosis is a close relationship between two species in which at least one species benefits.
- Mutualism is a symbiotic relationship in which both species benefit.
- Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected.
- Parasitism is a symbiotic relationship in which one species (the parasite) benefits while the other species (the host) is harmed.

Review

1. Define mutualism and commensalism.
2. Give examples of mutualism.
3. Explain why most parasites do not kill their host. Why is it in their own best interest to keep their host alive?

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6.16 Succession

FlexBooks 2.0 > Biology For High School Diploma > Succession

Last Modified: May 16, 2021

[Figure 1]

Can a plant really grow in hardened lava?

It can if it is very hardy and tenacious. And that is how succession starts. It begins with a plant that must be able to grow on new land with minimal soil or nutrient.

Ecological Succession

community are not usually static. The numbers and types of species that live in them generally change over time. This is called **ecological succession**. Important cases of succession are primary and **secondary succession**.

Primary Succession

primary succession occurs in an area that has never before been colonized. Generally, the area is nothing but bare rock. This type of environment may come about when

- lava flows from a volcano and hardens into rock.
- a glacier retreats and leaves behind bare rock.
- a landslide uncovers an area of bare rock.

The first species to colonize a disturbed area such as this are called **pioneer species** (see **Figure** below). They change the environment and pave the way for other species to come into the area. Pioneer species are likely to include bacterium and lichens that can live on bare rock. Along with wind and water, they help weather the rock and form soil. Once soil begins to form, plants can move in. At first, the plants include grasses and other species that can grow in thin, poor soil. As more plants grow and die, organic matter is added to the soil. This improves the soil and helps it hold water. The improved soil allows shrubs and trees to move into the area.

[Figure 2]

Pioneer species such as lichens can live on bare rock.

Secondary Succession

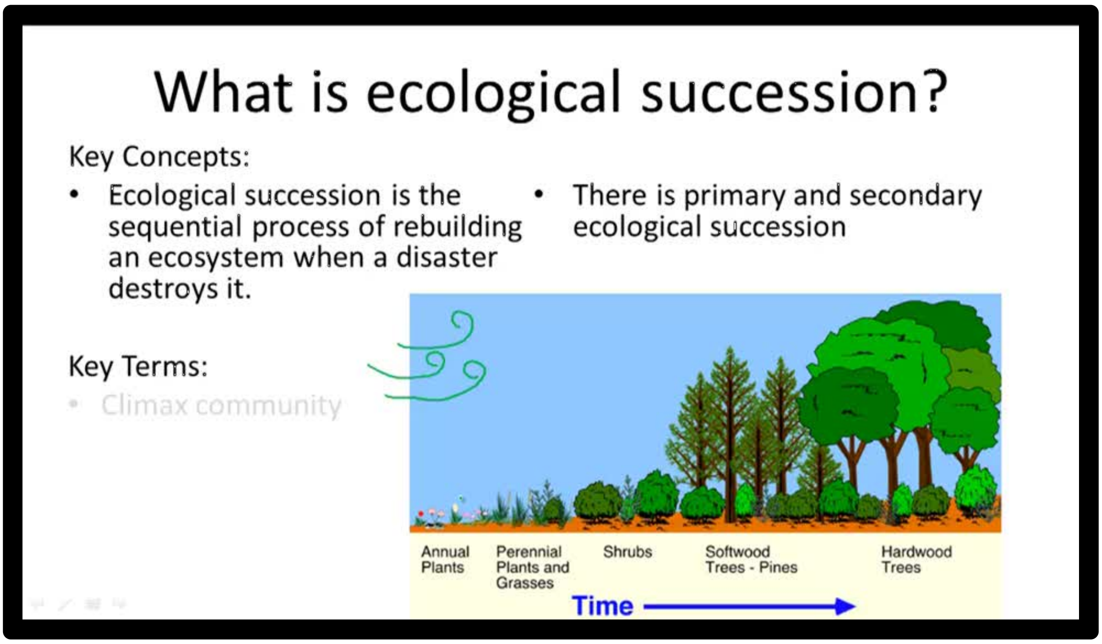
Secondary succession occurs in a formerly inhabited area that was disturbed. The disturbance could be a fire, flood, or human action such as farming. This type of succession is faster because the soil is already in place. In this case, the pioneer species are plants such as grasses, birch trees, and fireweed. Organic matter from the pioneer species improves the soil. This lets other plants move into the area. An example of this type of succession is shown in **Figure** below.

[Figure 3]

Secondary Succession. A year after a forest fire, new plants are already sprouting among the charred logs.

Climax Communities

Many early ecologists thought that a community always goes through the same series of stages during succession. They also assumed that succession always ends with a final stable stage. They called this stage the **climax community**. Today, most ecologists no longer hold these views. They believe that continued change is normal in most ecosystem. They think that most communities are disturbed too often to become climax communities.



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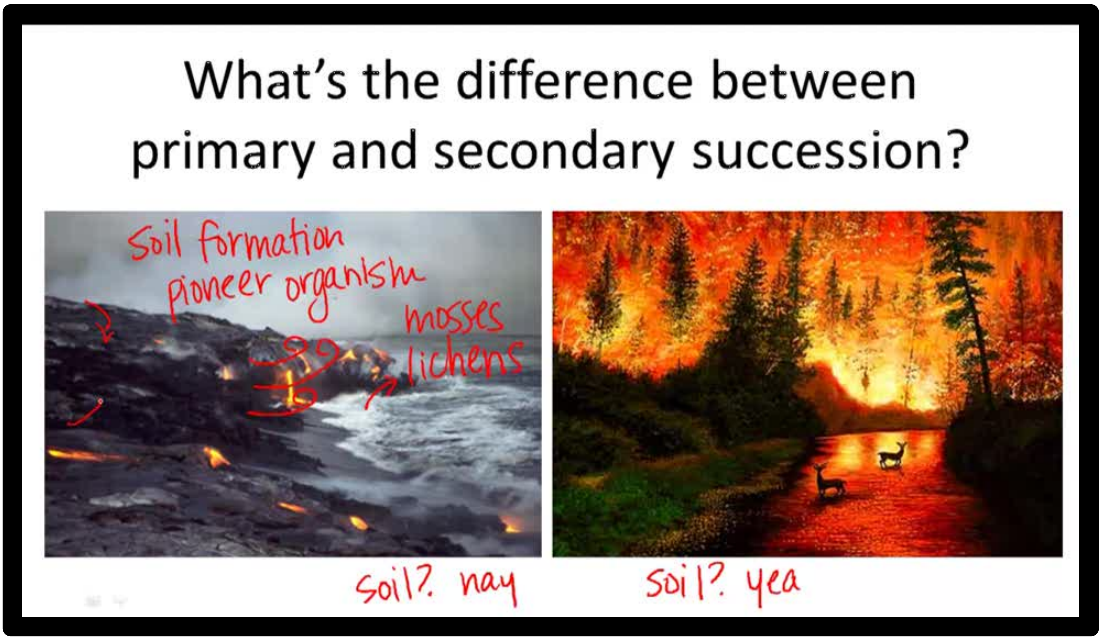

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Summary

- Ecological succession is the process in which a community changes through time.
- Primary succession occurs in an area that has never before been colonized.
- Secondary succession occurs in a formerly inhabited area that was disturbed.

Review

1. What is ecological succession?

2. Describe the main difference between primary and secondary succession.
3. Give two examples of habitats that will go through primary succession.
4. What is a climax community?
5. Summarize how ideas about ecological succession and climax communities have changed.

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6.17 Population

FlexBooks 2.0 > Biology For High School Diploma > Population

Last Modified: Aug 12, 2018

[Figure 1]

Is this any way to live?

It is if you're a penguin. This population of penguins is made of all the individuals of the same species of penguins who live together. They seem to exist in a very crowded - or densely populated - environment, and in a random configuration.

Population Size, Density, and Distribution

community are made up of populations of different species. In biology, a **population** is a group of organism of the same species that live in the same area. The population is impacted by natural selection and evolution. How large a population is and how fast it is growing are often used as measures of its health.

Population Size

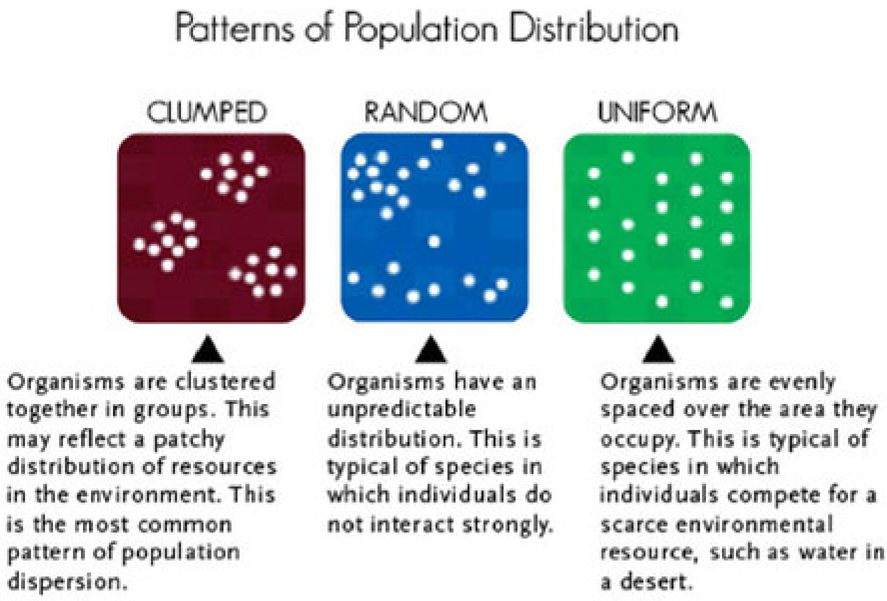
population size is the number of individuals in a population. For example, a population of insects might consist of 100 individual insects, or many more. Population size influences the chances of a species surviving or going extinct. Generally, very small populations are at greatest risk of extinction. However, the size of a population may be less important than its density.

Population Density

population density is the average number of individuals in a population per unit of area or volume. For example, a population of 100 insects that live in an area of 100 square meters has a density of 1 insect per square meter. If the same population lives in an area of only 1 square meter, what is its density? Which population is more crowded? How might crowding affect the health of a population?

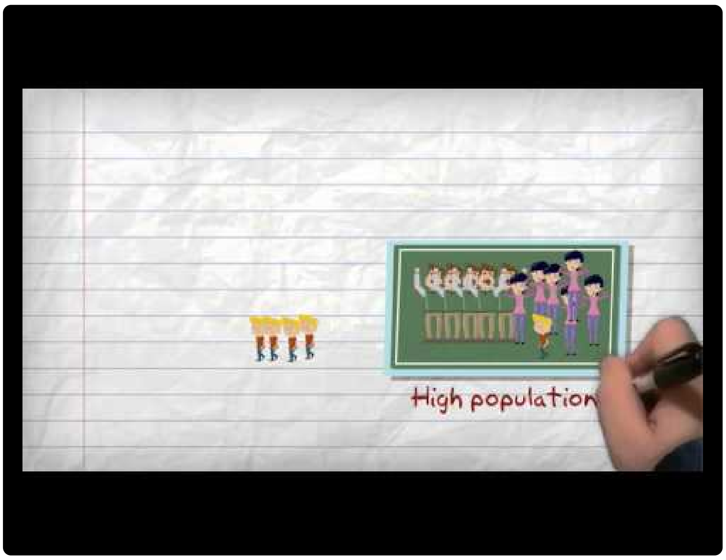
Population Distribution

Population density just represents the average number of individuals per unit of area or volume. Often, individuals in a population are not spread out evenly. Instead, they may live in clumps or some other pattern (see **Figure** below). The pattern may reflect characteristics of the species or its environment. **population distribution** describes how the individuals are distributed, or spread throughout their habitat.



[Figure 2]

Patterns of Population Distribution. What factors influence the pattern of a population over space?



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Further Reading

Population Structure

Summary

- Population size is the number of individuals in a population.
- Population density is the average number of individuals per unit of area or volume.
- The pattern of spacing of individuals in a population may be affected by the characteristics of a species or its environment.

Review

1. What is population density?
2. What are the differences between population density and distribution?
3. A population of 820 insects lives in a 1.2-acre area. They gather nectar from a population of 560 flowering plants. The plants live in a 0.2-acre area. Which population has greater density, the insects or the plants? Why?
4. What can you infer about a species that has a random pattern of distribution over space? A uniform pattern?

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6.18 Population Structure

FlexBooks 2.0 > Biology For High School Diploma > Population Structure

Last Modified: Oct 27, 2020

[Figure 1]

Young vs. old. Does it matter?

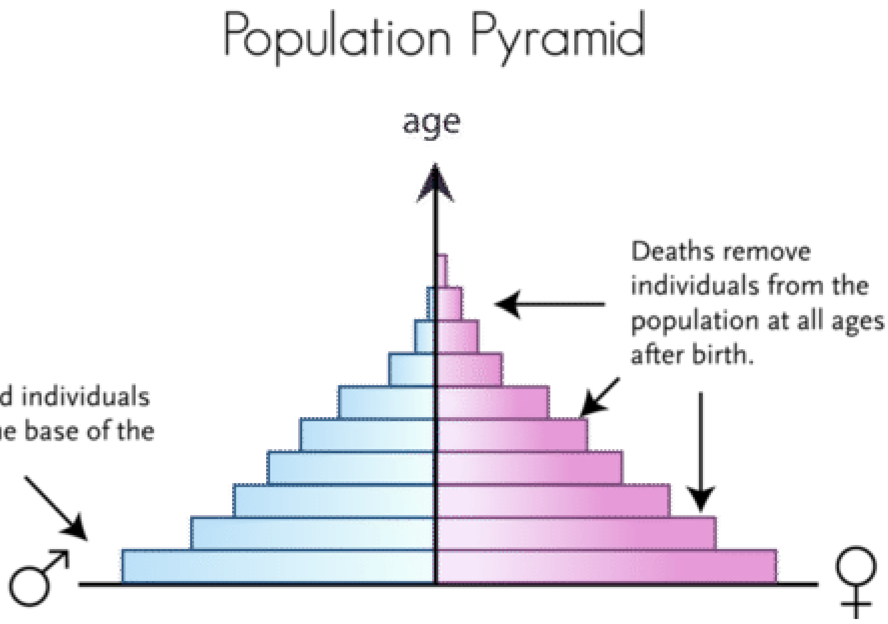
When it comes to population, yes it does. The age structure (and the sex structure) of a population influences **population growth**. Can you explain why?

Population Structure

Population growth is the change in the size of the population over time. An important factor in population growth is **age-sex structure**. This is the number of individuals of each sex and age in the population. The age-sex structure influences population growth. This is because younger people are more likely to reproduce, while older people have higher rates of dying.

Population Pyramids

Age-sex structure is represented by a **population pyramid**. This is a bar graph, like the one **Figure** below. In this example, the bars become narrower from younger to older ages. Can you explain why?

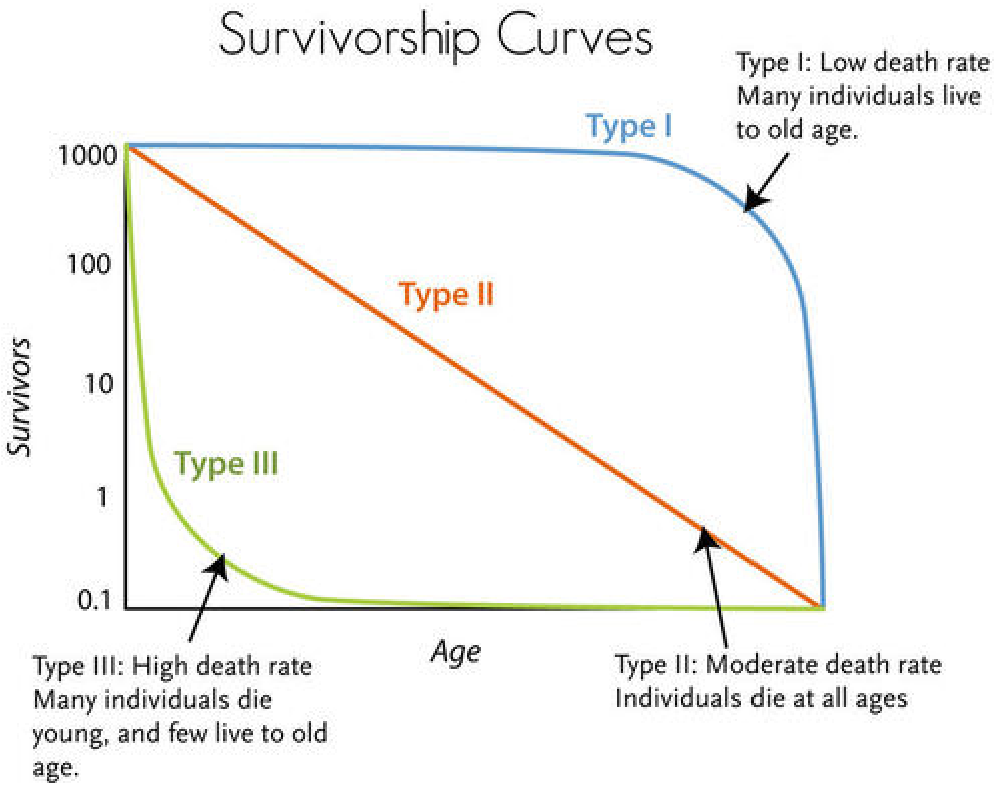


[Figure 2]

A population pyramid represents the age-sex structure of a population. What does a large base represent?

Survivorship Curves

Another way to show how deaths affect populations is with **survivorship curves**. These are graphs that represent the number of individuals still alive at each age. Examples are shown in **Figure** below.



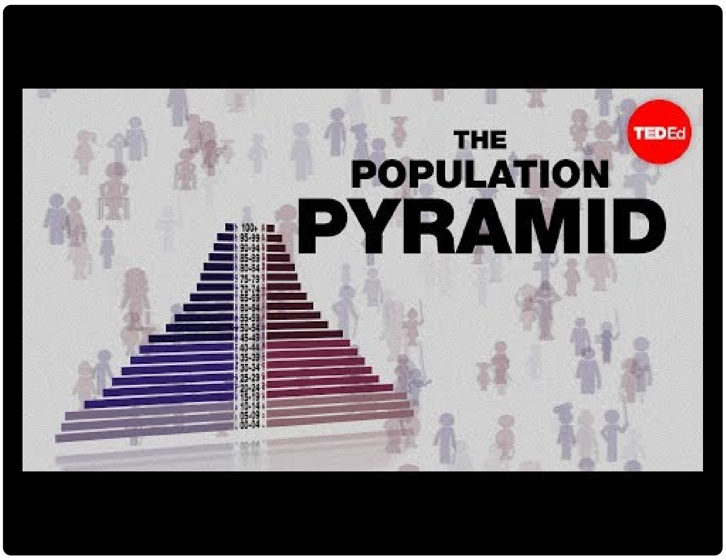
[Figure 3]

Survivorship curves reflect death rates at different ages.

The three types of curves shown in the figure actually represent different strategies species use to adapt to their environment:

- Type I: Parents produce relatively few offspring and provide them with a lot of care. As a result, most of the offspring survive to adulthood so they can reproduce. This pattern is typical of large animal, including humans.
- Type II: Parents produce moderate numbers of offspring and provide some parental care. Deaths occur more uniformly throughout life. This pattern occurs in some bird and many asexual species.
- Type III: Parents produce many offspring but provide them with little or no care. As a result, relatively few offspring survive to adulthood. This pattern is typical of plants, invertebrate, and many species of fish.

The Type I strategy occurs more often in stable environments. The Type III strategy is more likely in unstable environments. Can you explain why?



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Summary

- The age-sex structure of a population is the number of individuals of each sex and age in the population.
- Age-sex structure influences population growth. It is represented by a population pyramid.
- The number of survivors at each age is plotted on a survivorship curve.

Review

1. How does the age-sex structure of a population influence growth?
2. Assume that a population pyramid has a very broad base. What does that tell you about the population it represents?
3. Compare and contrast Type I and Type III survivorship curves.

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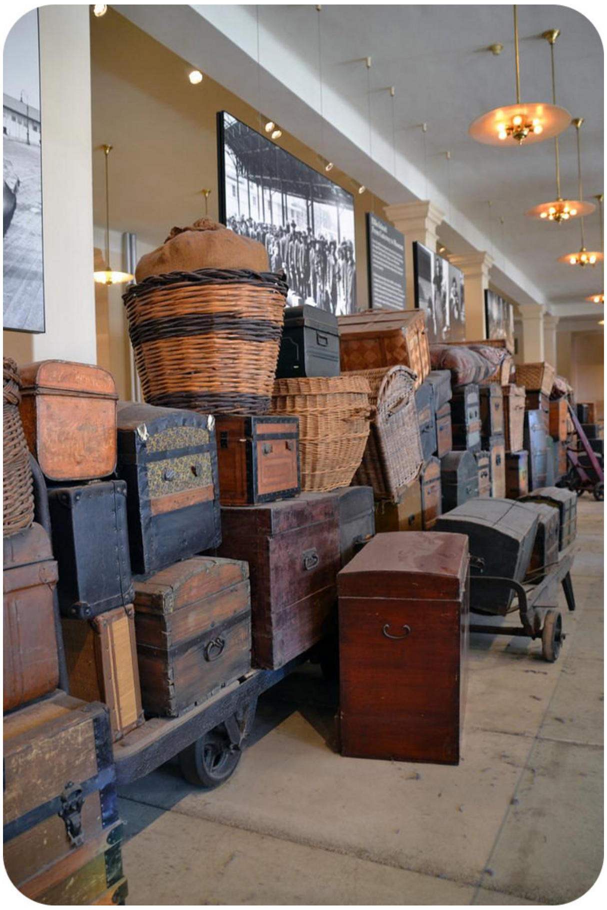
6.19 Population Growth

FlexBooks 2.0 > Biology For High School Diploma > Population Growth

Last Modified: Aug 01, 2018



[Figure 1]

What would old luggage have to do with population growth?

Moving into an area, or **immigration**, is a key factor in the growth of population. Shown above is actual vintage luggage left by some of the millions of immigrants who came through Ellis Island and into the United States.

Population Growth

Populations gain individuals through births and immigration. They lose individuals through deaths and **emigration**. These factors together determine how fast a population grows.

Population Growth Rate

population growth rate (*r*) is how fast a population changes in size over time. A positive growth rate means a population is increasing. A negative growth rate means it is decreasing.

The two main factors affecting population growth are the birth rate (*b*) and death rate (*d*). Population growth may also be affected by people coming into the population from somewhere else (**immigration**, *i*) or leaving the population for another area (**emigration**, *e*). The formula for population growth takes all these factors into account.

$r = (b + i) - (d + e)$

- r = population growth rate
- b = birth rate
- i = immigration rate
- d = death rate
- e = emigration rate

Dispersal

Other types of movement may also affect population size and growth. For example, many species have some means of **dispersal**. This refers to offspring moving away from their parents. This prevents the offspring from competing with the parents for resources such as light or water. For example, dandelion seed have "parachutes." They allow the wind to carry the seeds far from the parents (see **Figure** below).

[Figure 2]

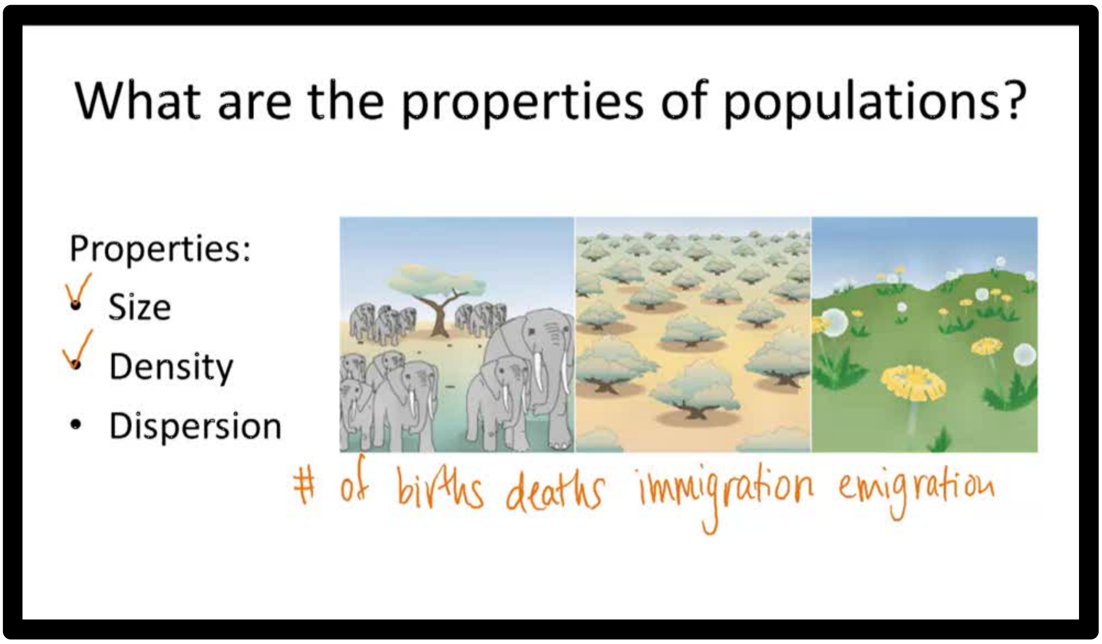
Dandelion Seeds. These dandelion seeds may disperse far from the parent plant. Why might this be beneficial to both parents and offspring?

Migration

migration is another type of movement that changes population size. **Migration** is the regular movement of individuals or populations each year during certain seasons. The purpose of migration usually is to find food, mates, or other resources. For example, many northern hemisphere bird migrate thousands of miles south each fall. They go to areas where the weather is warmer and more resources are available (see **Figure** below). Then they return north in the spring to nest. Some animal, such as elk, migrate vertically. They go up the sides of mountains in spring as snow melts. They go back down the mountain sides in fall as snow returns.

[Figure 3]

Swainson's hawks migrate from North to South America and back again each year. This map shows where individual hawks have been identified during their migration.



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Summary

- Population growth rate is how fast a population changes in size over time.
- Population growth is determined by rates of birth, death, immigration, and emigration.

Review

1. Define immigration and emigration.
2. What is migration? Give an example.
3. Write the formula for the population growth rate. Identify all the variables.
4. What is dispersal? State why dispersal of offspring away from their parents might be beneficial

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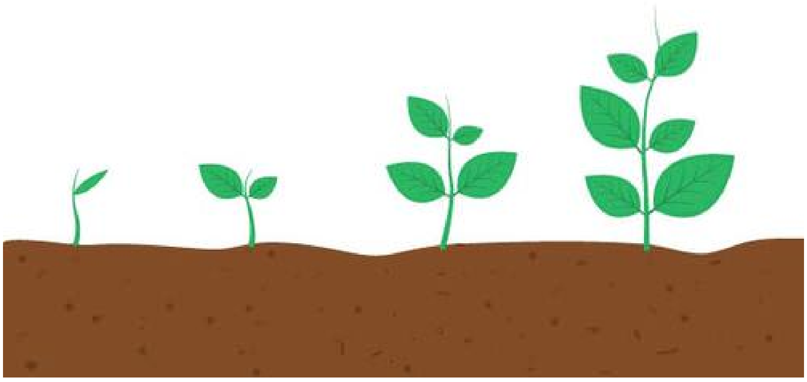
6.20 Population Growth Patterns

FlexBooks 2.0 > Biology For High School Diploma > Population Growth Patterns

Last Modified: Oct 27, 2020



[Figure 1]

What starts out very small and has the potential to grow considerably larger?

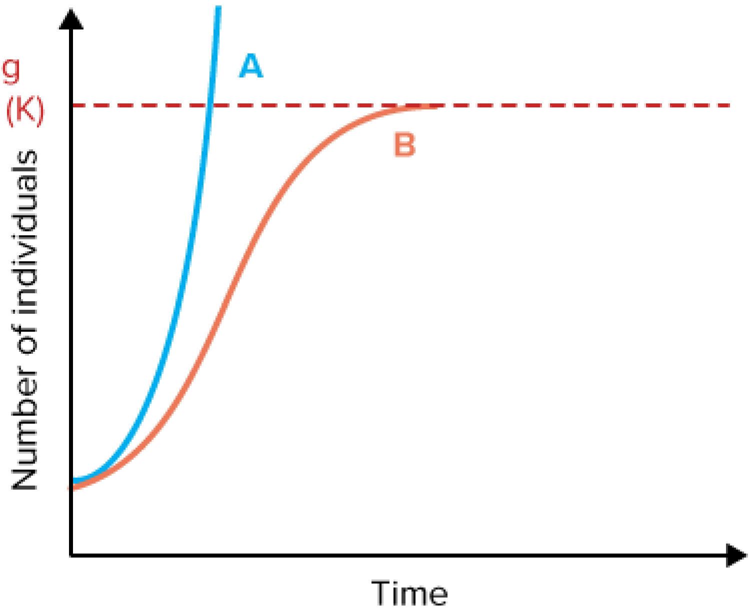
Trees, of course. But also population. Give a population everything it needs to survive, and the growth of that population will be tremendous.

Patterns of Population Growth

Populations may show different patterns of growth. The growth pattern depends partly on the conditions under which a population lives.

Exponential Growth

Under ideal conditions, populations of most species can grow at exponential rates. Curve A in **Figure** below represents **exponential growth**. The population starts out growing slowly. As population size increases, the growth rate also increases. The larger the population becomes, the faster it grows.



[Figure 2]

Exponential and Logistic Growth. Curve A shows exponential growth. Curve B shows logistic growth.

Logistic Growth

Most populations do not live under ideal conditions. Therefore, most do not grow exponentially. Certainly, no population can keep growing exponentially for very long. Many factors may limit growth. Often, the factors are density dependent (known as **density-dependent factors**). These are factors that are influential when the population becomes too large and crowded. For example, the population may start to run out of food or be poisoned by its own wastes. As a result, population growth slows and population size levels off. Curve B in **Figure** above represents this pattern of growth, which is called **logistic growth**.

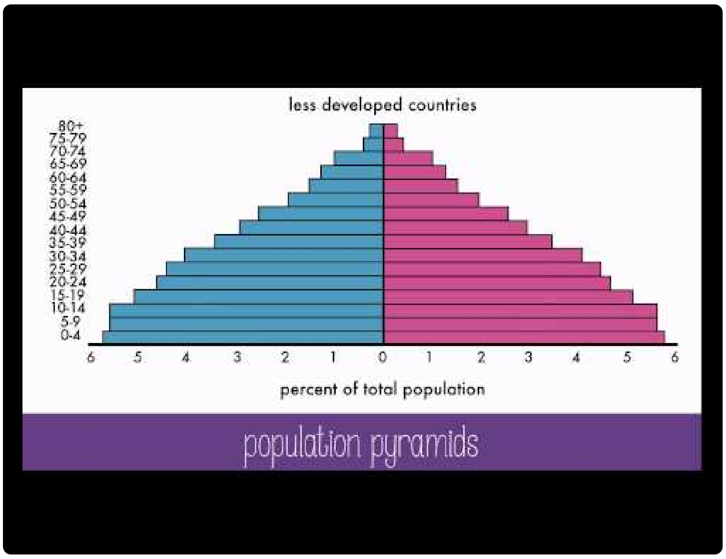
At what population size does growth start to slow in the logistic model of growth? That depends on the population's carrying capacity (see **Figure** above). The **carrying capacity** (K) is the largest population size that can be supported in an area without harming the environment. Population growth hits a ceiling at that size in the logistic growth model.

***K*-Selected and *r*-Selected Species**

Species can be divided into two basic types when it comes to how their populations grow.

- Species that live in stable environments are likely to be ***K*-selected**. Their population growth is controlled by density-dependent factors. Population size is generally at or near the carrying capacity. These species are represented by curve B in **Figure** above.
- Species that live in unstable environments are likely to be ***r*-selected**. Their potential population growth is rapid. For example, they have large numbers of offspring. However, individuals are likely to die young. Thus, population size is usually well below the

carrying capacity. These species are represented by the lower part of curve A in **Figure above**. (*r* is the population growth rate. See the "Population Growth" concept.)



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Summary

- Under ideal conditions, populations can grow exponentially.
- The growth rate increases as the population gets larger.
- Most populations do not live under ideal conditions and grow logistically instead.
- Density-dependent factors slow population growth as population size nears the carrying capacity.

Review

1. Describe exponential population growth.
2. Describe logistic growth.
3. What are density-dependent factors?
4. What does the carrying capacity refer to?
5. What are *K*-selected and *r*-selected species?

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6.21 Human Population

FlexBooks 2.0 > Biology For High School Diploma > Human Population

Last Modified: Oct 27, 2020

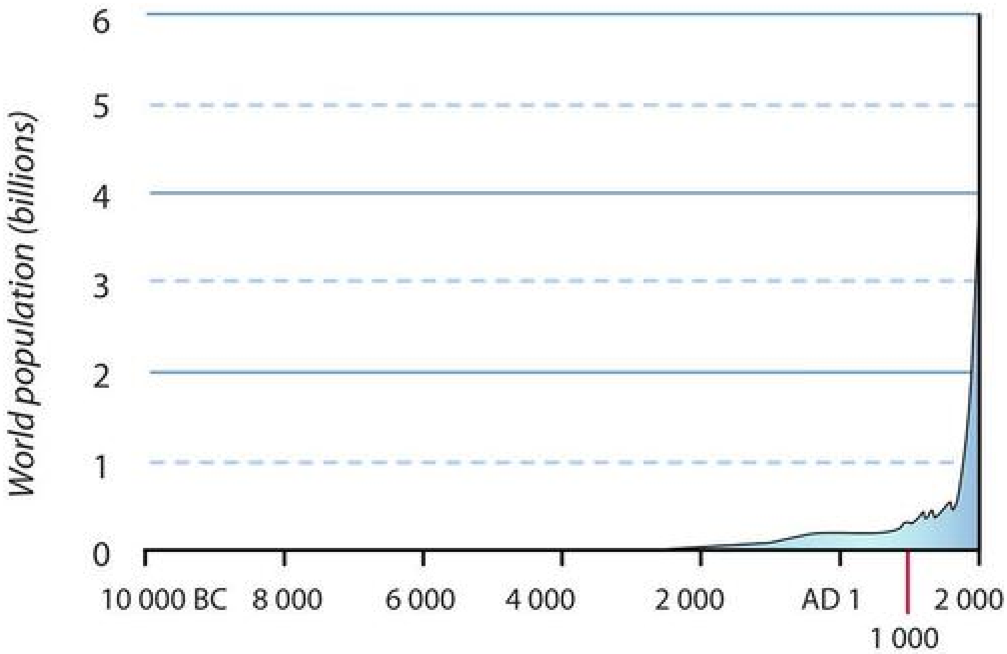
[Figure 1]

How do humans adapt to their environment?

It could be said that the human population does not have to adapt to its environment, but forces the environment to change to suit us. We can live practically anywhere we want, eat all types of food, and build all types of housing. Because of all of these "adaptation," our population has grown, after a slow start, considerably fast.

The Human Population

Humans have been called the most successful "weed species" Earth has ever seen. Like weeds, human populations are fast growing. They also disperse rapidly. They have colonized habitat from pole to pole. Overall, the human population has had a pattern of exponential growth, as shown in **Figure** below. The population increased very slowly at first. As it increased in size, so did its rate of growth.



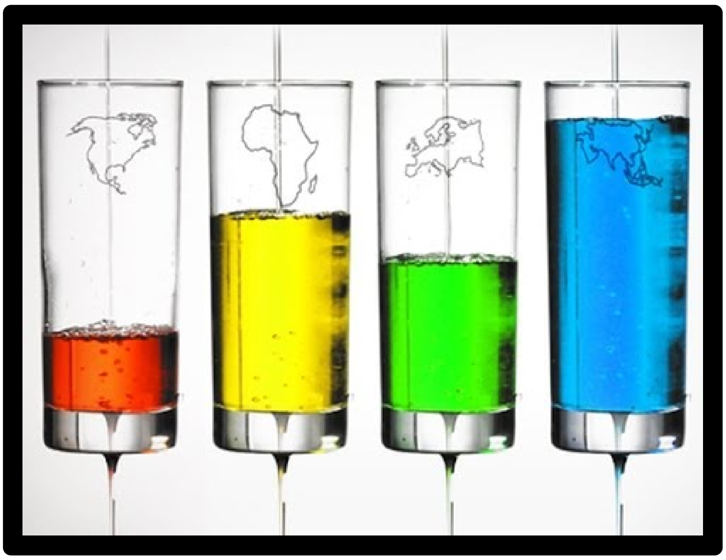
[Figure 2]

Growth of the Human Population. This graph gives an overview of human population growth since 10,000 BC. It took until about 1800 AD for the number of humans to reach 1 billion. It took only a little over 100 years for the number to reach 2 billion. The human population recently passed the 7 billion mark! Why do you think the human population began growing so fast?

Early Population Growth

Homo sapiens arose about 200,000 years ago in Africa. Early humans lived in small populations of nomadic hunters and gatherers. They first left Africa about 40,000 years ago. They soon moved throughout Europe, Asia, and Australia. By 10,000 years ago, they had reached the Americas. During this long period, birth and death rates were both fairly high. As a result, population growth was slow.

Humans invented agriculture about 10,000 years ago. This provided a bigger, more dependable food supply. It also let them settle down in villages and cities for the first time. The death rate increased because of diseases associated with domestic animal and crowded living conditions. The birth rate increased because there was more food and settled life offered other advantages. The combined effect was continued slow population growth.



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Summary

- Early humans lived in small populations of nomadic hunters and gatherers. Both birth and death rates were fairly high. As a result, human population growth was very slow.
- The invention of agriculture increased both birth and death rates. The population continued to grow slowly.

Review

1. Describe human population growth rates.
2. How did the invention of agriculture affect human birth and death rates? How did it affect human population growth?

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6.22 Demographic Transition

FlexBooks 2.0 > Biology For High School Diploma > Demographic Transition

Last Modified: Jun 07, 2018

[Figure 1]

Do populations continuously grow?

Not necessarily. The growth of a population depends on a number of issues. Obviously, the average age of the individuals of that population is important. But other factors, such as the local economy, also play a role.

Demographic Transition

Major changes in the human population first began during the 1700s in Europe and North America. First death rates fell, followed somewhat later by birth rates.

Death Rates Fall

Several advances in science and technology led to lower death rates in 18th century Europe and North America:

- New scientific knowledge of the causes of disease led to improved water supplies, sewers, and personal hygiene.
- Better farming techniques and machines increased the food supply.
- The Industrial Revolution of the 1800s led to new sources of energy, such as coal and electricity. This increased the efficiency of the new agricultural machines. It also led to train transport, which improved the distribution of food.

For all these reasons, death rates fell, especially in children. This allowed many more children to survive to adulthood, so birth rates increased. As the gap between birth and death rates widened, the human population grew faster.

Birth Rates Fall

It wasn't long before birth rates started to fall as well in Europe and North America. People started having fewer children because large families were no longer beneficial for several reasons.

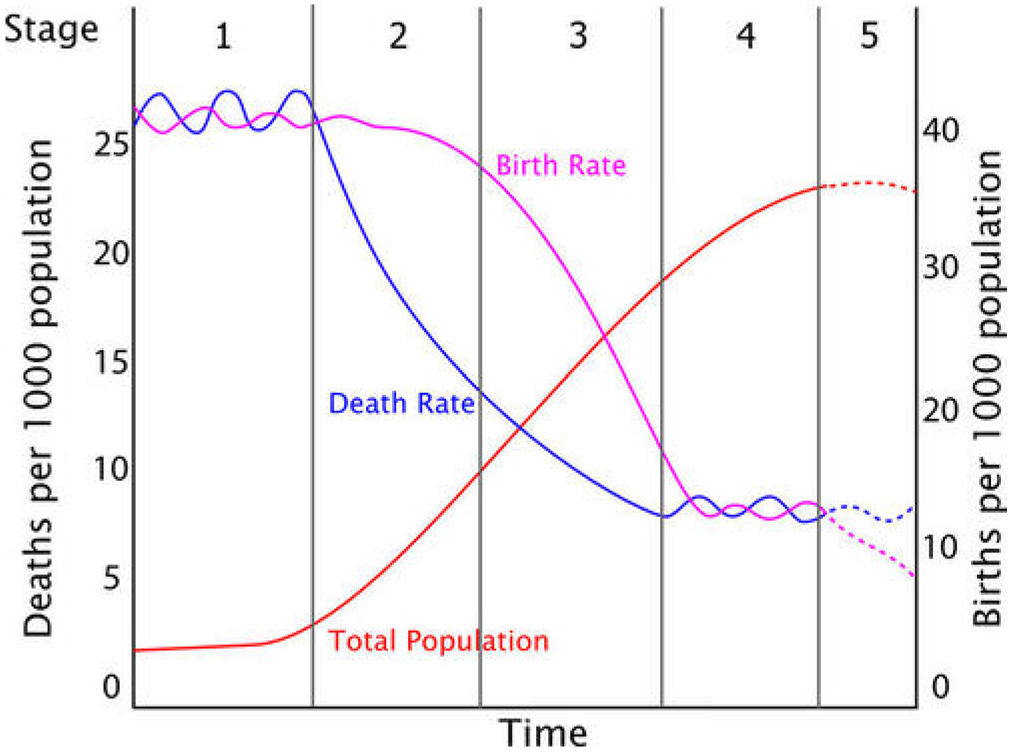
- As child death rates fell and machines did more work, farming families no longer needed to have as many children to work in the fields.
- Laws were passed that required children to go to school. Therefore, they could no longer work and contribute to their own support. They became a drain on the family's income.

Eventually, birth rates fell to match death rates. As a result, population growth slowed to nearly zero.

Stages of the Demographic Transition

These changes in population that occurred in Europe and North America have been called the **demographic transition**. The transition can be summarized in the following four stages, which are illustrated in **Figure** below:

- Stage 1—High birth and death rates lead to slow population growth.
- Stage 2—The death rate falls but the birth rate remains high, leading to faster population growth.
- Stage 3—The birth rate starts to fall, so population growth starts to slow.
- Stage 4—The birth rate reaches the same low level as the death rate, so population growth slows to zero.



[Figure 2]

Stages of the Demographic Transition. In the demographic transition, the death rate falls first. After a lag, the birth rate also falls. How do these changes affect the rate of population growth over time?

Summary

- Major changes in the human population first began during the 1700s. This occurred in Europe and North America.
- First, death rates fell while birth rates remained high. This led to rapid population growth.
- Later, birth rates also fell. As a result, population growth slowed.

Review

1. How did science and technology affect the human population?
2. List two important scientific changes that affected the human growth rate.
3. Outline the four stages of the demographic transition as it occurred in Europe and North America.

Report Content Errors

6.23 Recent and Future Population Growth

FlexBooks 2.0 > Biology For High School Diploma > Recent and Future Population Growth

Last Modified: Oct 27, 2020

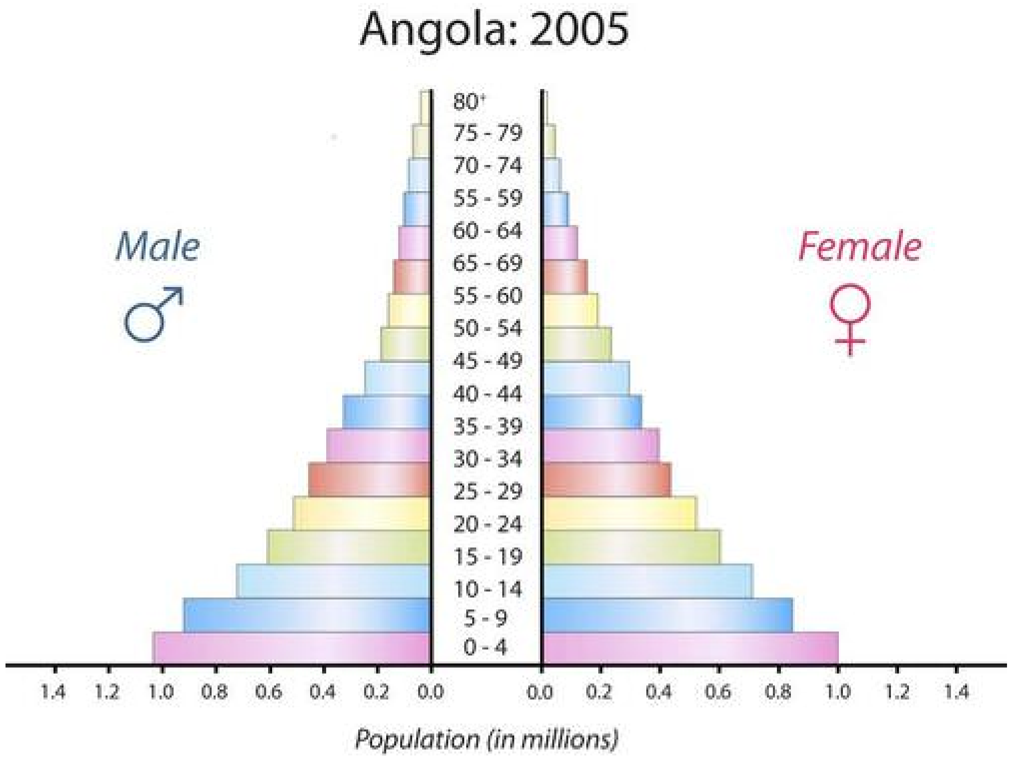
[Figure 1]

Should the population of the planet by characterized by individual country, or as one general population?

How many people is too many? Is there a limit? Is there a carrying capacity for humans? These are important questions that do not have an easy answer. But as our population continues to grow, these questions and others should be discussed.

Recent Population Growth

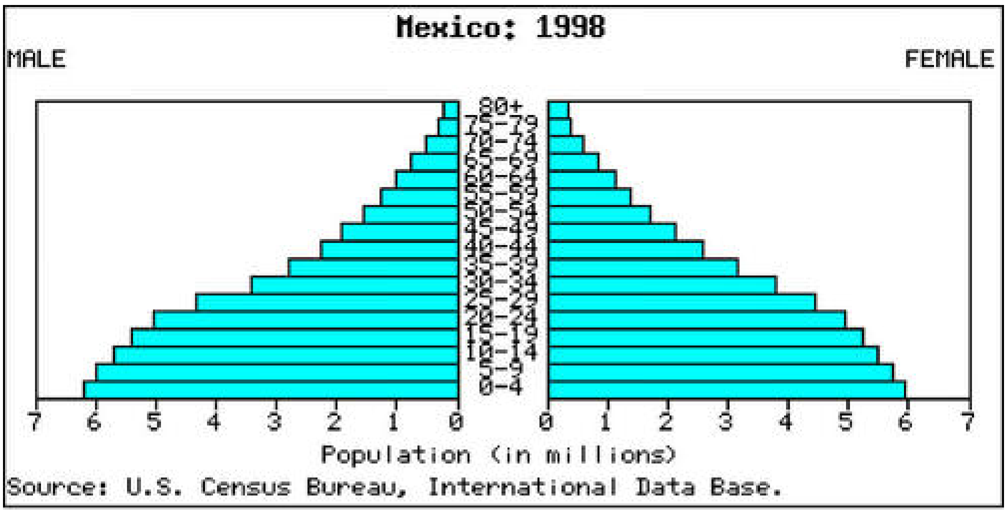
At one time, scientists predicted that all human populations would pass through the same **demographic transition** as Europe and North America. Now, they are not so sure. Death rates have fallen throughout the world. No country today remains in Stage 1 of the transition. However, birth rates are still high in many poor countries. These populations seem to be stuck in Stage 2. An example is the African country of Angola. Its population pyramid for 2005 is shown in **Figure** below. The wide base of the pyramid base reflects the high birth rate of this population.



[Figure 2]

Angola's population pyramid is typical of Stage 2 of the demographic transition.

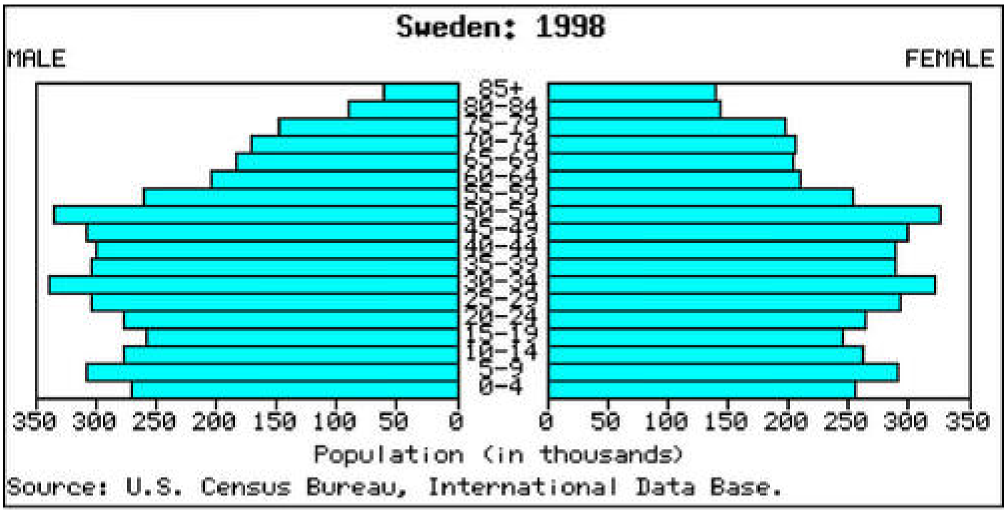
Many other countries have shifted to Stage 3 of the transition. Birth rates have started to fall. As a result, population growth is slowing. An example is Mexico. Its population pyramid for 1998 is shown in **Figure** below. It reflects a recent fall in the birth rate.



[Figure 3]

Mexico's 1998 population pyramid is typical of Stage 3 population. How can you tell that the birth rate has started to fall?

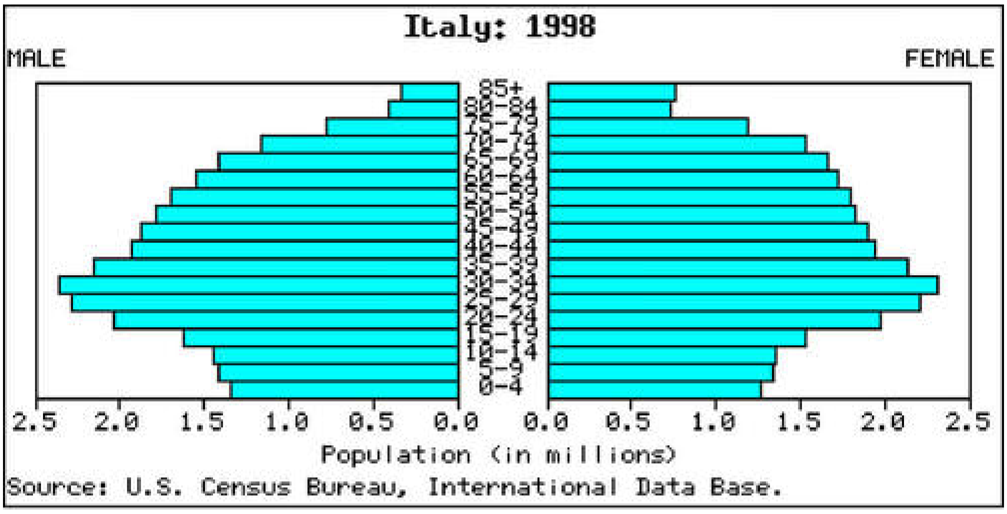
Most developed nations have entered Stage 4. Sweden is an example (see **Figure** below). The birth rate has been low for many years in Sweden. Therefore, the rate of population growth is near zero.



[Figure 4]

Sweden's 1998 population pyramid shows a population in Stage 4.

In some countries, birth rates have fallen even lower than death rates. As result, their population growth rates are negative. In other words, the populations are shrinking in size. These populations have top-heavy population pyramids, like the one for Italy shown in **Figure** below. This is a new stage of the demographic transition, referred to as Stage 5. You might think that a negative growth rate would be a good thing. In fact, it may cause problems. For example, growth-dependent industries decline. Supporting the large aging population is also a burden for the shrinking younger population of workers.



[Figure 5]

This 1998 population pyramid for Italy represents a Stage 5 population.

Future Population Growth

During the month of October 2011, the world's population surpassed 7 billion people. It took just 12 years for the population to increase by a billion people. At this rate, there may be well over 9 billion people by 2050, and easily 10 billion people by 2100. This raises many questions for both people and the planet.

The human population is now growing by more than 200,000 people a day. The human population may well be close to its carrying capacity. It has already harmed the environment. An even larger human population may cause severe environmental problems. This could lead to outbreaks of disease, starvation, and global conflict. There are three potential solutions:

1. Use technology to make better use of resources to support more people.
2. Change behaviors to reduce human numbers and how much humans consume.
3. Distribute resources more fairly among all the world's people.

Which solution would you choose?

> *"If growth continued at this rate...by 2600 we would all be standing literally shoulder to shoulder" - Steven Hawking*

Census Update: What the World Will Look like in 2050

According to the U.S. Census Bureau, in 2050, there will be 9.4 billion people:

- India will be the most populous nation, surpassing China sometime around 2025.
- The U.S. will remain the third most populous nation, with a population of 423 million (up from 308 million in 2010).
- Declining birth rates in Japan and Russia will cause them to fall from their current positions as the 9th and 10th most populous nations, respectively, to 16th and 17th.
- Nigeria will have a population of 402 million, up from 166 million people.
- Ethiopia's population will likely triple, from 91 million to 278 million, making the East African nation one of the top 10 most populous countries in the world.

So what does all this mean?

- The African continent is expected to experience significant population growth in the coming decades, which could compound existing food supply problems in some African nations.
- immigration and differing birth rates among races will change the ethnic composition of the U.S.

- Population booms in Africa and India, the decline of Russia, and the expected plateau of China will all change the makeup of the estimated 9.4 billion people who will call Earth home in 2050.

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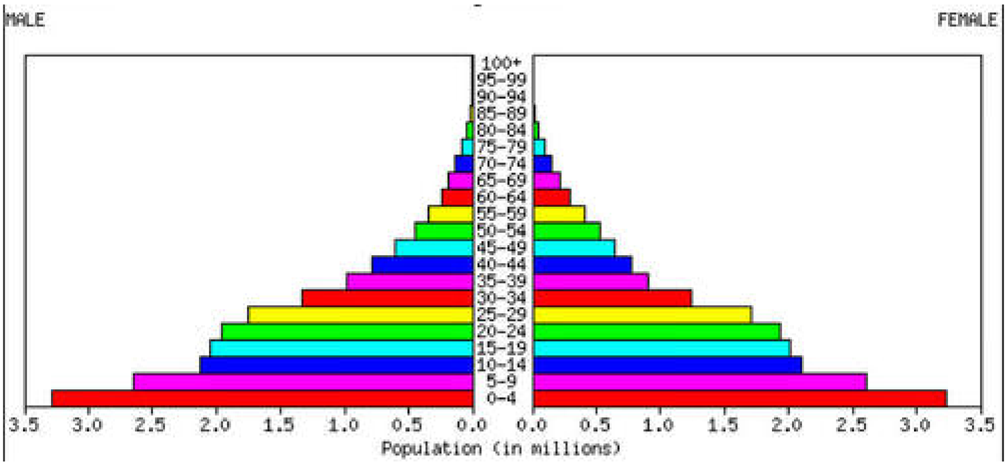
Summary

- Other countries have completed similar demographic transitions. However, some countries seem stalled at early stages. They have high birth rates and rapidly growing populations.
- The total human population may have to stop growing eventually. Even if we reduce our use of resources and distribute them more fairly, at some point the carrying capacity will be reached.

Review

1. Why was a fifth stage added to the demographic transition model? Describe a population at this stage.

2. Which stage of the demographic transition is represented by the population pyramid in the **Figure** below? Why?



[Figure 6]

3. Evaluate how well the original demographic transition model represents human populations today.

4. What is the human population problem? What are some potential solutions? Which solution do you think is best?

Report Content Errors

6.24 Biodiversity

FlexBooks 2.0 > Biology For High School Diploma > Biodiversity

Last Modified: Oct 26, 2020

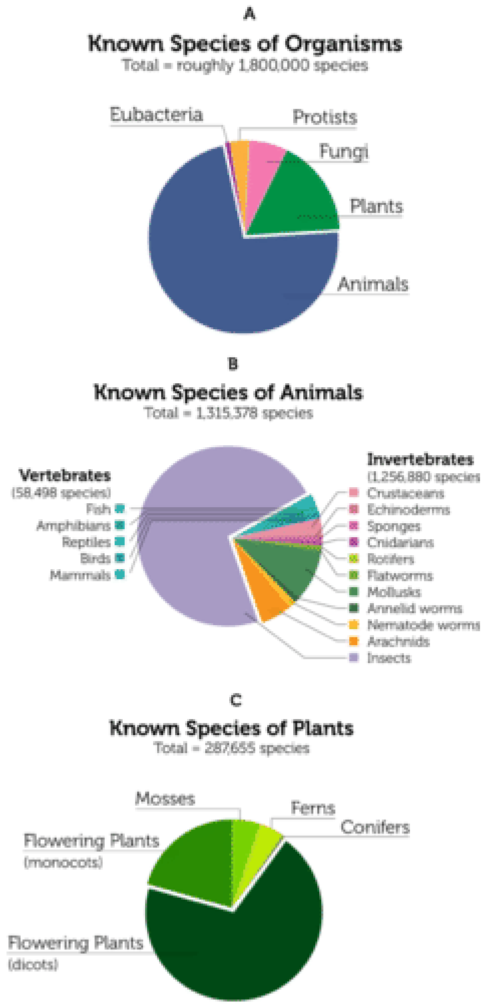
[Figure 1]

What is biodiversity?

How many species exist? We don't really know for sure. But all those species together, from the smallest bacterium, the deadliest protist, the most bizarre fungus, the prettiest plant, and the biggest mammal, compile the diversity of life, or biodiversity.

What Is Biodiversity?

Biodiversity refers to the variety of life and its processes, including the variety of living organism, the genetic differences among them, and the community and ecosystem in which they occur. Scientists have identified about 1.9 million species alive today. They are divided into the six kingdoms of life shown in **Figure** below. Scientists are still discovering new species. Thus, they do not know for sure how many species really exist today. Most estimates range from 5 to 30 million species.



[Figure 2]

Known species represent only a fraction of all species that exist on Earth.

Cogs and Wheels

"The first rule of intelligent tinkering is to save all the pieces." --attributed to Aldo Leopold, but probably a shortened version of: ***"To save every cog and wheel is the first precaution of intelligent tinkering."* - Aldo Leopold, *Round River: from the Journals of Aldo Leopold*, 1953**

What are the "cogs" and "wheels" of life?

Although the concept of biodiversity did not become a vital component of biology and political science until nearly 40 years after Aldo Leopold's death in 1948, Leopold – often considered the father of modern ecology - would have likely found the term an appropriate description of his "cogs and wheels." Literally, biodiversity is the many different kinds (*diversity*) of life (*bio*-). Biologists, however, always alert to levels of organization, have identified three measures of life's variation. **species diversity** best fits the literal translation: the number of different species in a particular ecosystem or on Earth. A second measure recognizes variation within a species: differences among individuals or population make up

genetic diversity. Finally, as Leopold clearly understood, the "cogs and wheels" include not only life but also the land, sea, and air that support life. **ecosystem diversity** describes the many types of functional units formed by living communities interacting with their environments. Although all three levels of diversity are important, the term biodiversity usually refers to species diversity.

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Science Friday: The Unlikely Tale of a Tenacious Snail

For over 70 years, no one had seen the oblong rocksnail. Declared extinct in 2000, the species was considered to be another native Alabaman mollusk gone and forgotten. But one day in the spring of 2011, biology grad student Nathan Whelan picked up a tiny rock and got a big surprise.

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Further Reading

Importance of Biodiversity

Summary

- Biodiversity refers to the number of species in an ecosystem or the biosphere as a whole.

Review

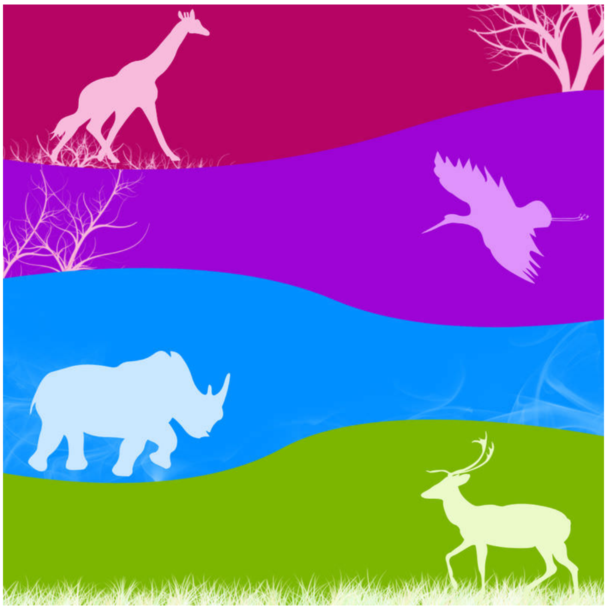
1. What is biodiversity?
2. What are the three measures of life's variations?
3. What is meant by ecosystem diversity?

Report Content Errors

6.25 Importance of Biodiversity

FlexBooks 2.0 > Biology For High School Diploma > Importance of Biodiversity

Last Modified: May 02, 2022



[Figure 1]

Why is biodiversity important?

Think about how many species exist. Most likely well over 5 million. Now think about how much information about those species we do not yet understand. We do not know what we can learn from them.

Why Is Biodiversity Important?

Human beings benefit in many ways from **biodiversity**. Biodiversity has direct economic benefits. It also provides services to entire ecosystem.

Economic Benefits of Biodiversity

The diversity of species provides humans with a wide range of economic benefits:

- Wild plants and animal maintain a valuable pool of **genetic variation**. This is important because domestic species are genetically uniform. This puts them at great risk of dying out due to disease.
- Other organism provide humans with many different products. Timber, fibers, adhesives, dyes, and rubber are just a few.

- Certain species may warn us of toxins in the environment. When the peregrine falcon nearly went extinct, for example, it warned us of the dangers of DDT.
- More than half of the most important prescription drug come from wild species. Only a fraction of species have yet been studied for their medical potential.
- Other living things provide inspiration for engineering and technology. For example, the car design in **Figure** below was based on a fish.

The rosy periwinkle is an invaluable source of two important cancer-fighting drugs.

The yellow box fish provided a design model for the car shown here. The fish is the result of millions of years of natural selection for two traits that are also important in cars: efficient aerodynamics and maximum interior space.

[Figure 2]

From flowers to fish, biodiversity benefits humans in many ways.

Ecosystem Services of Biodiversity

Biodiversity generally increases the productivity and stability of **ecosystems**. It helps ensure that at least some species will survive environmental change. It also provides many other ecosystem services. For example:

- Plants and alga maintain the atmosphere. During photosynthesis, they add oxygen and remove carbon dioxide.
- Plants help prevent soil erosion. They also improve soil quality when they decompose.
- Microorganisms purify water in rivers and lakes. They also return nutrient to the soil.
- bacterium fix nitrogen and make it available to plants. Other bacteria recycle the nitrogen from organic wastes and remains of dead organisms.
- Insects and bird pollinate flowering plants, including crop plants.
- Natural predator control insect pests. They reduce the need for expensive pesticides, which may harm people and other living things.

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Summary

- Biodiversity has direct economic benefits. It also provides services to entire ecosystems.

Review

1. List three economic benefits of biodiversity.
2. Identify three ecosystem services of biodiversity.
3. Predict what would happen to other organisms in an ecosystem in which all the decomposers went extinct?

Report Content Errors

6.26 Mass Extinction

FlexBooks 2.0 > Biology For High School Diploma > Mass Extinction

Last Modified: Aug 01, 2018

[Figure 1]

This is one of the most powerful birds in the world. Could it go extinct?

The Philippine Eagle, also known as the Monkey-eating Eagle, is among the rarest, largest, and most powerful bird in the world. It is critically endangered, mainly due to massive loss of habitat due to deforestation in most of its range. Killing a Philippine Eagle is punishable under Philippine law by twelve years in jail and heavy fines.

Human Actions and the Sixth Mass Extinction

Over 99 percent of all species that ever lived on Earth have gone extinct. Five mass extinctions are recorded in the fossil record. They were caused by major geologic and climatic events. evidence shows that a **sixth mass extinction** is occurring now. Unlike previous mass extinctions, the sixth extinction is due to human actions.

Some scientists consider the sixth extinction to have begun with early hominids during the Pleistocene. They are blamed for over-killing big mammal such as mammoths. Since then, human actions have had an ever greater impact on other species. The present rate of extinction is between 100 and 100,000 species per year. In 100 years, we could lose more than half of Earth's remaining species.

Causes of Extinction

The single biggest cause of extinction today is **habitat loss**. Agriculture, forestry, mining, and urbanization have disturbed or destroyed more than half of Earth's land area. In the U.S., for example, more than 99 percent of tall-grass prairies have been lost. Other causes of extinction today include:

- **exotic species** introduced by humans into new habitats. They may carry disease, prey on native species, and disrupt food web. Often, they can out-compete native species because they lack local predator. An example is described in **Figure** below.
- Over-harvesting of fish, trees, and other organism. This threatens their survival and the survival of species that depend on them.
- Global climate change, largely due to the burning of fossil fuel. This is raising Earth's air and ocean temperatures. It is also raising sea levels. These changes threaten many species.
- Pollution, which adds chemicals, heat, and noise to the environment beyond its capacity to absorb them. This causes widespread harm to organisms.
- Human overpopulation, which is crowding out other species. It also makes all the other causes of extinction worse.

[Figure 2]

The brown tree snake is an exotic species that has caused many extinctions on Pacific islands such as Guam.

Effects of Extinction

The results of a study released in the summer of 2011 have shown that the decline in the numbers of large predators like sharks, lions and wolves is disrupting Earth's ecosystem in all kinds of unusual ways. The study, conducted by scientists from 22 different institutions in six countries, confirmed the sixth mass extinction. The study states that this mass extinction differs from previous ones because it is entirely driven by human activity through changes in land use, climate, pollution, hunting, fishing and poaching. The effects of the loss of these large predators can be seen in the oceans and on land.

- Fewer cougars in the western US state of Utah led to an explosion of the deer population. The deer ate more vegetation, which altered the path of local streams and lowered overall biodiversity.
- In Africa, where lions and leopards are being lost to poachers, there is a surge in the number of olive baboons, who are transferring intestinal parasite to humans living nearby.
- In the oceans, industrial whaling led a change in the diets of killer whales, who eat more sea lions, seals, and otters and have dramatically lowered the population counts of those species.

The study concludes that the loss of big predators has likely driven many of the pandemics, population collapses and ecosystem shifts the Earth has seen in recent centuries.

Disappearing Frogs

Around the world, frog are declining at an alarming rate due to threats like pollution, disease, and climate change. Frogs bridge the gap between water and land habitats, making them the first indicators of ecosystem changes.

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Nonnative Species

Scoop a handful of critters out of the San Francisco Bay and you'll find many organisms from far away shores. Invasive kinds of mussels, fish, and more are choking out native species, challenging experts around the state to change the human behavior that brings them here.

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How You Can Help Protect Biodiversity

There are many steps you can take to help protect biodiversity. For example:

- Consume wisely. Reduce your consumption wherever possible. Re-use or recycle rather than throw out and buy new. When you do buy new, choose products that are energy efficient and durable.
- Avoid plastics. Plastics are made from petroleum and produce toxic waste.
- Go organic. Organically grown food is better for your health. It also protects the environment from pesticides and excessive nutrient in fertilizers.
- Save energy. Unplug electronic equipment and turn off lights when not in use. Take mass transit instead of driving.

Lost Salmon

Why is the salmon population of Northern California so important? Salmon do not only provide food for humans, but also supply necessary nutrients for their ecosystems. Because of a sharp decline in their numbers, in part due to human interference, the entire salmon fishing season off California and Oregon was canceled in both 2008 and 2009. The species in the most danger of extinction is the California coho salmon.

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Summary

- Evidence shows that a sixth mass extinction is occurring. The single biggest cause is habitat loss caused by human actions.
- There are many steps you can take to help protect biodiversity. For example, you can use less energy.

Review

1. How is human overpopulation related to the sixth mass extinction?
2. Why might the brown tree snake or the Philippine Eagle serve as “poster species” for causes of the sixth mass extinction?
3. Describe a hypothetical example showing how rising sea levels due to global warming might cause extinction.
4. Create a poster that conveys simple tips for protecting biodiversity.

Resources

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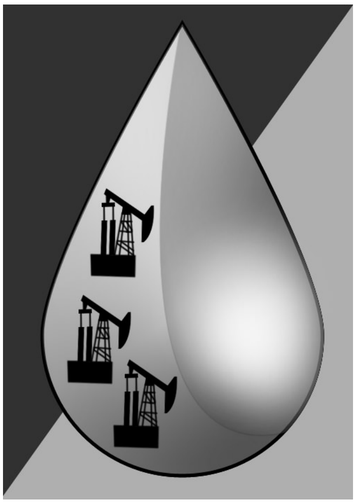
Report Content Errors

6.27 Resources

FlexBooks 2.0 > Biology For High School Diploma > Resources

Last Modified: Aug 01, 2018



[Figure 1]

Renewable or nonrenewable, what's the difference?

That's like asking the difference between having an endless supply and having a limited supply. Will this planet eventually run out of oil? Probably. So oil is a **nonrenewable resource**.

Renewable and Nonrenewable Resources

A **natural resource** is something supplied by nature that helps support life. When you think of natural resources, you may think of mineral and **fossil fuel**. However, ecosystem and the services they provide are also natural resources. **biodiversity** is a natural resource as well.

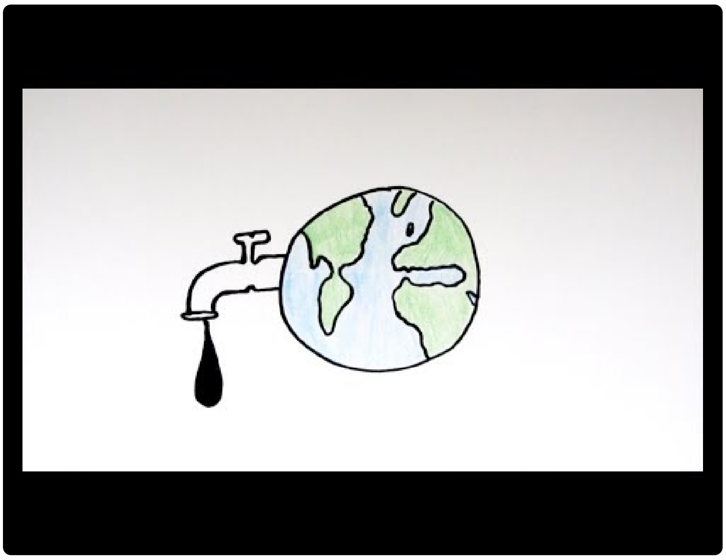
Renewable Resources

renewable resource can be replenished by natural processes as quickly as humans use them. Examples include sunlight and wind. They are in no danger of being used up (see **Figure** below). Metals and other minerals are renewable too. They are not destroyed when they are used and can be recycled.

[Figure 2]

Wind is a renewable resource. Wind turbines like this one harness just a tiny fraction of wind energy.

Living things are considered to be renewable. This is because they can reproduce to replace themselves. However, they can be over-used or misused to the point of extinction. To be truly renewable, they must be used sustainably. **sustainable use** is the use of resources in a way that meets the needs of the present and also preserves the resources for future generations.



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Nonrenewable Resources

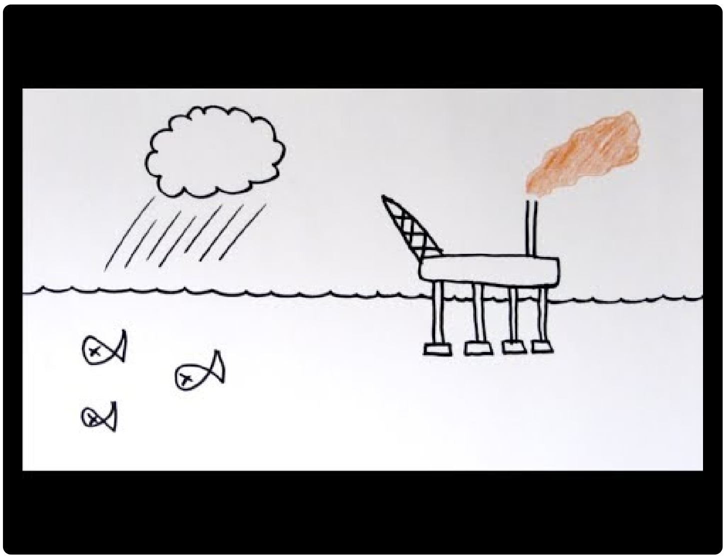
Nonrenewable resources are natural resources that exist in fixed amounts and can be used up. Examples include fossil fuels such as petroleum, coal, and natural gas. These fuels formed from the remains of plants over hundreds of millions of years. We are using them up far faster than they could ever be replaced. At current rates of use, petroleum will be used up in just a few decades and coal in less than 300 years. Nuclear power is also considered to be a nonrenewable resource because it uses up uranium, which will sooner or later run out. It also produces harmful wastes that are difficult to dispose of safely.

[Figure 3]

Gasoline is made from crude oil. The crude oil pumped out of the ground is a black liquid called petroleum, which is a nonrenewable resource.

[Figure 4]

Coal is another nonrenewable resource.



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Turning Trash Into Treasure

Scientists at the Massachusetts of Technology are turning trash into coal, which can readily be used to heat homes and cook food in developing countries. This coal burns cleaner than that from fossil fuels. It also save a tremendous amount of energy.

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Summary

- Renewable resources can be replaced by natural processes as quickly as humans use them. Examples include sunlight and wind.
- Nonrenewable resources exist in fixed amounts. They can be used up. Examples include fossil fuels such as coal.

Review

1. Define natural resource. Give an example.
2. Distinguish between renewable and nonrenewable resources and give examples.
3. Infer factors that determine whether a natural resource is renewable or nonrenewable.

Report Content Errors

6.28 Soil and Water

FlexBooks 2.0 > Biology For High School Diploma > Soil and Water

Last Modified: Aug 01, 2018

[Figure 1]

Could this land be used for agriculture?

Probably not. The quality of **soil** is very important in determining what can grow in a particular area. Good soil is not so easy to come by. Soil should be considered another resource that we, as a population, must strive to protect.

Soil and Water Resources

Theoretically, soil and water are renewable resource. However, they may be ruined by careless human actions.

Soil

Soil is a mixture of eroded rock, mineral, partly decomposed organic matter, and other materials. It is essential for plant growth, so it is the foundation of terrestrial ecosystem. Soil is important for other reasons as well. For example, it removes toxins from water and breaks down wastes.

Although renewable, soil takes a very long time to form—up to hundreds of millions of years. So, for human purposes, soil is a nonrenewable resource. It is also constantly depleted of nutrient through careless use, and eroded by wind and water. For example, misuse of soil caused a huge amount of it to simply blow away in the 1930s during the Dust Bowl (see **Figure** below). Soil must be used wisely to preserve it for the future. Conservation practices include contour plowing and terracing. Both reduce soil erosion. Soil also must be protected from toxic wastes.

[Figure 2]

The Dust Bowl occurred between 1933 and 1939 in Oklahoma and other southwestern U.S. states. Plowing had exposed prairie soil. Drought turned the soil to dust. Intense dust storms blew away vast quantities of the soil. Much of the soil blew all the way to the Atlantic Ocean.

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Water

Water is essential for all life on Earth. For human use, water must be fresh. Of all the water on Earth, only 1 percent is fresh, liquid water. Most of the rest is either salt water in the ocean or ice in glaciers and ice caps.

Although water is constantly recycled through the **water cycle**, it is in danger. Over-use and pollution of freshwater threaten the limited supply that people depend on. Already, more than 1 billion people worldwide do not have adequate freshwater. With the rapidly growing human population, the water shortage is likely to get worse.

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Too Much of a Good Thing

Water pollution comes from many sources. One of the biggest sources is runoff. **Runoff** picks up chemicals such as fertilizer from agricultural fields, lawns, and golf courses. It carries the chemicals to bodies of water. The added nutrients from fertilizer often cause excessive growth of alga, creating **algal bloom** (see **Figure** below). The algae use up oxygen in the water so that other aquatic organism cannot survive. This has occurred over large areas of the ocean, creating **dead zone**, where low oxygen levels have killed all ocean life. A very large dead zone exists in the Gulf of Mexico. Measures that can help prevent these problems include cutting down on fertilizer use. Preserving wetland also helps because wetlands filter runoff water.

[Figure 3]

Algal Bloom. Nutrients from fertilizer in runoff caused this algal bloom.

Summary

- Soil and water are renewable resources but may be ruined by careless human actions. Soil can be depleted of nutrients. It can also be eroded by wind or water.
- Over-use and pollution of freshwater threaten the limited supply that people depend on.

Review

1. What is soil?
2. Why is soil considered a nonrenewable resource?
3. How much water is drinkable?
4. Why would you expect a dead zone to start near the mouth of a river, where the river flows into a body of water?

Report Content Errors

6.29 Air Pollution

FlexBooks 2.0 > Biology For High School Diploma > Air Pollution

Last Modified: Aug 01, 2018

[Figure 1]

Why is the atmosphere important?

Well, it contains all of the air that we breathe. The atmosphere also has other roles and functions, so when we interfere with the atmosphere, we interfere with some important biological processes. And this can have consequences.

The Atmosphere

The **atmosphere** plays an important part in maintaining Earth's freshwater supply. It is part of the water cycle. It refills lakes and rivers with precipitation. The atmosphere also provides organism with gases needed for life. It contains oxygen for cellular respiration and carbon dioxide for photosynthesis.

Air Pollution

[Figure 2]

Air pollution comes from many sources, including waste expelled into the atmosphere by numerous factories.

Earth's atmosphere is vast. However, it has been seriously polluted by human activities. **Air pollution** consists of chemical substances and particles released into the atmosphere, mainly by human actions. The major cause of outdoor air pollution is the burning of fossil fuel. Power plants, motor vehicles, and home furnaces all burn fossil fuels and contribute to the problem (see **Table** below). Ranching and using chemicals such as fertilizers also cause air pollution. Erosion of soil in farm fields and construction sites adds dust particles to the air as well. Fumes from building materials, furniture, carpets, and paint add toxic chemicals to indoor air.

Pollutant	Example/Major Source	Problem
Sulfur oxides (SO_x)	Coal-fired power plants	**acid rain**
Nitrogen oxides (NO_x)	Motor vehicle exhaust	Acid Rain
carbon monoxide (CO)	Motor vehicle exhaust	Poisoning
Carbon dioxide (CO_2)	All fossil fuel burning	global warming
Particulate matter (smoke, dust)	Wood and coal burning	Respiratory disease, Global Dimming
Mercury	Coal-fired power plants, medical waste	Neurotoxicity
smog	Coal burning	Respiratory problems; eye irritation
Ground-level ozone	Motor vehicle exhaust	Respiratory problems; eye irritation

In humans, air pollution causes respiratory and cardiovascular problems. In fact, more people die each year from air pollution than automobile accidents. Air pollution also affects ecosystem worldwide by causing acid rain, ozone depletion, and global warming. Ways to reduce air pollution from fossil fuels include switching to nonpolluting energy sources (such as solar energy) and using less energy. What are some ways you could use less energy?

Acid Rain

All life relies on a relatively narrow range of pH, or acidity. That's because protein structure and function are very sensitive to pH. Air pollution can cause precipitation to become acidic. Nitrogen and sulfur oxides, mainly from motor vehicle exhaust and coal burning, create acids when they combine with water in the air. The acids lower the pH of precipitation, forming **acid rain**. If acid rain falls on the ground, it may damage soil and soil organisms. If it falls on plants, it may kill them (see **Figure** below). If it falls into lakes, it lowers the pH of the water and kills aquatic organisms.

[Figure 3]

Effects of Acid Rain. These trees in a European forest were killed by acid rain.

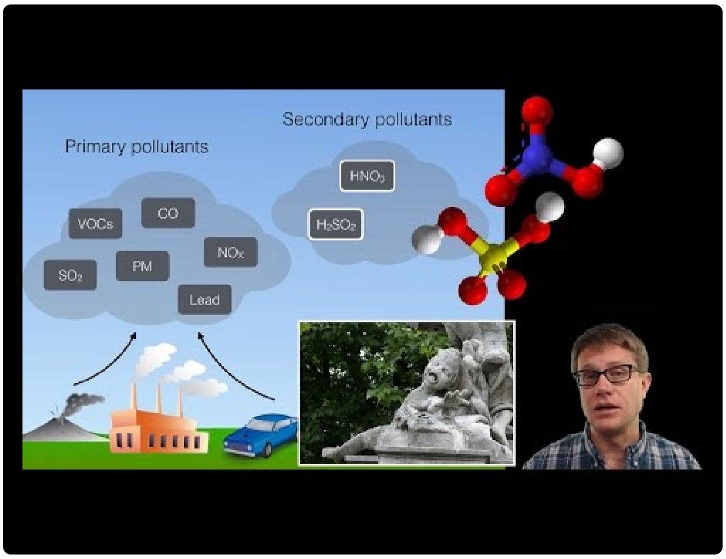
Ozone Depletion

There are two types of **ozone**. You can think of them as bad ozone and good ozone. Both are affected by air pollution.

- Bad ozone forms near the ground when sunlight reacts with pollutants in the air. Ground-level ozone is harmful to the respiratory systems of humans and other animal.
- Good ozone forms in a thin layer high up in the atmosphere, between 15 and 35 kilometers above Earth's surface. This ozone layer shields Earth from most of the sun's

harmful UV radiation. It plays an important role in preventing mutation in the DNA of organisms.

Unfortunately, the layer of good ozone is being destroyed by air pollution. The chief culprits are chlorine and bromine gases. They are released in aerosol sprays, coolants, and other products. Loss of ozone has created an **ozone hole** over Antarctica. Ozone depletion results in higher levels of UV radiation reaching Earth. In humans, this increases skin cancers and eye cataracts. It also disturbs the nitrogen cycle, kills plankton, and disrupts ocean food web. The total loss of the ozone layer would be devastating to most life. Its rate of loss has slowed with restrictions on pollutants, but it is still at risk.



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Summary

- Air pollution consists of chemical substances and particles released into the air, mainly by human actions.
- The major cause of outdoor air pollution is the burning of fossil fuels.
- Indoor air can also be polluted.
- Air pollution causes acid rain, ozone depletion, and global warming.

Review

1. What two environmental effects are mainly associated with the burning of fossil fuels?
2. Explain how air pollution is related to acid rain and ozone depletion.
3. What benefits does the ozone layer provide?

Report Content Errors

6.30 Global Warming

FlexBooks 2.0 > Biology For High School Diploma > Global Warming

Last Modified: Aug 24, 2020

[Figure 1]

Is the Earth really fragile?

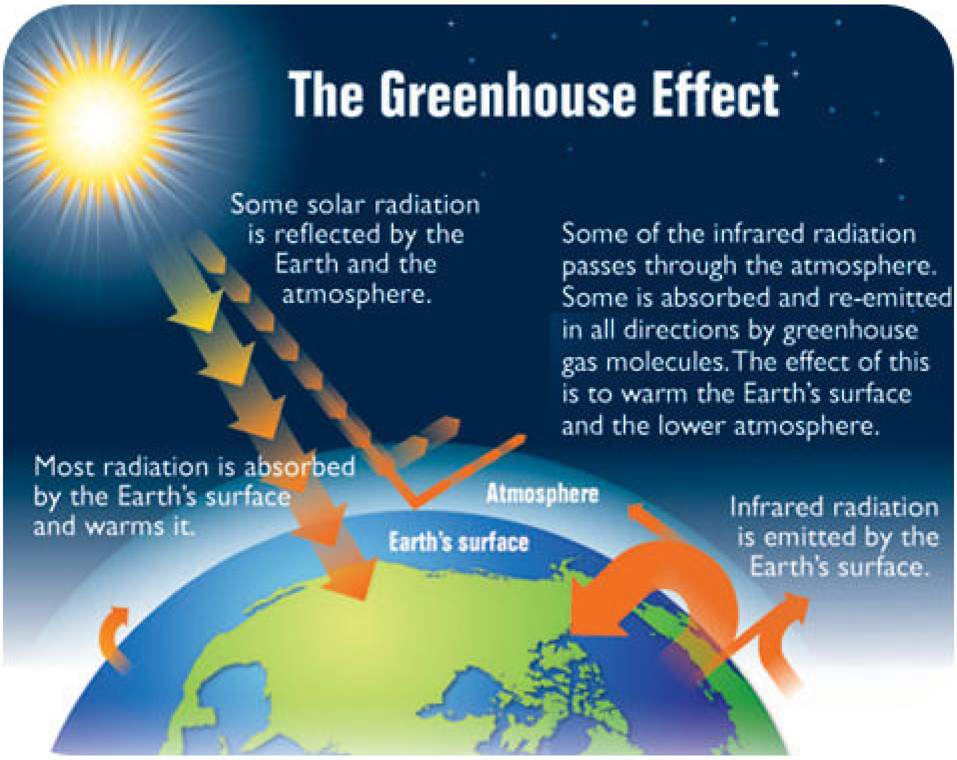
Maybe not the planet, but how about the ecosystem? It may soon be hard to argue that global climate change does not exist. Climate change can definitely be seen in numerous ecosystems. So what will we do about it?

Global Climate Change

Another major problem caused by air pollution is global climate change. Gases such as carbon dioxide from the burning of fossil fuel increase the natural **greenhouse effect**. This raises the temperature of Earth's surface.

What Is The Greenhouse Effect?

The **greenhouse effect** is a natural feature of Earth's atmosphere. It occurs when gases in the atmosphere radiate the sun's heat back down to Earth's surface (see **Figure** below). Otherwise, the heat would escape into space. Without the greenhouse effect, Earth's surface temperature would be far cooler than it is. In fact, it would be too cold to support life as we know it.

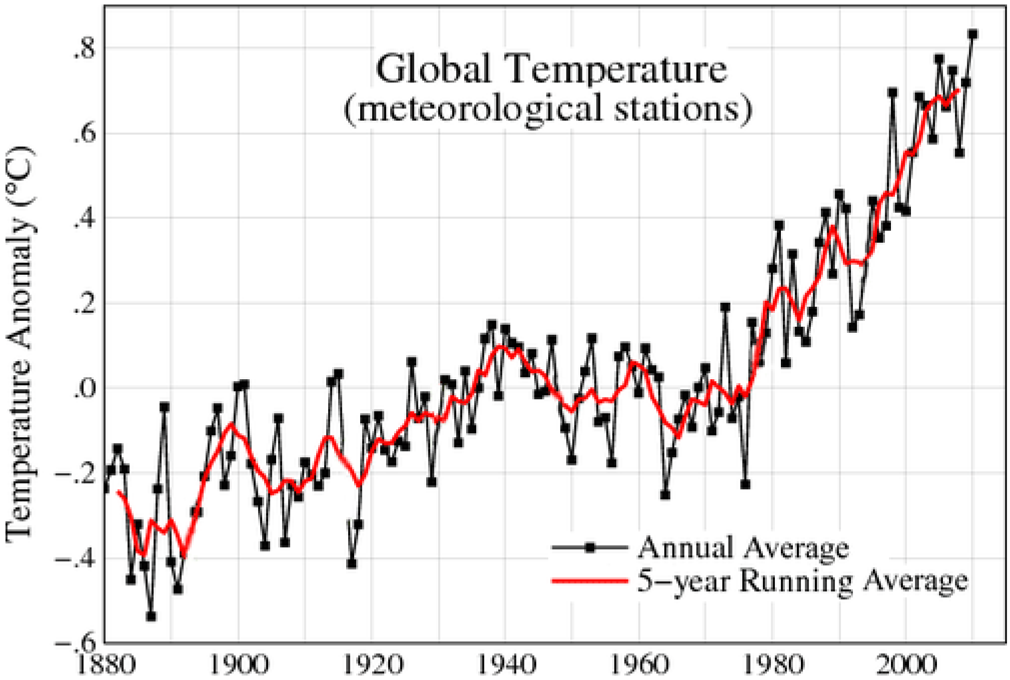


[Figure 2]

The Greenhouse Effect. Without greenhouse gases, most of the sun's energy would be radiated from Earth's surface back out to space.

Global Warming

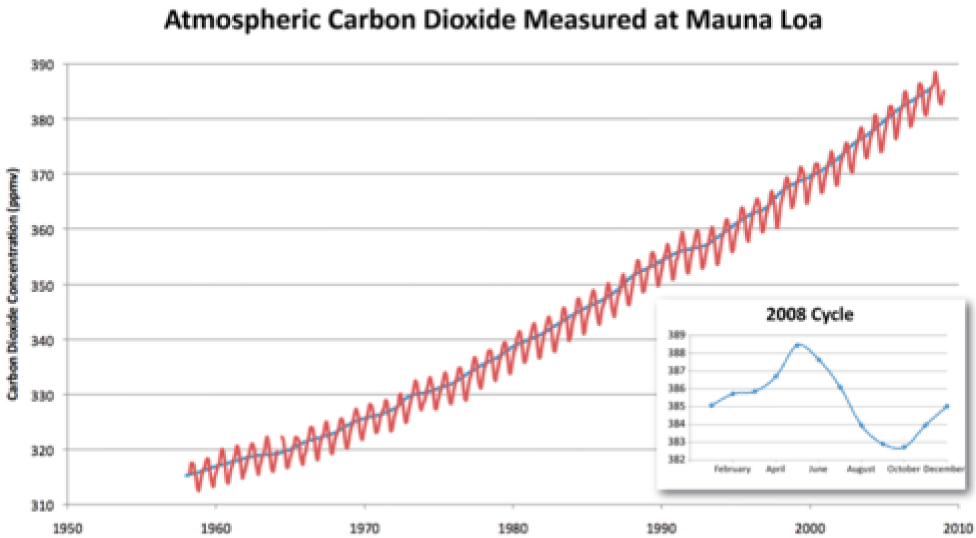
Global warming refers to a recent increase in Earth's average surface temperature (see **Figure** below). During the past century, the temperature has risen by almost 1°C (about 1.3°F). That may not seem like much. But consider that just 10°C is the difference between an ice-free and an ice-covered Earth.



[Figure 3]

The average annual temperature on Earth has been rising for the past 100 years.

Most scientists agree that global warming is caused by more carbon dioxide in the atmosphere (see **Figure** below). This increases the greenhouse effect. There is more carbon dioxide mainly because of the burning of fossil fuels. Destroying forests is another cause. With fewer forests, less carbon dioxide is removed from the atmosphere by photosynthesis.



[Figure 4]

This graph shows the recent trend in carbon dioxide in the atmosphere.

Effects of Climate Change

How has global warming affected Earth and its life? Some of its effects include:

- Decline in cold-adapted species such as polar bears.
- Melting of glaciers and rising sea levels.
- Coastal flooding and shoreline erosion.
- Heat-related human health problems.
- More droughts and water shortages.
- Changing patterns of precipitation.
- Increasing severity of storms.
- Major crop losses.

KQED: Climate Watch: California at the Tipping Point

The world's climate is changing and California is now being affected in both dramatic and subtle ways. In 2008, scientists determined that California's temperatures increased by more than 2.1°F during the last century. What's more, the data showed that human activity has played a significant role in that climate change. "What's just 2 degrees?" you may wonder. But, as the science shows, just 2 degrees is extremely significant.

What does all this temperature change mean? For starters, declining mountain snowpack and prolonged drought conditions could pose a threat to limited water supplies. Heat waves are projected to be longer, bringing increased danger from wildfires and heat-related deaths. Rising sea levels due to temperature shifts jeopardize life in coastal areas, both for human community and the plants and animal that rely on intertidal and rich wetland ecosystems. Also, more precipitation is expected to fall as rain rather than snow, thereby increasing the risk of floods. And, as heat increases the formation of smog, poor air quality could get even worse.

Climate change may also profoundly affect the economy in California and elsewhere. Shorter ski seasons and damage to the marine ecosystem mean a reduction in tourism. Water shortages mean issues with the commercial and recreational fishing industry, and higher temperatures will affect crop growth and quality, weakening the agricultural industry, to name just a few of the economic issues associated with climate change.

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KQED: Acidic Seas

Melting glaciers, rising temperatures and droughts are all impacts of global warming. But how does global warming actually affect the oceans? The sea, it turns out, absorbs carbon dioxide emissions. The ocean acts like a giant sponge, absorbing carbon dioxide emissions from the air. And as we add more and more carbon dioxide to air by burning fossil fuels, the ocean is absorbing it. On one level, it's done us a big favor. Scientists say that we would be experiencing much more extreme climate change were it not for the ocean's ability to remove the heat-trapping gas. However, these emissions are causing the oceans to become more acidic. Changing pH levels threaten entire marine food web, from coral reefs to salmon.

https://www.youtube.com/embed/p2_VuclJymY

As carbon dioxide levels increase in the atmosphere, the levels also increase in the oceans. What effects does this have? Can ocean acidification make it difficult for sea life to produce their hard exoskeletons?

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What Can Be Done?

Efforts to reduce future global warming mainly involve energy use. We need to use less energy, for example, by driving more fuel-efficient cars. We also need to switch to energy sources that produce less carbon dioxide, such as solar and wind energy. At the same time, we can increase the amount of carbon dioxide that is removed from air. We can stop destroying forests and plant new ones.

Summary

- Gases such as carbon dioxide from the burning of fossil fuels increase the natural greenhouse effect. This is raising the temperature of Earth's surface, and is called global warming.

Review

1. How does air pollution contribute to global warming?
2. What is the greenhouse effect?
3. What are three effects of global warming?

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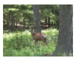	**Credit:** Bill Hayden, NPS **Source:** https://www.flickr.com/photos/43288043@N04/4479394475 **License:** Public Domain
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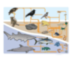	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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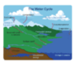	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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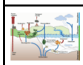	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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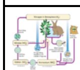	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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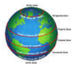
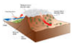
	**Credit:** Laura Guerin, using globe graphic courtesy of the Defense Institute of Security Assistance Management **Source:** CK-12 Foundation (globe graphic: http://commons.wikimedia.org/wiki/File:Globe_Atlantic.svg) **License:** CC BY-NC 3.0; Globe graphic: Public Domain
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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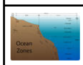	**Credit:** Jodi So **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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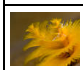	**Credit:** Sunphol Sorakul **Source:** http://www.flickr.com/photos/83424882@N00/3484697438/ **License:** CC BY 2.0
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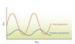	**Credit:** Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0

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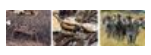	**Credit:** Crab: Thomas Hubauer; Mantis: Adrian Pingstone; Zebra: Paul Maritz, edited by User:Pharaoh Hound/Wikimedia Commons and User:Fir0002/Wikimedia Commons **Source:** Crab: http://www.flickr.com/photos/drth80/8754597558/; Mantis: http://commons.wikimedia.org/wiki/File:Bristol.zoo.dead.leaf.mantis.arp.jpg; Zebra: http://commons.wikimedia.org/wiki/File:Zebra_Botswana_edit02.jpg **License:** Crab: CC BY 2.0; Mantis: Public Domain; Zebra: CC BY 2.5
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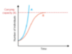	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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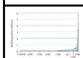	**Credit:** Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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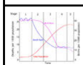	**Credit:** User:Charmed88/Wikipedia and User:NikNaks/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Stage5.svg **License:** Public Domain
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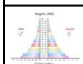
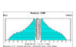
	**Credit:** Hana Zavadska, based on data from the U.S. Census Bureau **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** U.S. Census Bureau **Source:** http://www.census.gov/ipc/www/idb/country.php **License:** Public Domain

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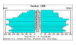
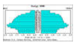
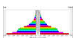
	**Credit:** U.S. Census Bureau **Source:** http://www.census.gov/ipc/www/idb/country.php **License:** Public Domain
	**Credit:** U.S. Census Bureau **Source:** http://www.census.gov/ipc/www/idb/country.php **License:** Public Domain
	**Credit:** U.S. Census Bureau **Source:** http://www.census.gov/ipc/www/idb/country.php **License:** Public Domain
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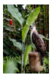	**Credit:** Flickr: Bro. Jeffrey Pioquinto, SJ **Source:** https://www.flickr.com/photos/90412460@N00/9559781611/ **License:** CC BY 2.0
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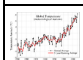
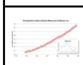
	**Credit:** NASA, modified by Zachary Wilson/CK-12 Foundation **Source:** http://commons.wikimedia.org/wiki/File:Temperature_global.gif **License:** Public Domain; CC BY-NC 3.0
	**Credit:** Steven Lai and Zachary Wilson, based on data from the Carbon Dioxide Information Analysis Center (http://cdiac.ornl.gov/ftp/trends/co2/maunaloa.co2) **Source:** CK-12 Foundation **License:** CC BY-NC 3.0

CHAPTER 7

Prokaryotes and Viruses

Chapter Outline

7.1 Prokaryotes

FlexBooks 2.0 > Biology For High School Diploma > Prokaryotes

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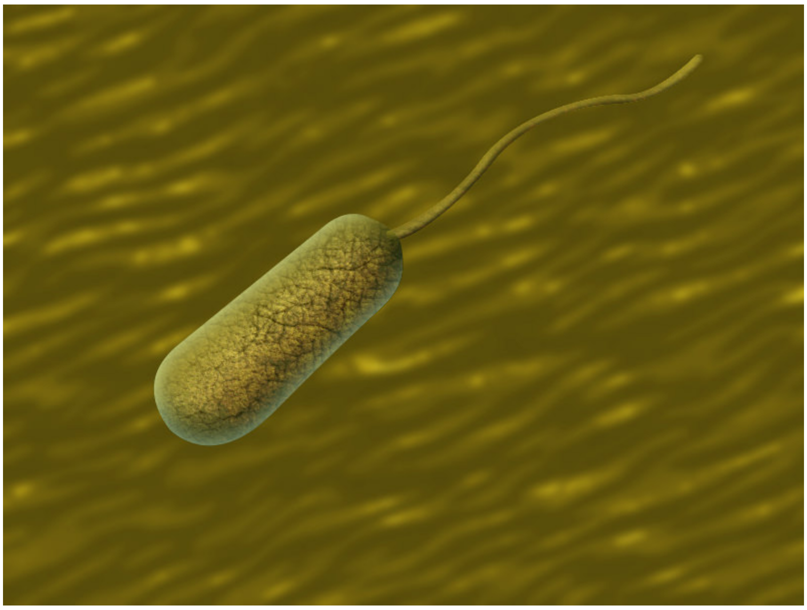


[Figure 1]

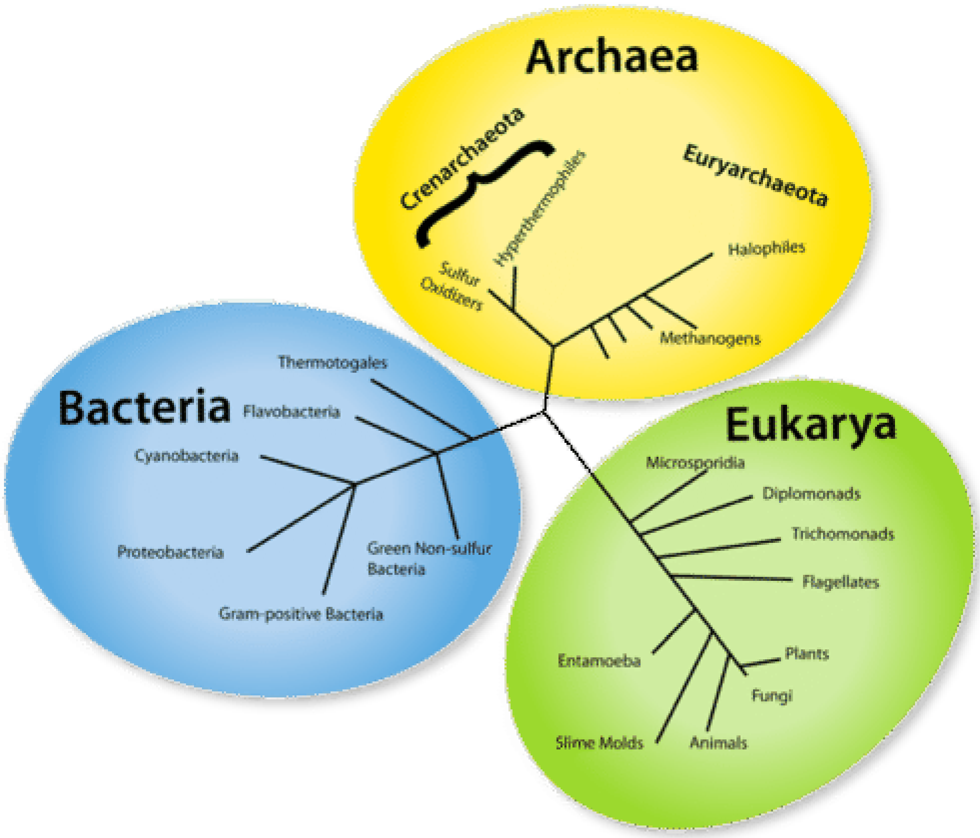
What are the most numerous organisms on the planet?

bacterium. And all it takes is one to quickly grow, under just the right conditions, into millions and billions. Luckily, we know how to control bacteria when necessary. But bacteria do serve many important purposes. In fact, we could not survive without them.

Evolution of Prokaryotes

No doubt you've had a sore throat before, and you've probably eaten cheese or yogurt. If so, then you've encountered the fascinating world of prokaryotes. **Prokaryotes** are single-celled organism that lack a nucleus. They also lack other membrane-bound organelle. Prokaryotes are tiny and sometimes bothersome, but they are the most numerous organisms on Earth. Without them, the world would be a very different place. Prokaryotes are the simplest organisms. The first cell and organisms to evolve would be classified as prokaryotic.

Prokaryotes are currently placed in two **domain**. A **domain** is the highest **taxon**, just above the **kingdom**. The prokaryote domains are **Bacteria** and **Archaea** (see **Figure** below). The third domain is **Eukarya**. It includes all eukaryote. Unlike prokaryotes, eukaryotes have a nucleus in their cells.



[Figure 2]

The Three Domains of Life. All living things are grouped in three domains. The domains Bacteria and Archaea consist of prokaryotes. The Eukarya domain consists of eukaryotes.

It's not clear how the three domains are related. Archaea were once thought to be offshoots of Bacteria that were adapted to extreme environments. For their part, Bacteria were considered to be ancestors of Eukarya. Scientists now know that Archaea share several traits with Eukarya that Bacteria do not share (see **Table** below). How can this be explained? One hypothesis is that Eukarya arose when an Archaean cell fused with a Bacterial cell. The two cells became the nucleus and cytoplasm of a new Eukaryan cell. How well does this hypothesis fit the evidence in **Table** below?

Characteristic	Bacteria	Archaea	Eukarya
flagellum	Unique to Bacteria	Unique to Archaea	Unique to Eukarya
cell membrane	Unique to Bacteria	Like Bacteria and Eukarya	Unique to Eukarya
protein synthesis	Unique to Bacteria	Like Eukarya	Like Archaea
intron	Absent in most	Present	Present
peptidoglycan (in cell wall)	Present	Absent in most	Absent

Summary

- Prokaryotes include Bacteria and Archaea. An individual prokaryote consists of a single cell without a nucleus.
- Bacteria live in virtually all environments on Earth.
- Archaea live everywhere on Earth, including extreme environments.

Review

1. What are prokaryotes?
2. What are two major differences between Bacteria and Archaea?

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7.2 Bacteria Classification

FlexBooks 2.0 > Biology For High School Diploma > Bacteria Classification

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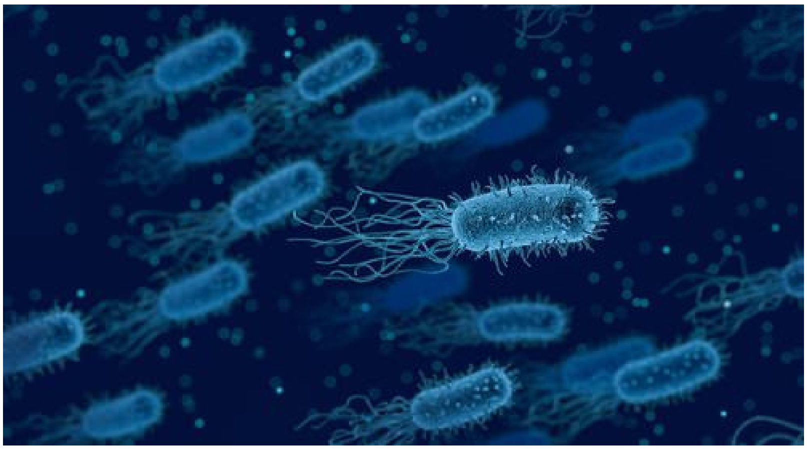


[Figure 1]

With so many different bacteria, how are they all classified?

By shape? By size? By some other criteria? As you can imagine, classifying bacterium is probably not an easy task. Bacteria are classified by their traits, some of which have to do with their shape, others with the cell wall, and even additional traits.

The Prokaryotic Domains

Domain Bacteria

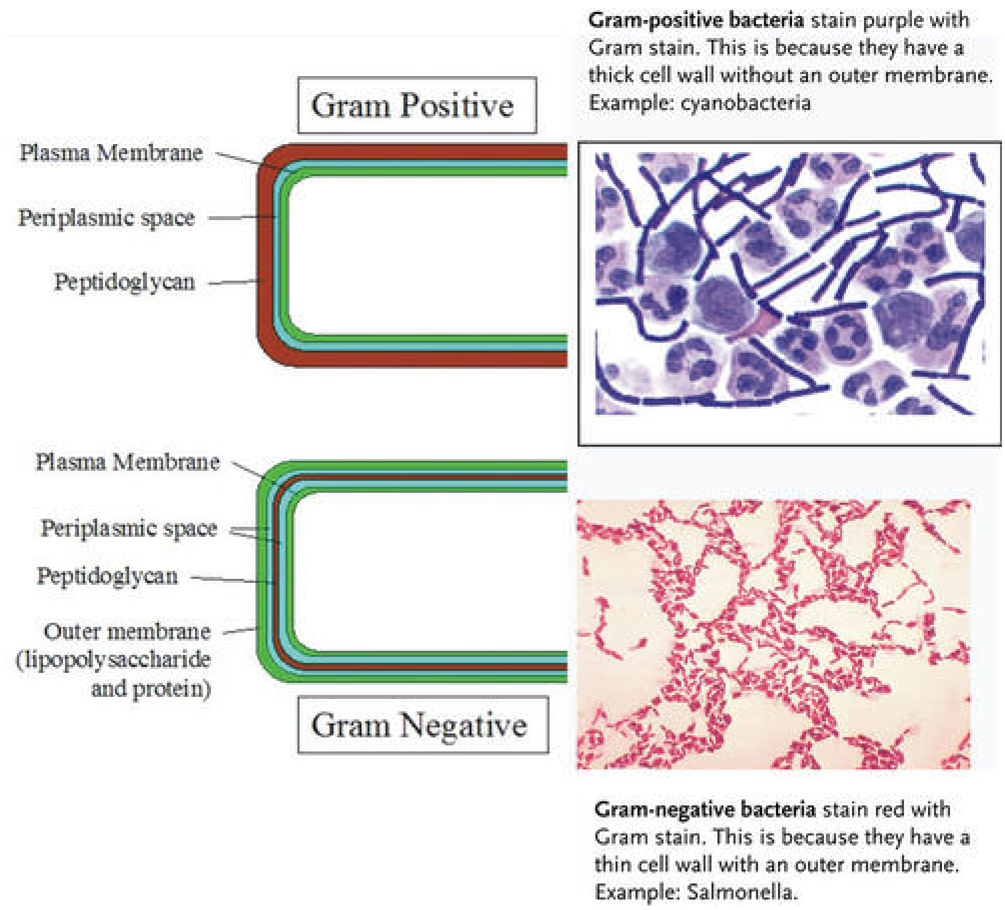
Bacteria are the most diverse and abundant group of organism on Earth. They live in almost all environments. They are found in the ocean, the soil, and the intestines of animal. They are even found in rocks deep below Earth's surface. Any surface that has not been sterilized is likely to be covered with bacteria. The total number of bacteria in the world is amazing. It's estimated to be 5×10^{30}, or five million trillion. You have more bacteria in and on your body than you have body cells!

Bacteria called **cyanobacterium** are very important. They are bluish green in color (see **Figure** below) because they contain chlorophyll (but not chloroplast, of course). They make food through photosynthesis and release oxygen into the air. These bacteria were probably responsible for adding oxygen to the air on early Earth. This changed the planet's atmosphere. It also changed the direction of evolution. Ancient cyanobacteria also may have evolved into the chloroplasts of plant cell.

[Figure 2]

Cyanobacteria Bloom. The green streaks in this lake consist of trillions of cyanobacteria. Excessive nutrients in the water led to overgrowth of the bacteria.

Thousands of species of bacteria have been discovered, and many more are thought to exist. The known species can be classified on the basis of various traits. One classification is based on differences in their cell walls and outer membranes. It groups bacteria into **Gram-positive** and **Gram-negative** bacteria, as described in **Figure** below.



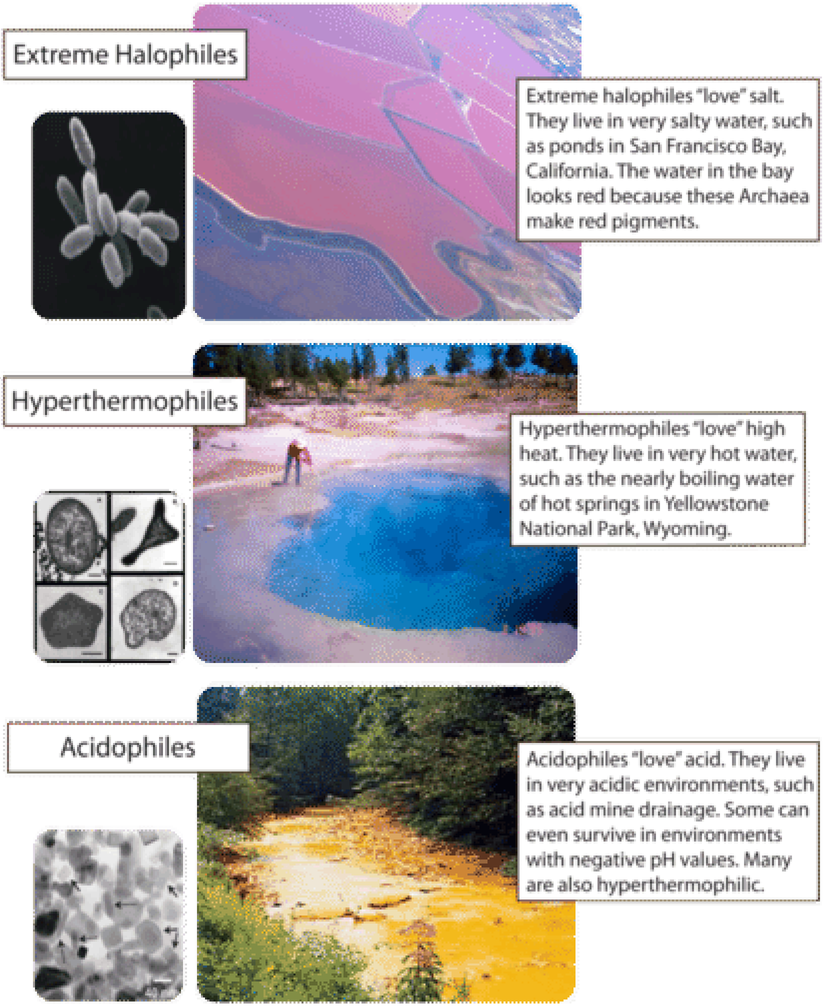
[Figure 3]

Classification of Bacteria. Different types of bacteria stain a different color when stained with Gram stain. This makes them easy to identify.

Domain Archaea

Scientists still know relatively little about Archaea. This is partly because they are hard to grow in the lab. Many live inside the bodies of animals, including humans. However, none are known for certain to cause disease.

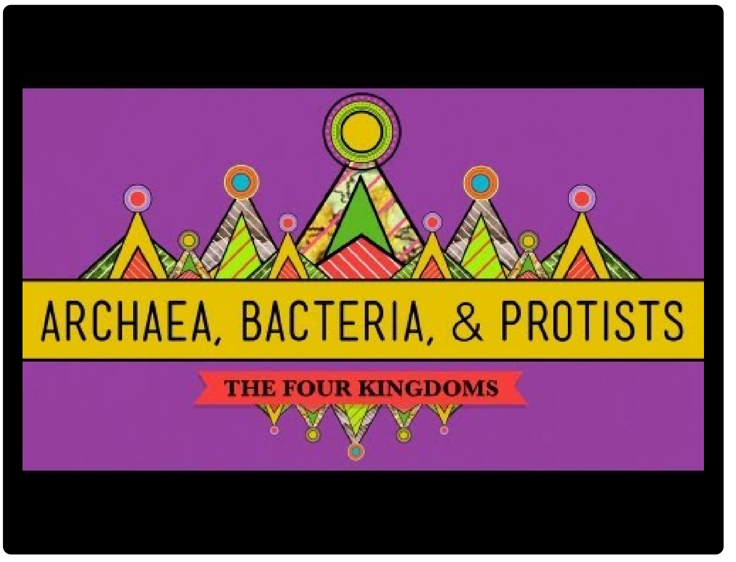
Archaea were first discovered in extreme environments. For example, some were found in hot springs. Others were found around deep sea vents. Such Archaea are called **extremophile**, or "lovers of extremes." **Figure** below describes three different types of Archaean extremophiles. The places where some of them live are thought to be similar to the environment on ancient Earth. This suggests that they may have evolved very early in Earth's history.



[Figure 4]

Extremophile Archaea. Many Archaea are specialized to live in extreme environments. Just three types are described here.

Archaea are now known to live just about everywhere on Earth. They are particularly numerous in the ocean. Archaea in plankton may be one of the most abundant types of organisms on the planet. Archaea are also thought to play important roles in the carbon and nitrogen cycles. For these reasons, Archaea are now recognized as a major aspect of life on Earth.



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Science Friday: Subvisual Subway: The Art of New York City's Bacterial World

An urban legend states that "using the handrails on the subway is like shaking hands with 100 people." In this video by science Friday, Craig Ward sampled the bacteria on subway lines around New York City to create striking and unconventional "portraits" of NYC commuters.

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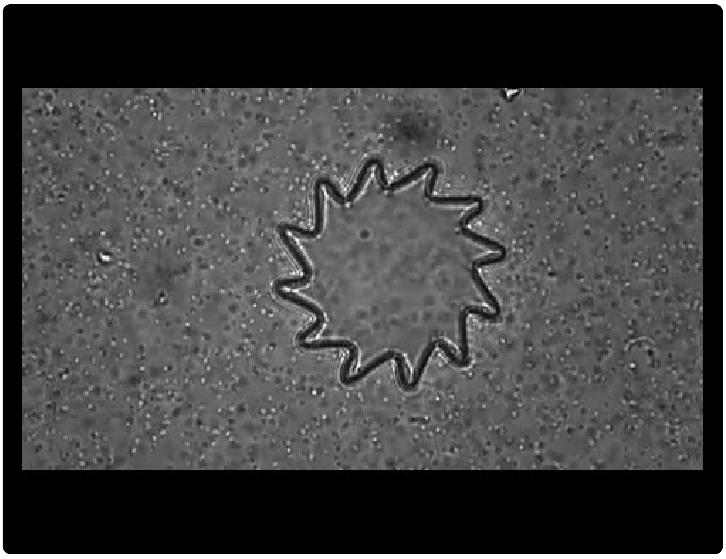
Science Friday: Dawn of the Cyborg Bacteria

Does using bacteria to power microscopic robots sound like a horror film? In this video by Science Friday, Ph.D. students Elizabeth Beattie and Denise Wong hope these nano bio-robots will provide a platform for future medical and micro-engineering endeavors.



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Summary

- Bacteria live in virtually all environments on Earth.
- Archaea live everywhere on Earth, including extreme environments.

Review

1. Distinguish between Gram-positive and Gram-negative bacteria, and give an example of each.
2. Summarize the evolutionary significance of cyanobacteria.
3. What are extremophiles? Name three types.
4. Describe the habitat of extreme halophiles.

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7.3 Bacteria Structure

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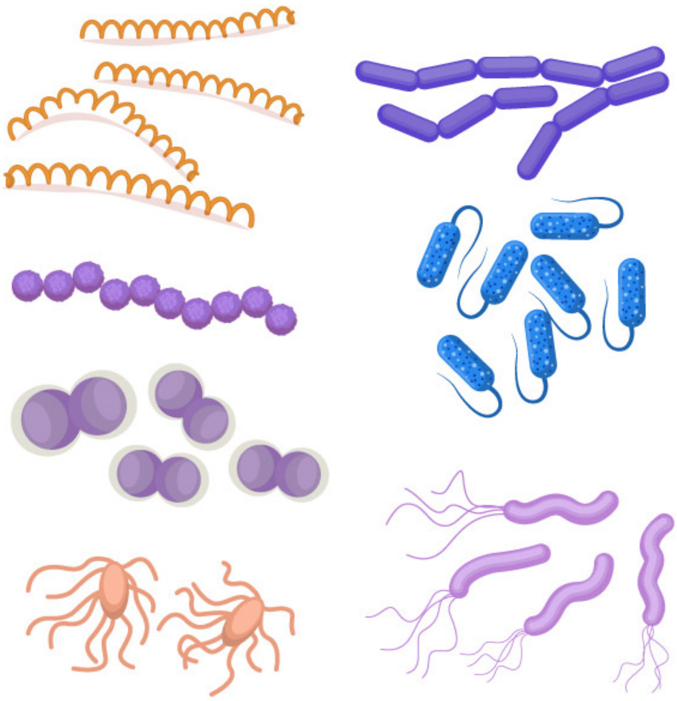


[Figure 1]

Does the shape matter?

It does if you're a bacterium. prokaryotic cell are distinguished by their shape. And as you can imagine, shape may have something to do with mobility.

Prokaryote Structure

Most prokaryotic cells are much smaller than eukaryotic cell. Although they are tiny, prokaryotic cells can be distinguished by their shapes. The most common shapes are helices, spheres, and rods (see **Figure** below).

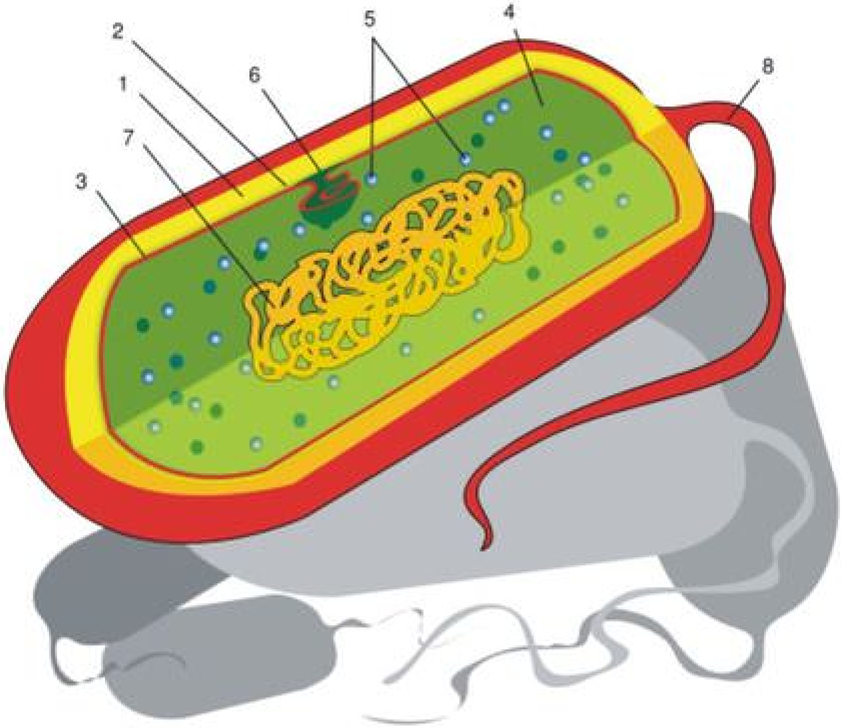
[Figure 2]

Prokaryotic Cell Shapes. The three most common prokaryotic cell shapes are shown here.

Plasma Membrane and Cell Wall

Like other cell, prokaryotic cells have a plasma membrane (see **Figure** below). It controls what enters and leaves the cell. It is also the site of many metabolic reactions. For example, cellular respiration and photosynthesis take place in the plasma membrane.

Most prokaryote also have a cell wall. It lies just outside the plasma membrane. It gives strength and rigidity to the cell. Bacteria and Archaea differ in the makeup of their cell wall. The cell wall of Bacteria contains **peptidoglycan**, composed of sugars and amino acid. The cell wall of most Archaea lacks peptidoglycan.

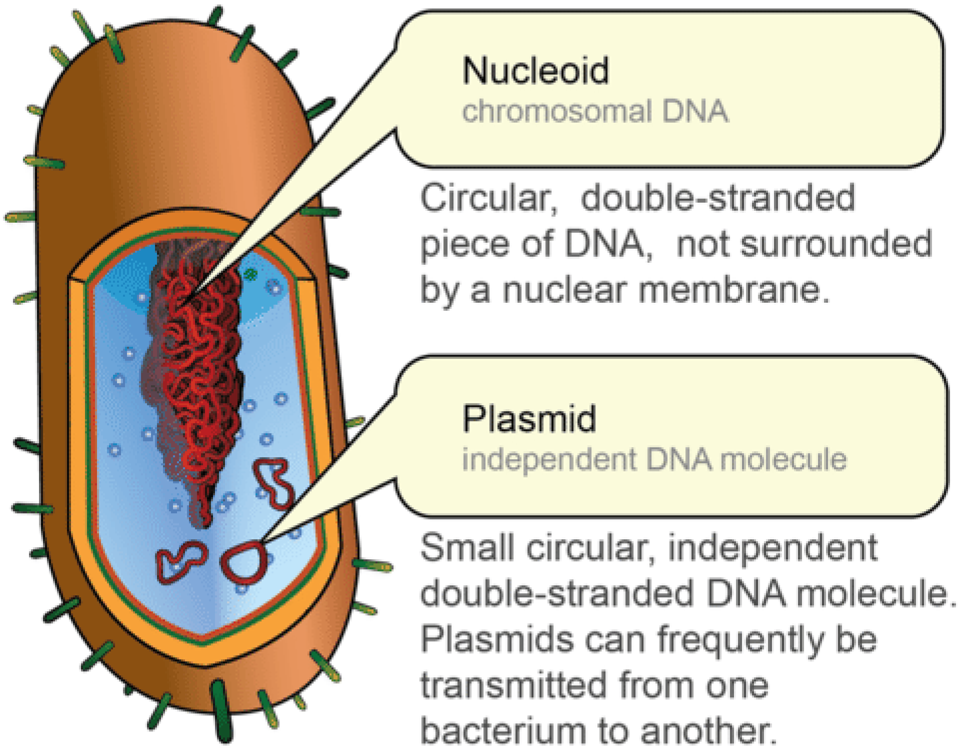


[Figure 3]

Prokaryotic Cell. The main parts of a prokaryotic cell are shown in this diagram. The structure called a mesosome was once thought to be an organelle. More evidence has convinced most scientists that it is not a true cell structure at all. Instead, it seems to be an artifact of cell preparation. This is a good example of how scientific knowledge is revised as more evidence becomes available. Can you identify each of the labeled structures?

Cytoplasm and Cell Structures

Inside the plasma membrane of prokaryotic cells is the cytoplasm. It contains several structures, including ribosome, a cytoskeleton, and **genetic material**. Ribosomes are sites where protein are made. The cytoskeleton helps the cell keep its shape. The genetic material is usually a single loop of DNA. There may also be small, circular pieces of DNA, called **plasmid**. (see **Figure** below). The cytoplasm may contain microcompartments as well. These are tiny structures enclosed by proteins. They contain enzyme and are involved in metabolic processes.



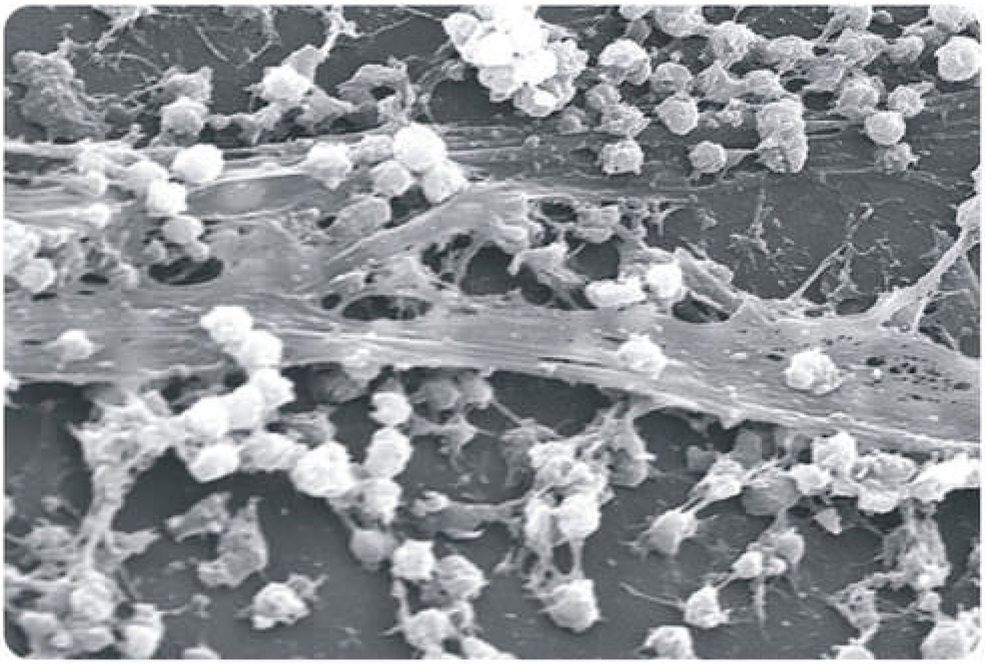
[Figure 4]

Prokaryotic DNA. The DNA of a prokaryotic cell is in the cytoplasm because the cell lacks a nucleus.

Extracellular Structures

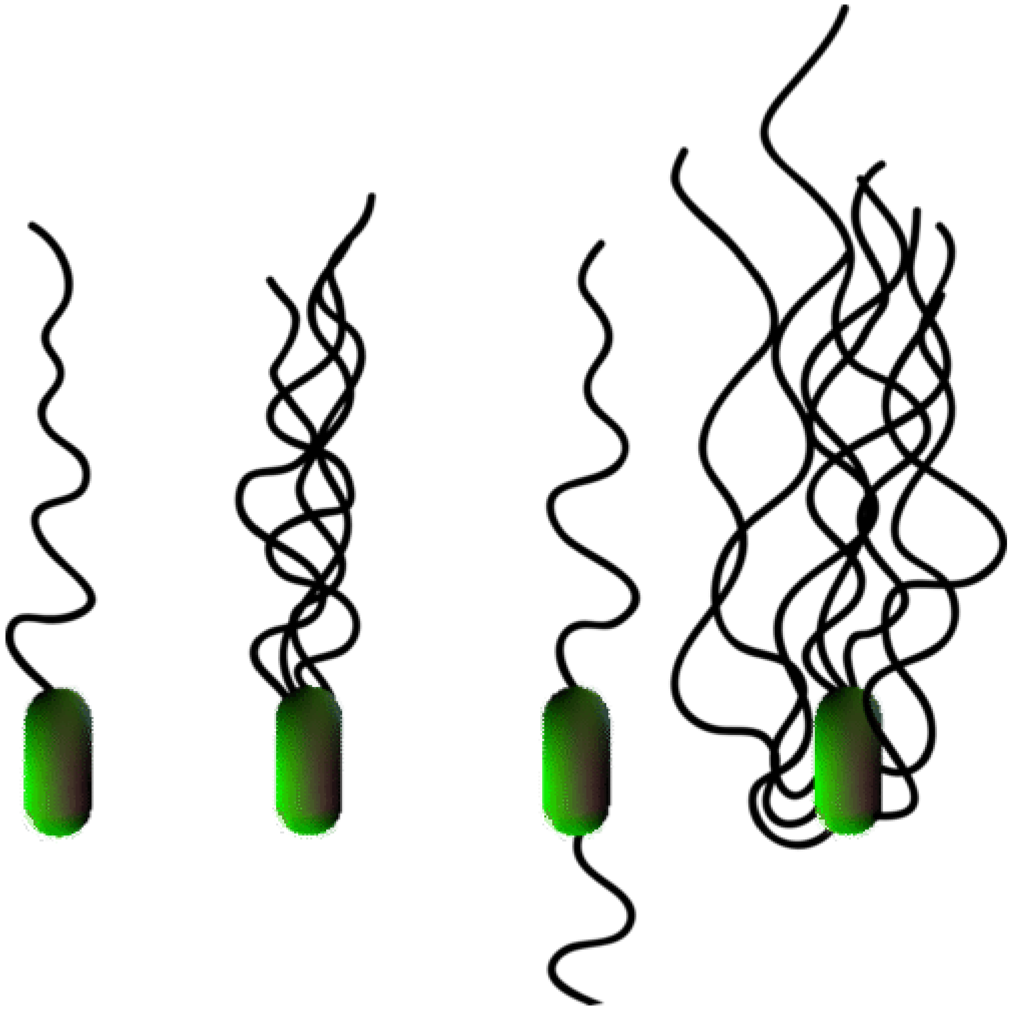
Many prokaryotes have an extra layer, called a capsule, outside the cell wall. The **capsule** protects the cell from chemicals and from drying out. It also allows the cell to stick to surfaces and to other cells. Because of this, many prokaryotes can form **biofilm**, like the one shown in **Figure** below. A **biofilm** is a colony of prokaryotes that is stuck to a surface such as a rock or a host's tissue. The sticky plaque that collects on your teeth between brushings is a biofilm. It consists of millions of bacteria.

Most prokaryotes also have long, thin protein structures called **flagellum** (singular, **flagellum**). They extend from the plasma membrane. Flagella help prokaryotes move. They spin around a fixed base, causing the cell to roll and tumble. As shown in **Figure** below, prokaryotes may have one or more flagella.



[Figure 5]

Bacterial Biofilm. The greatly magnified biofilm shown here was found on a medical catheter (tubing) removed from a patient's body.

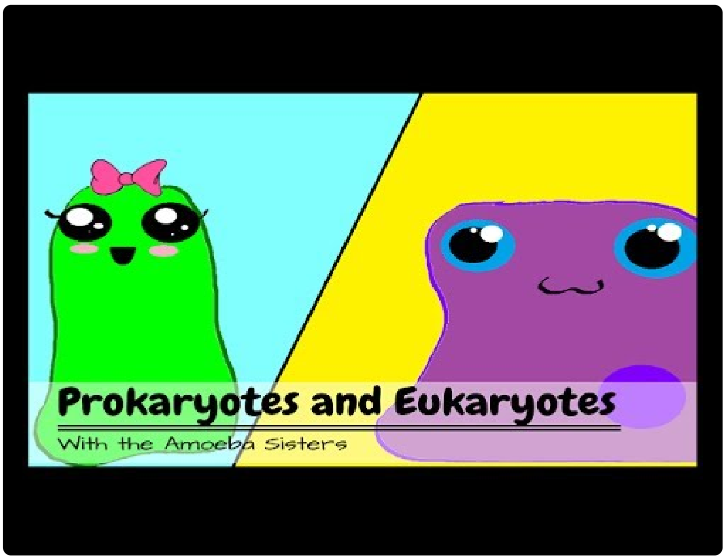


[Figure 6]

Variations in the Flagella of Bacteria. Flagella in prokaryotes may be located at one or both ends of the cell or all around it. They help prokaryotes move toward food or away from toxins.

Endospores

Many organism form spores for reproduction. Some prokaryotes form spores for survival. Called **endospore**, they form inside prokaryotic cells when they are under stress. The stress could be UV radiation, high temperatures, or harsh chemicals. Endospores enclose the DNA and help it survive under conditions that may kill the cell. Endospores are commonly found in soil and water. They may survive for long periods of time.



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Summary

- Most prokaryotic cells are much smaller than eukaryotic cells.
- Prokaryotic cells have a cell wall outside their plasma membrane.
- Prokaryotic DNA consists of a single loop. Some prokaryotes also have small, circular pieces of DNA called plasmids.

Review

1. Identify the three most common shapes of prokaryotic cells.
2. Describe a typical prokaryotic cell.
3. What are the roles of flagella and endospores in prokaryotes?

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7.4 Bacteria Nutrition

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[Figure 1]

What do bacteria need to grow?

Like most everything else, they need food. Given the right conditions, bacterium can grow from just a few cell to millions or billions overnight.

Prokaryote Metabolism

Like all living things, prokaryote need energy and carbon. They meet these needs in a variety of ways. In fact, prokaryotes have just about every possible type of **metabolism**. They may get energy from light (photo) or chemical compounds (chemo). They may get carbon from carbon dioxide (**autotroph**) or other living things (**heterotroph**). Most prokaryotes are **chemoheterotroph**. They depend on other organism for both energy and carbon. Many break down organic wastes and the remains of dead organisms. They play vital roles as decomposer and help recycle carbon and nitrogen. **photoautotroph** are important producer. They are especially important in aquatic ecosystem.

Classification of Prokaryotes Based on Metabolism

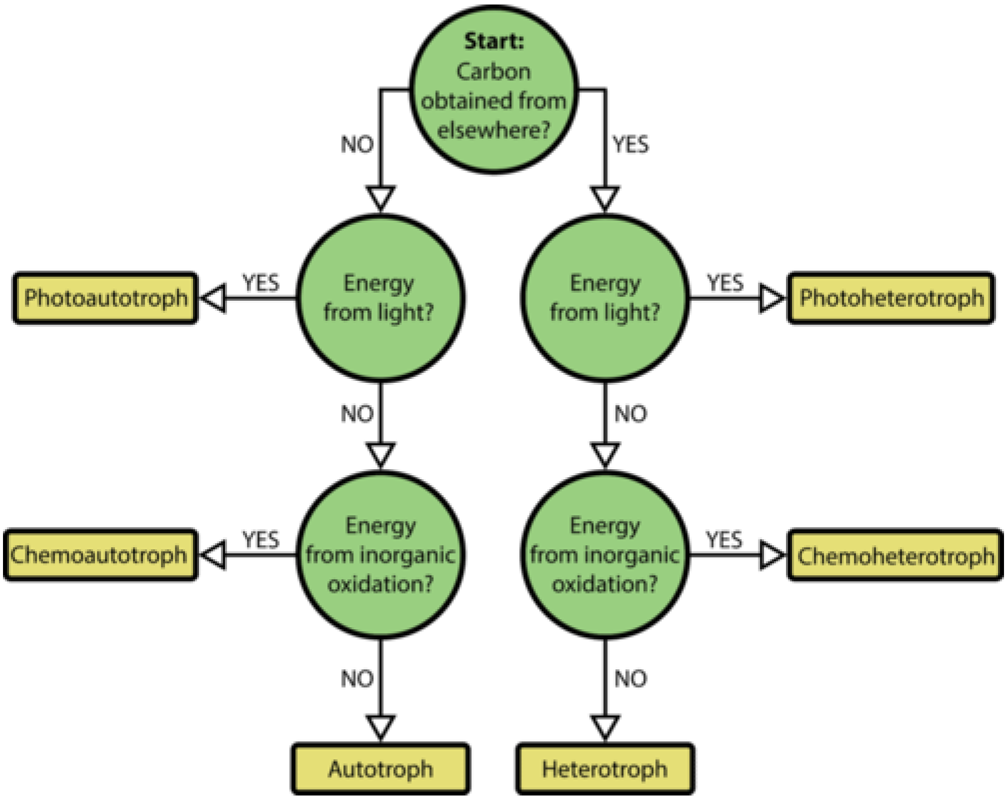
Two major nutritional needs can be used to group prokaryotes. These are (1) carbon metabolism, their source of carbon for building organic molecule within the cells, and (2) energy metabolism, their source of energy used for growth.

In terms of carbon metabolism, prokaryotes are classified as either heterotrophic or autotrophic:

- Heterotrophic organisms use organic compound, usually from other organisms, as carbon sources.
- Autotrophic organisms use carbon dioxide (CO_2) as their only source or their main source of carbon. Many autotrophic bacteria are photosynthetic, and get their carbon from the carbon dioxide in the atmosphere.

Energy metabolism in prokaryotes is classified as one of the following:

- Phototrophic organisms capture light energy from the sun and convert it into chemical energy inside their cells.
- Chemotrophic organisms break down either organic or inorganic molecules to supply energy for the cell. Some chemotrophic organisms can also use their organic energy-supplying molecules as a carbon supply, which would make them chemoheterotrophs.
- **photoheterotroph** are organisms that capture light energy to convert to chemical energy in the cells, but they get carbon from organic sources (other organisms). Examples are purple non-sulfur bacteria, green non-sulfur bacteria and heliobacteria.
- Chemoheterotrophs are organisms that get their energy source and carbon source from organic sources. Chemoheterotrophs must consume organic building blocks that they are unable to make themselves. Most get their energy from organic molecules such as sugars. This nutritional mode is very common among eukaryote, including humans.
- Photoautotrophs are cells that capture light energy, and use carbon dioxide as their carbon source. There are many photoautotrophic prokaryotes, which include cyanobacterium. Photoautotrophic prokaryotes use similar compounds to those of plants to trap light energy.
- **chemoautotroph** are cells that break down inorganic molecules to supply energy for the cell, and use carbon dioxide as a carbon source. Chemoautotrophs include prokaryotes that break down hydrogen sulfide (H_2S the “rotten egg” smelling gas), and ammonia (NH_4). *Nitrosomonas*, a species of soil bacterium, oxidizes NH_4^+ to nitrite (NO_2^-). This reaction releases energy that the bacteria use. Many chemoautotrophs also live in extreme environments such as deep sea vents.



[Figure 2]

This flowchart helps to determine if a species is an autotroph or a heterotroph, a phototroph or a chemotroph. For example, “Obtain carbon elsewhere?” asks if the source of carbon is another organism. If the answer is “yes”, the organism is heterotrophic. If the answer is “no,” the organisms is autotrophic.

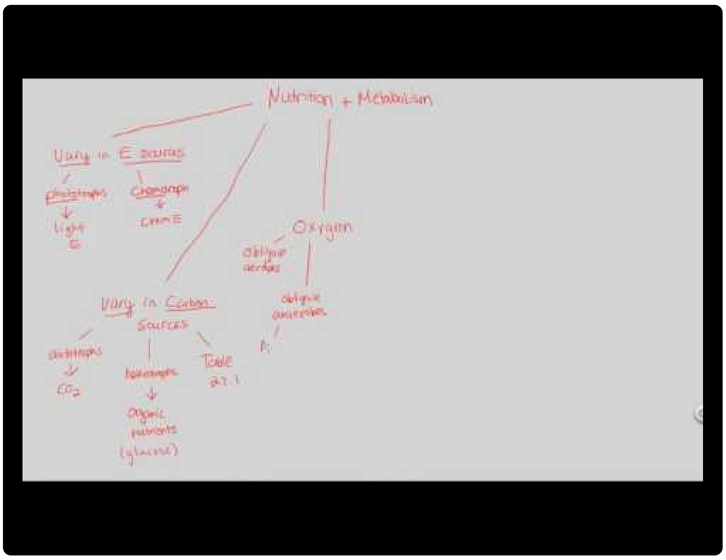
Summary

- Prokaryotes fulfill their carbon and energy needs in various ways. They may be photoautotrophs, chemoautotrophs, photoheterotrophs, or chemoheterotrophs.

Review

1. Describe metabolism of most prokaryotes.
2. Define phototrophic and chemotrophic organisms.
3. What are photoautotrophs?
4. What are photoheterotrophs?

Resources



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7.5 Bacteria Habitat

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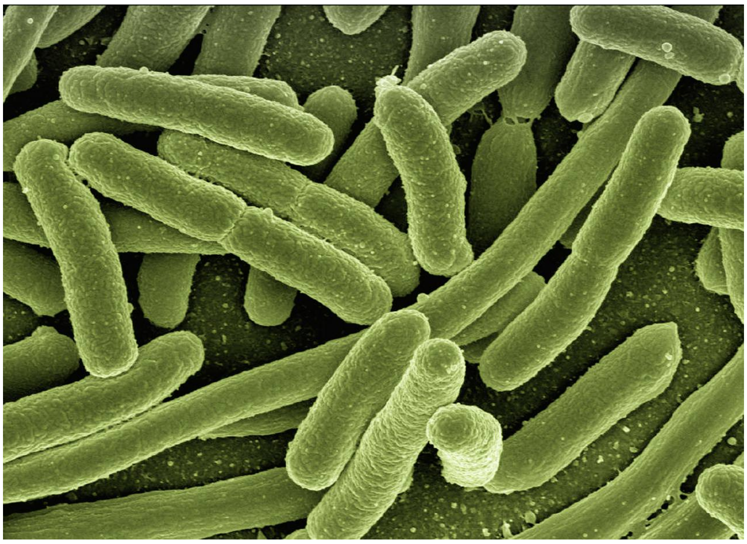

[Figure 1]

Where do you find lots of bacteria?

Practically all surfaces. bacterium can live and grow in practically any environment. It is this ability that has made bacteria the most numerous species on the planet.

Prokaryote Habitats

prokaryote have a wide range of metabolisms, and this determines where they live. They live in a particular habitat because they are able to "eat" whatever is around them. For example, there are bacteria and archaea that break down hydrogen sulfide to produce ATP. Hydrogen sulfide is the gas that gives rotten egg and sewage their distinctive smell. It is poisonous to animal, but some prokaryotes depend on it for life.

organism that are **obligate aerobe** need oxygen to live. That is, they use oxygen as a terminal electron acceptor while making ATP (see the "Cellular Respiration" concept). Humans are obligate aerobes, and so are *Mycobacterium tuberculosis* bacteria. *M. tuberculosis* causes tuberculosis (TB). Obligate aerobes are found only in places with molecular oxygen.

An **anaerobic** organism is any organism that does not need oxygen for growth and even dies in its presence. **obligate anaerobe** will die when exposed to atmospheric levels of oxygen. *Clostridium perfringens* bacteria, which are commonly found in soil around the world, are obligate anaerobes. Infection of a wound by *C. perfringens* bacteria causes the disease gas gangrene. Obligate anaerobes use molecules other than oxygen as terminal electron acceptors.

facultative anaerobic organisms, which are usually prokaryotic, make ATP by aerobic respiration, if oxygen is present, but can also survive without oxygen. In the absence of oxygen they switch to the process of **fermentation** to make ATP. **Fermentation** is a type of heterotrophic metabolism that uses organic carbon instead of oxygen as a terminal electron acceptor. Examples of facultative anaerobic bacteria are the *Staphylococci*, *Escherichia coli*, *Corynebacterium*, and *Listeria* species. Many bacteria that cause human diseases are facultative anaerobic organisms.

Temperature

Like most organisms, prokaryotes live and grow best within certain temperature ranges. Prokaryotes can be classified by their temperature preferences, as shown in the **Table** below. Which type of prokaryote would you expect to find inside the human body?

thermophile live at relatively high temperatures, above 45°C (113°F). Thermophiles are found in geothermally heated regions of the Earth, such as hot springs like the Morning Glory pool in Yellowstone National Park (see **Figure** below), and deep sea hydrothermal vents. Some thermophiles live in decaying plant matter such as peat bogs and compost. Many thermophiles are archaea. Extreme thermophiles (or **hyperthermophile**), live in temperatures hotter than 80°C (176°F).

psychrophile grow and reproduce in cold temperatures. The optimal growth temperature of some psychrophiles is 15°C or lower; they cannot grow in temperatures above 20°C. The environments that psychrophiles inhabit are found all over Earth. Psychrophiles live in such places as permafrost soils, deep-ocean waters, Arctic and Antarctic glaciers and snowfields.

mesophile grow best in moderate temperature, typically between 20°C and 45°C (77°F and 104°F). Mesophiles are often found living in or on the bodies of humans or other animals. The optimal growth temperature of many pathogenic mesophiles is 37°C (98°F), the normal human body temperature. Mesophilic organisms have important uses in food preparation, including cheese, yogurt, beer and wine.

Type of Prokaryote	Preferred Temperature	Where It Might Be Found
Thermophile	above 45°C (113°F)	in compost
Mesophile	about 37°C (98°F)	inside animals
Psychrophile	below 20°C (68°F)	in the deep ocean

[Figure 2]

The Morning Glory pool of Yellowstone National Park in the United States is a geothermal pool whose waters are heated to high temperatures by magma deep underground. Hyperthermophilic organisms, such as members of the archaeal genus Sulfolobus can live at temperatures between 60°C-80°C and a pH of 3.

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Summary

- Aerobic prokaryotes live in habitats with oxygen.
- Anaerobic prokaryotes live in habitats without oxygen.
- Prokaryotes may also be adapted to habitats that are hot, moderate, or cold in temperature.

Review

1. Why are many prokaryotes adapted for living at the normal internal temperature of the human body.
2. Compare psychrophiles to thermophiles.
3. Compare obligate aerobes to facultative anaerobes.

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7.6 Bacteria Reproduction

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Last Modified: May 16, 2021

[Figure 1]

How do bacteria reproduce?

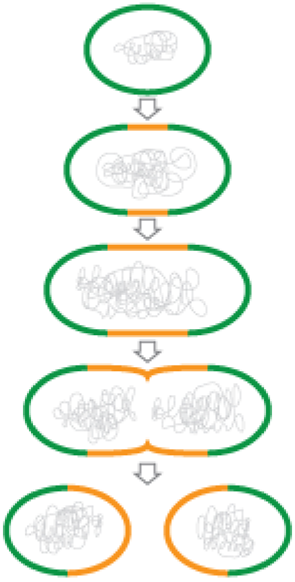
Essentially, they grow and divide. Shown here is an example of *Escherichia coli* bacterium. Notice how one bacterium is dividing into two.

Reproduction in Prokaryotes

Unlike multicellular organism, increases in the size of prokaryote (cell growth) and their reproduction by cell division are tightly linked. Prokaryotes grow to a fixed size and then reproduce through **binary fission.**

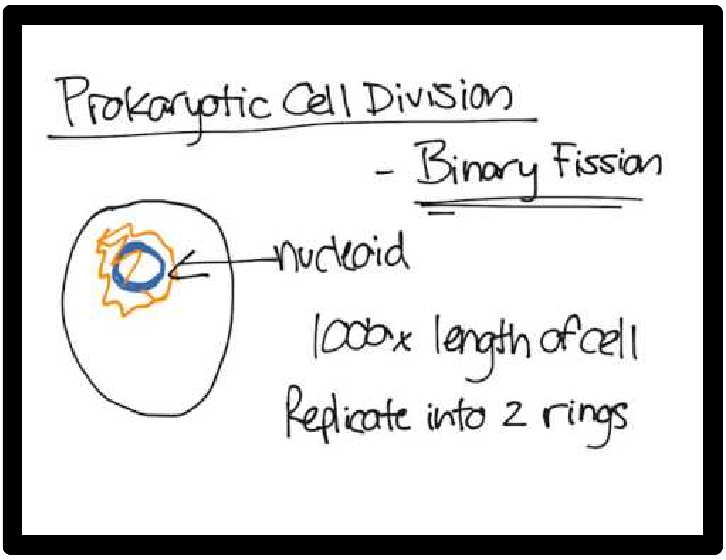
Binary Fission

Binary fission is a type of asexual reproduction. It occurs when a parent cell splits into two identical daughter cell. This can result in very rapid population growth. For example, under ideal conditions, bacterial population can double every 20 minutes. Such rapid population growth is an adaptation to an unstable environment. Can you explain why?



[Figure 2]

Schematic diagram of cellular growth (elongation) and binary fission of bacilli. Blue and red lines indicate old and newly-synthesized bacterial cell wall, respectively. The DNA inside the bacterium is copied and the daughter cells receive an exact copy of the parent DNA. Fission involves a cytoskeletal protein FtsZ that forms a ring at the site of cell division.



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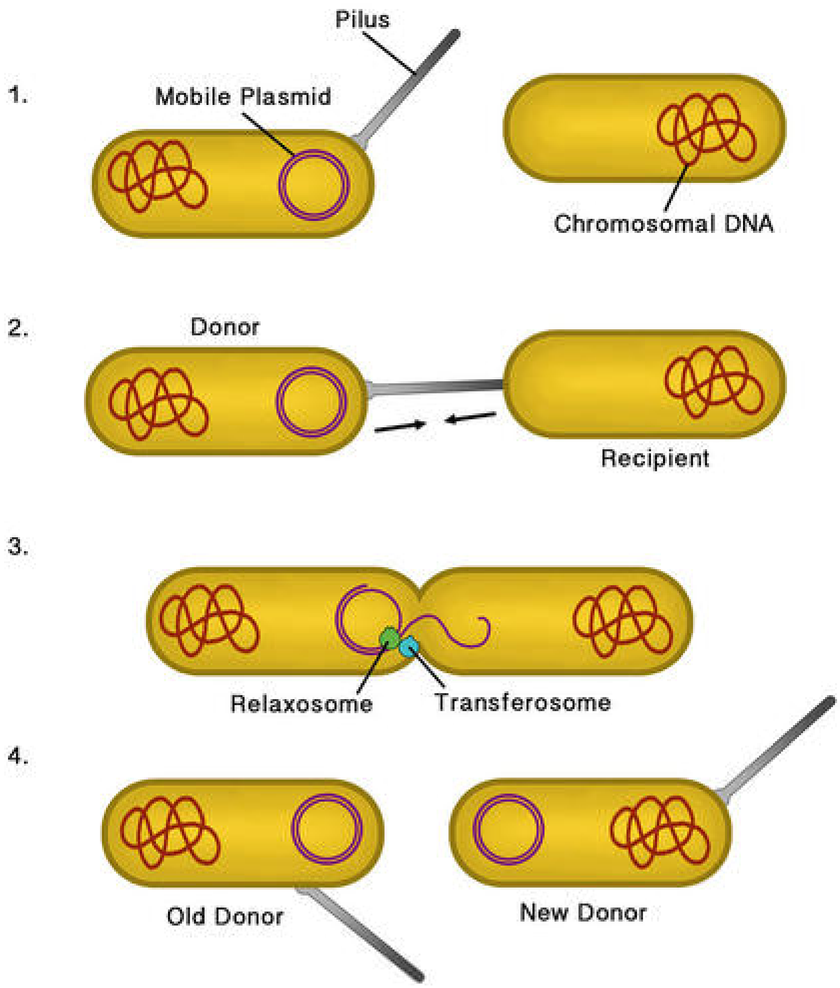
Genetic Transfer

In asexual reproduction, all the offspring are exactly the same. This is the biggest drawback of this type of reproduction. Why? Lack of genetic variation increases the risk of extinction.

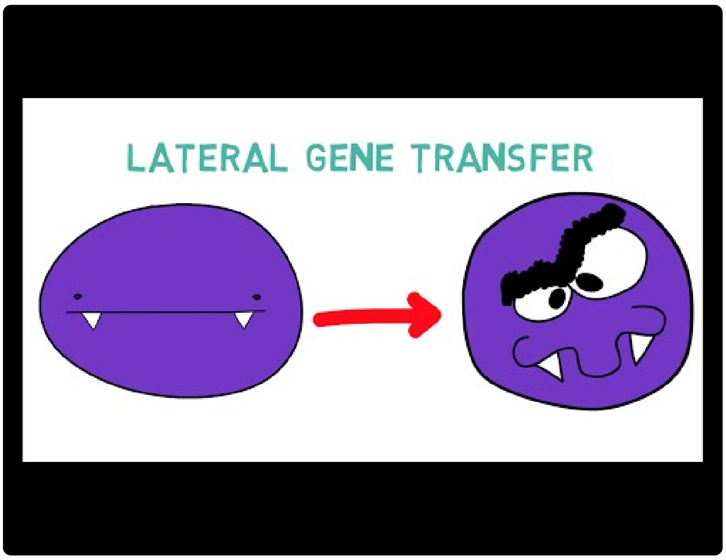
Without variety, there may be no organism that can survive a major change in the environment.

Prokaryotes have a different way to increase genetic variation. It's called **genetic transfer** or **bacterial conjugation**. It can occur in two ways. One way is when cells "grab" stray pieces of DNA from their environment. The other way is when cells directly exchange DNA (usually plasmids) with other cells. For example, as shown in **Figure** below, the donor cell makes a structure called an **F pilus**, or sex pilus. The F pilus attaches one cell to another cell. The membranes of the two cells merge and genetic material, usually a **plasmid**, moves into the recipient cell. Genetic transfer makes bacteria very useful in biotechnology. It can be used to create bacterial cells that carry new gene.



[Figure 3]

A flowchart showing bacterial conjugation. The donor cell makes a structure called an F pilus, or sex pilus. The F pilus attaches one cell to another cell. The membranes of the two cells merge and genetic material, usually a plasmid, moves into the recipient cell.



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Summary

- Prokaryotic cells grow to a certain size. Then they divide by binary fission. This is a type of asexual reproduction.
- Binary fission produces genetically identical offspring.
- Genetic transfer increases genetic variation in prokaryotes.

Review

1. Describe binary fission.
2. Why might genetic transfer be important for the survival of prokaryote species?
3. Under ideal conditions, in 2 hours how many bacteria can result from just a single bacterium? 5 hours?

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7.7 Bacteria and Humans

FlexBooks 2.0 > Biology For High School Diploma > Bacteria and Humans

Last Modified: May 16, 2021

[Figure 1]

Can you guess what organisms are pictured here?

Here's a clue: There are more organism like these than any other on Earth. Here's another clue: Each organism consists of a single cell without a nucleus.

The organisms are bacterium called *Salmonella*. If the word Salmonella rings a bell, that's probably because *Salmonella* causes human diseases such as food poisoning. Many other types of bacteria also cause human diseases. But not all bacteria are harmful to people. In fact, we could not survive without many of the trillions of bacteria that live in or on the human body.

Bacteria and Humans

Bacteria and humans have many important relationships. Bacteria make our lives easier in a number of ways. In fact, we could not survive without them. On the other hand, bacteria can also make us sick.

Benefits of Bacteria

Bacteria provide vital ecosystem services. They are important decomposer. They are also needed for the carbon and nitrogen cycles. There are billions of bacteria inside the human intestines. They help digest food, make vitamin, and play other important roles. Humans also use bacteria in many other ways, including:

- Creating products, such as ethanol and enzyme.

- Making drug, such as antibiotic and vaccine.
- Making biogas, such as methane.
- Cleaning up oil spills and toxic wastes.
- Killing plant pests.
- Transferring normal gene to human cells in gene therapy.
- Fermenting foods (see **Figure** below).

[Figure 2]

Fermented Foods. Fermentation is a type of respiration that doesn't use oxygen. Fermentation by bacteria is used in brewing and baking. It is also used to make the foods pictured here.

Bacteria and Disease

You have ten times as many bacteria as human cells in your body. Most of these bacteria are harmless. However, bacteria can also cause disease. Examples of bacterial diseases include tetanus, syphilis, and food poisoning. Bacteria may spread directly from one person to another. For example, they can spread through touching, coughing, or sneezing. They may also spread via food, water, or objects.

Another way bacteria and other pathogen can spread is by **vector**. A **vector** is an organism that spreads pathogens from host to host. Insects are the most common vectors of human diseases. **Figure** below shows two examples.

[Figure 3]

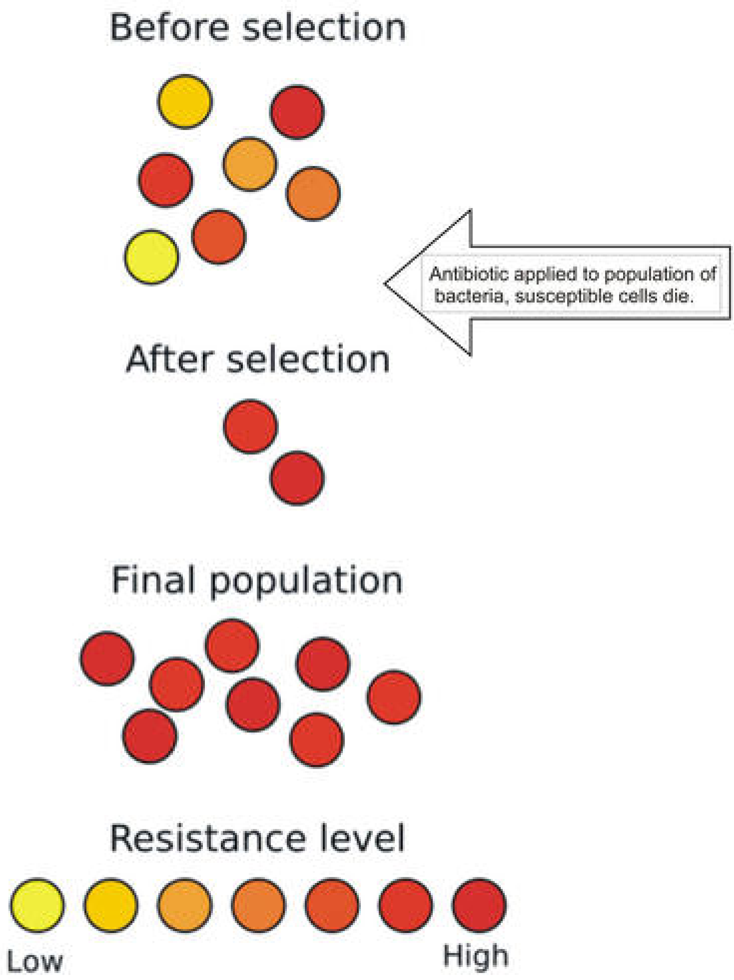
Bacterial Disease Vectors. Ticks spread bacteria that cause Lyme disease. Deerflies spread bacteria that cause tularemia.

Humans have literally walked into some new bacterial diseases. When people come into contact with wild population, they may become part of natural cycles of disease transmission. Consider Lyme disease. It's caused by bacteria that normally infect small, wild mammal, such as mice. A tick bites a mouse and picks up the bacteria. The tick may then bite a human who invades the natural habitat. Through the bite, the bacteria are transmitted to the human host.

Controlling Bacteria

Bacteria in food or water usually can be killed by heating it to a high temperature (generally, at least 74°C, or 165°F). Bacteria on many surfaces can be killed with chlorine bleach or other disinfectants. Bacterial infections in people can be treated with **antibiotic drugs**. For example, if you ever had "strep" throat, you were probably treated with an antibiotic.

Antibiotics have saved many lives. However, misuse and over-use of the drugs have led to **antibiotic resistance** in bacteria. **Figure** below shows how antibiotic resistance evolves. Some strains of bacteria are now resistant to most common antibiotics. These infections are very difficult to treat.



[Figure 4]

Evolution of Antibiotic Resistance in Bacteria. This diagram shows how antibiotic resistance evolves by natural selection.

Science Friday: Your Very Special Bacterial Cloud

There is a cloud surrounding you, formed by billions of bacteria that slough off your body with every movement you make. In this video by science Friday, researchers at the University of Oregon, revealed that they can detect and catalog this unique personal microbial cloud.

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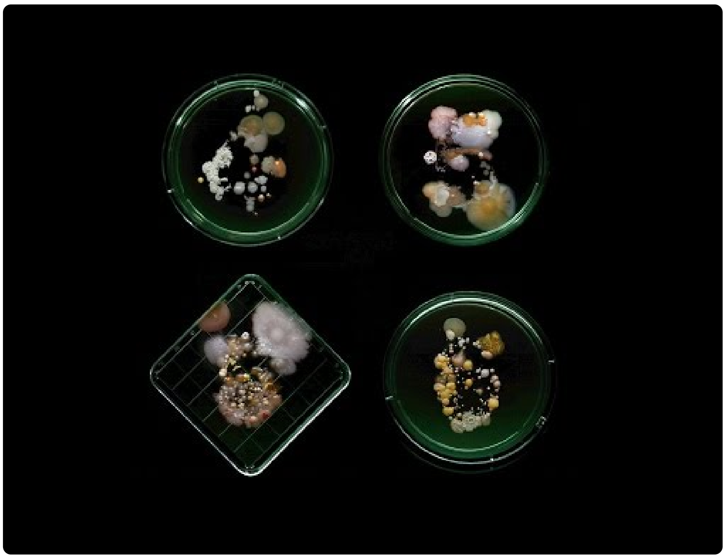
Science Friday: Subvisual Subway: The Art of New York City's Bacterial World

An urban legend states that "using the handrails on the subway is like shaking hands with 100 people." In this video by Science Friday, Craig Ward sampled the bacteria on subway lines around New York City to create striking and unconventional "portraits" of NYC commuters.



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Summary

- Bacteria and humans have many important relationships. Bacteria provide humans with a number of services. They also cause human diseases.

Review

1. How can bacteria cause disease?
2. List three benefits of bacteria.
3. How can bacteria be killed?

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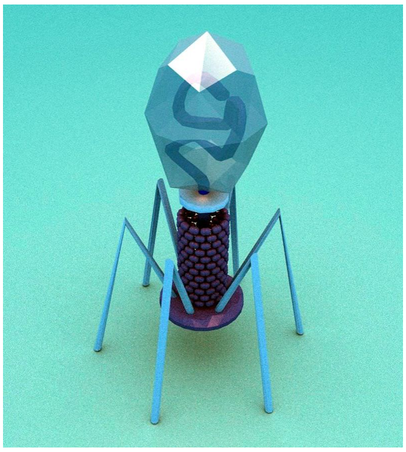
7.8 Viruses

FlexBooks 2.0 > Biology For High School Diploma > Viruses

Last Modified: Jul 04, 2019



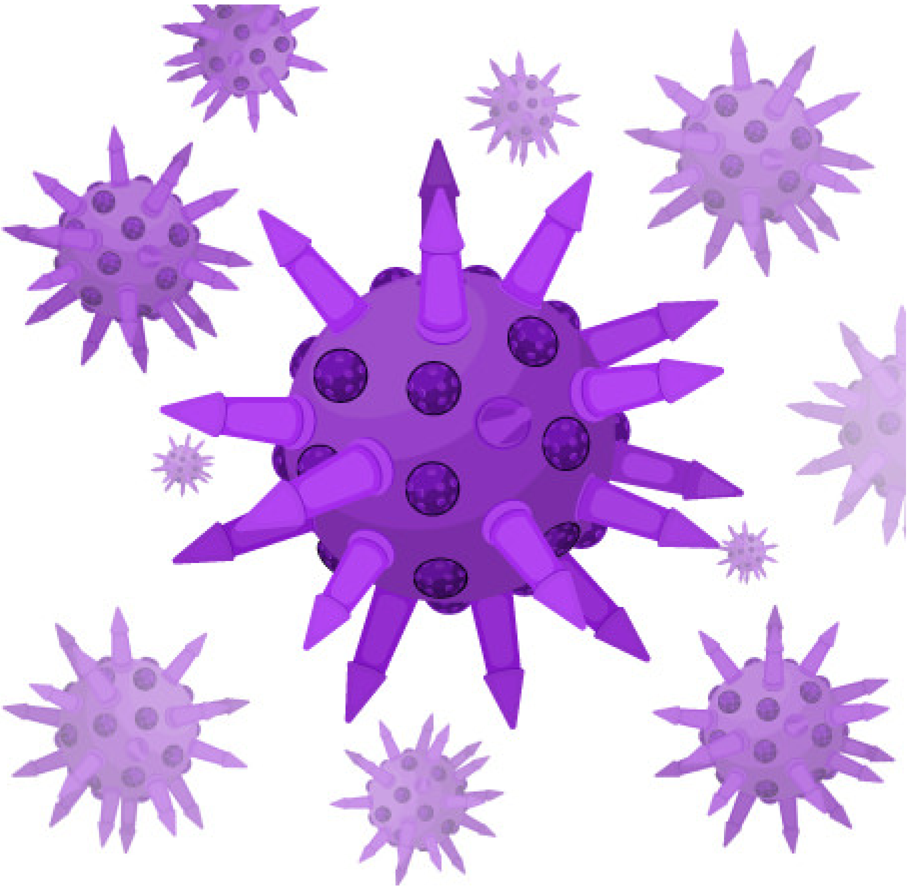
[Figure 1]

What is a virus? Is it even a living organism?

This alien-looking thing is a virus. But is it prokaryotic or eukaryotic? Or neither? Or both? A virus is essentially genetic material surrounded by protein. That's it. So, is a virus prokaryotic or eukaryotic? Or neither? Or both?

Viruses: Prokaryotes or Eukaryotes?

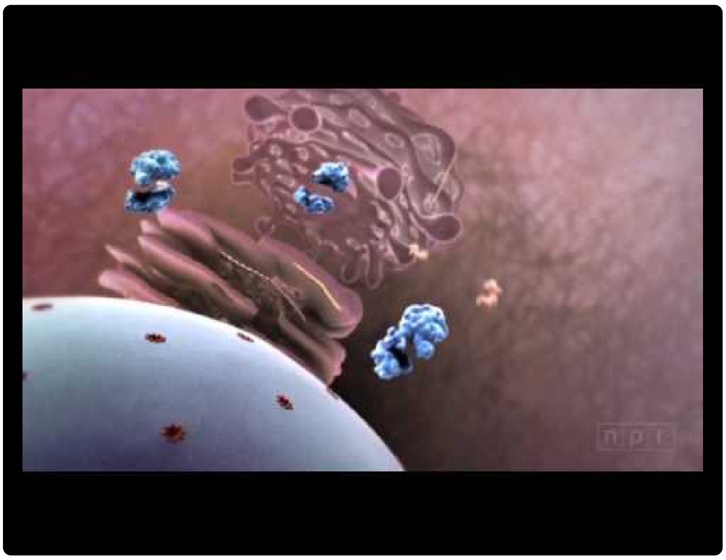
Viruses, like the one depicted in **Figure** below, are tiny particles that may cause disease. Human diseases caused by viruses include the common cold and flu. Do you think viruses are prokaryote or eukaryote? The answer may surprise you. Viruses are not cell at all, so they are neither prokaryotes nor eukaryotes.



[Figure 2]

Cartoon of a flu virus. The flu virus is a tiny particle that may cause illness in humans. What is a virus? Is it a cell? Is it even alive?

Viruses contain DNA but not much else. They lack the other parts shared by all cells, including a plasma membrane, cytoplasm, and ribosome. Therefore, viruses are not cells, but are they alive? All living things not only have cells; they are also capable of reproduction. Viruses cannot reproduce by themselves. Instead, they infect living hosts, and use the hosts' cells to make copies of their own DNA. Viruses also do not have their own metabolism or maintain homeostasis. For these reasons, most scientists do not consider viruses to be living things.



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Further Reading

Virus Characteristics

Summary

- Viruses are neither prokaryotic or eukaryotic.
- Viruses are not made of cells. Viruses cannot replicate on their own.
- Most scientists do not consider viruses to be living.

Review

1. What is a virus?
2. Explain why viruses are not considered to be living.
3. Is a virus made of cells?
4. Can a virus reproduce?
5. Does a virus metabolize?

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7.9 Virus Characteristics

FlexBooks 2.0 > Biology For High School Diploma > Virus Characteristics

Last Modified: Jul 04, 2019

[Figure 1]

This virus looks alive, but is it?

Notice the big **virus**. He (or she) looks very angry. But actually viruses cannot be a "he" or a "she" - or big either. In fact, viruses are the smallest things. Much smaller than most prokaryote. We also cannot say that viruses are the smallest living things or organism, as viruses do not meet the definition of living or of an organism.

Characteristics of Viruses

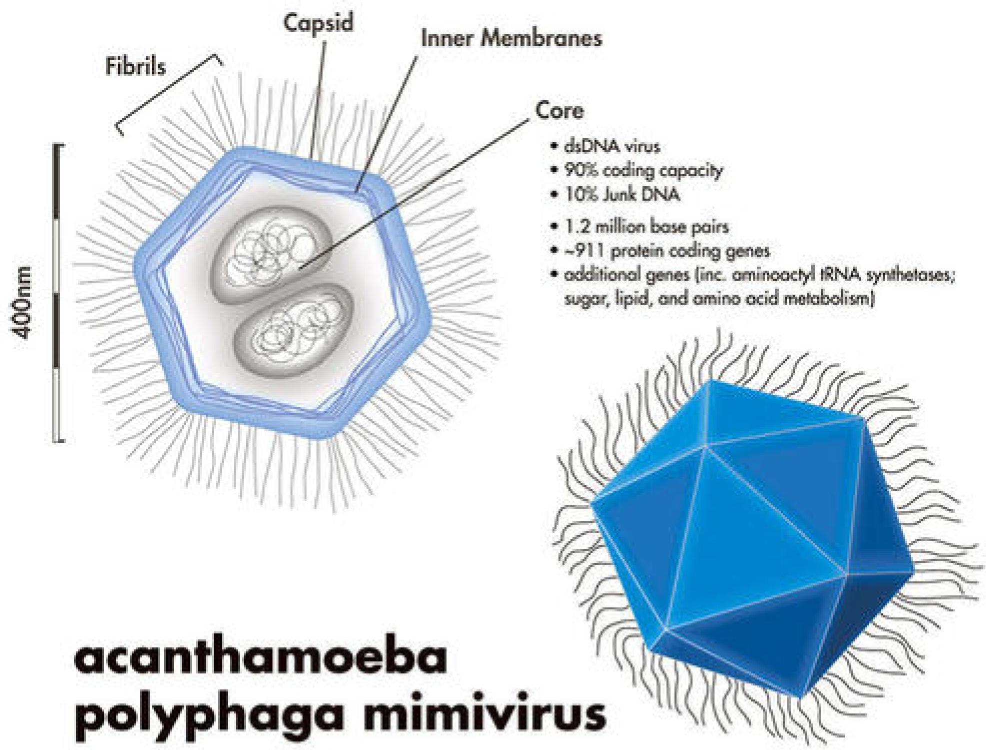
Which of the three domain of life do viruses belong to? None. Why? Viruses are usually considered to be nonliving. Viruses do not meet most of the criteria of life. They are not even made of cell.

A **virus** is a sub-microscopic particle that can infect living cells. Viruses are much smaller than prokaryotes, ranging in size from about 20–300 nanometers (nm), though some can be larger. Prokaryotes are typically 0.5–5.0 micrometers (μm) in length. For example, if a virus was about the size of three soccer balls lying side-by-side, then a prokaryote would be about the size of soccer field.

An individual virus is called a **virion.** It is a tiny particle much smaller than a prokaryotic cell. Because viruses do not consist of cells, they also lack cell membrane, cytoplasm, ribosome, and other cell organelle. Without these structures, they are unable to make protein or even reproduce on their own. Instead, they must depend on a host cell to synthesize their proteins and to make copies of themselves. Although viruses are not classified as living things, they share two important traits with living things. They have genetic material, and they can evolve. This is why the classification of viruses has been controversial. It calls into question just what it means to be alive. What do you think? How would you classify viruses?

The study of viruses is known as **virology** and people who study viruses are known as **virologist**. Viruses infect and live inside the cells of living organisms. When viruses infect the cells of their host, they may cause disease. For example, viruses cause AIDS (Acquired immune deficiency syndrome), influenza (flu), chicken pox, and the common cold. Therapy is sometimes difficult for viral diseases. antibiotic have no effect on viruses and only a few antiviral drug are available for some diseases. One of the best ways to prevent viral diseases is with a **vaccine**, which produces **immunity**. But vaccines are available for only a few diseases.

Mimivirus, shown in the **Figure** below, is the largest known virus, with a diameter of 400 nm. Protein filaments measuring 100 nm stick out from the surface of the virus, which increases the diameter of the virus to about 600 nm. This is bigger than a small bacterial cell. The virus appears hexagonal under an electron microscope; the viral shape is icosahedral (having 20 faces or sides).



[Figure 2]

The largest known virus, called mimivirus, is so large that scientists first mistook it for a bacterium. It was first discovered in amoeba, in 1992, and was identified as a virus in 2003. Scientists believe that mimivirus may cause certain types of pneumonia in humans. The core contains DNA, with the majority of the DNA in genes, and only 10% DNA of unknown function ("junk" DNA).

Replication

Viruses can replicate only by infecting a host cell. They cannot reproduce on their own. Viruses are not cells; they are a strand of genetic material within a protective protein coat called a **capsid**. They infect a wide variety of organisms, including both eukaryote and prokaryotes. Once inside the cell, they use the cell's ATP, ribosomes, enzyme, and other cellular parts to replicate.

Habitats

Viruses can be found almost anywhere there is life, including living within prokaryotes. A **phage** is a virus that infects prokaryotes. Phages are estimated to be the most widely distributed and diverse entities in the biosphere, even more numerous than prokaryotic organisms. Phages can be found everywhere their hosts are found, such as in soil, in the intestine of animal, or seawater. Up to 10^9 virions have been found in a milliliter of seawater, and up to 70 percent of marine bacterium may be infected by phages. They are also found in drinking water and in some foods, including fermented vegetables and meats, where they control the growth of bacteria.

Summary

- Viruses are tiny particles, smaller than prokaryotic cells.
- Viruses are not cells and cannot replicate without help, but they have nucleic acids and can evolve.

Review

1. What is a virus?
2. What are the two main components of a virus?
3. How do viruses differ from living things? How are they similar to living things?
4. Briefly describe how viruses depend on host cells.
5. What two characteristics of life are evident in viruses?
6. What is a phage?

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7.10 Virus Structure

FlexBooks 2.0 > Biology For High School Diploma > Virus Structure

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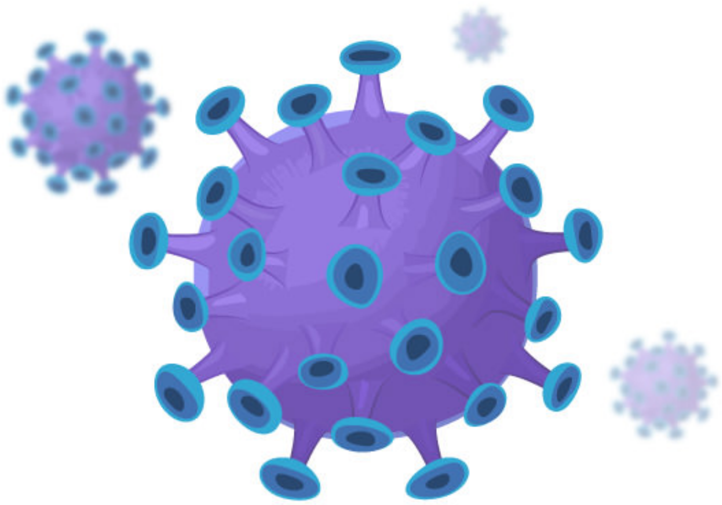


[Figure 1]

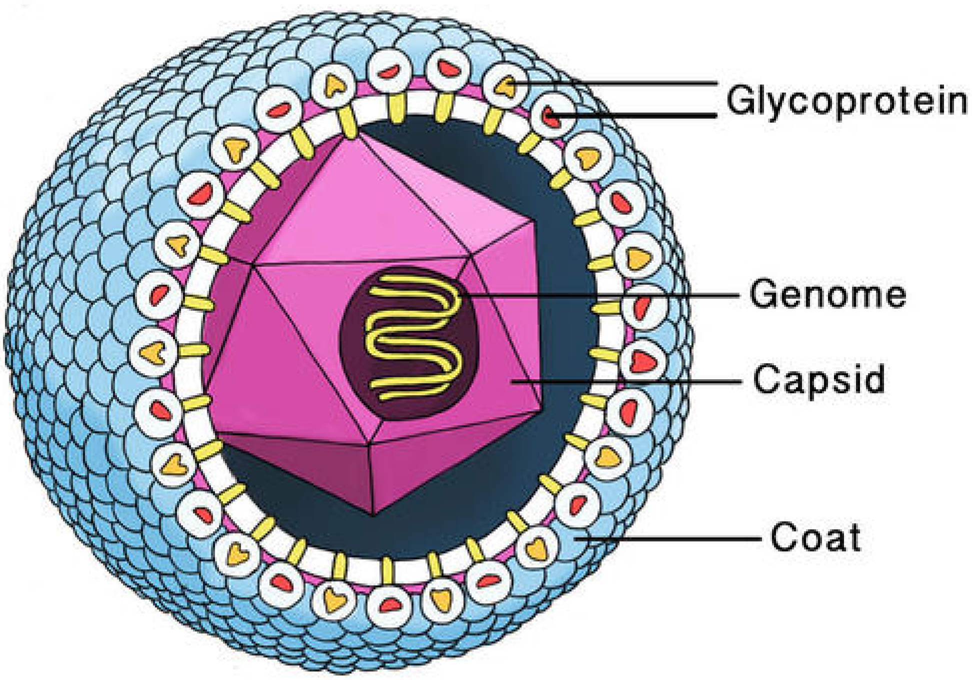
Is this a cell or a virus?

It is actually a representation of the HIV virus, the virus that causes AIDS. All the little "knobs" on the outside of the virus help to give the virus structure. And it is this structure that must be identified by a vaccine.

Structure of Viruses

Viruses vary in their structure. A virus particle consists of DNA or RNA within a protective protein coat called a **capsid.** The shape of the capsid may vary from one type of virus to another. The capsid is made from the proteins that are encoded by viral gene within their genome.

The shape of the capsid serves as one basis for classification of viruses. The capsid of the virus shown in **Figure** below is icosahedral. Virally coded proteins will self-assemble to form a capsid. Some viruses have an envelope of phospholipids and proteins. The envelope is made from portions of the host's cell membrane. It surrounds the capsid and helps protect the virus from the host's immune system. The envelope may also have receptor molecules that can bind with host cell. They make it easier for the virus to infect the cells.

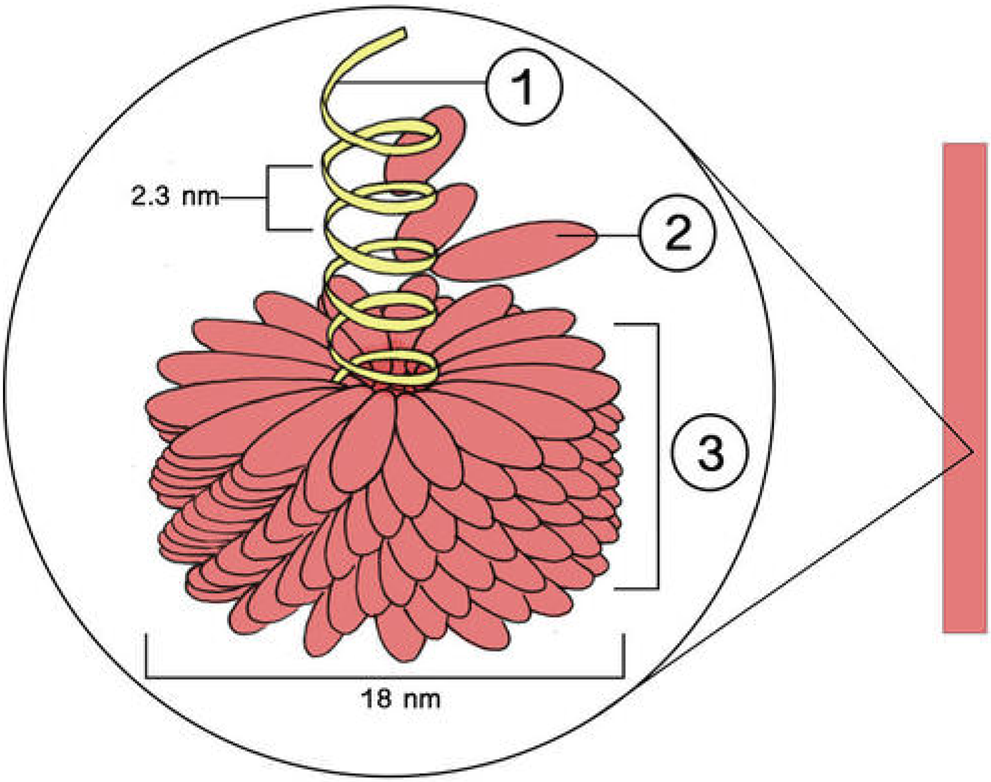


[Figure 2]

Diagram of a Cytomegalovirus. The capsid encloses the genetic material of the virus. The envelope which surrounds the capsid is typically made from portions of the host cell membranes (phospholipids and proteins). Not all viruses have a viral envelope.

Helical Viruses

helical capsid are made up of a single type of protein subunit stacked around a central axis to form a helical structure. The helix may have a hollow center, which makes it look like a hollow tube. This arrangement results in rod-shaped or filamentous virion. These virions can be anything from short and very rigid, to long and very flexible. The well-studied **tobacco mosaic virus** (TMV) is an example of a helical virus, as seen in the **Figure** below.

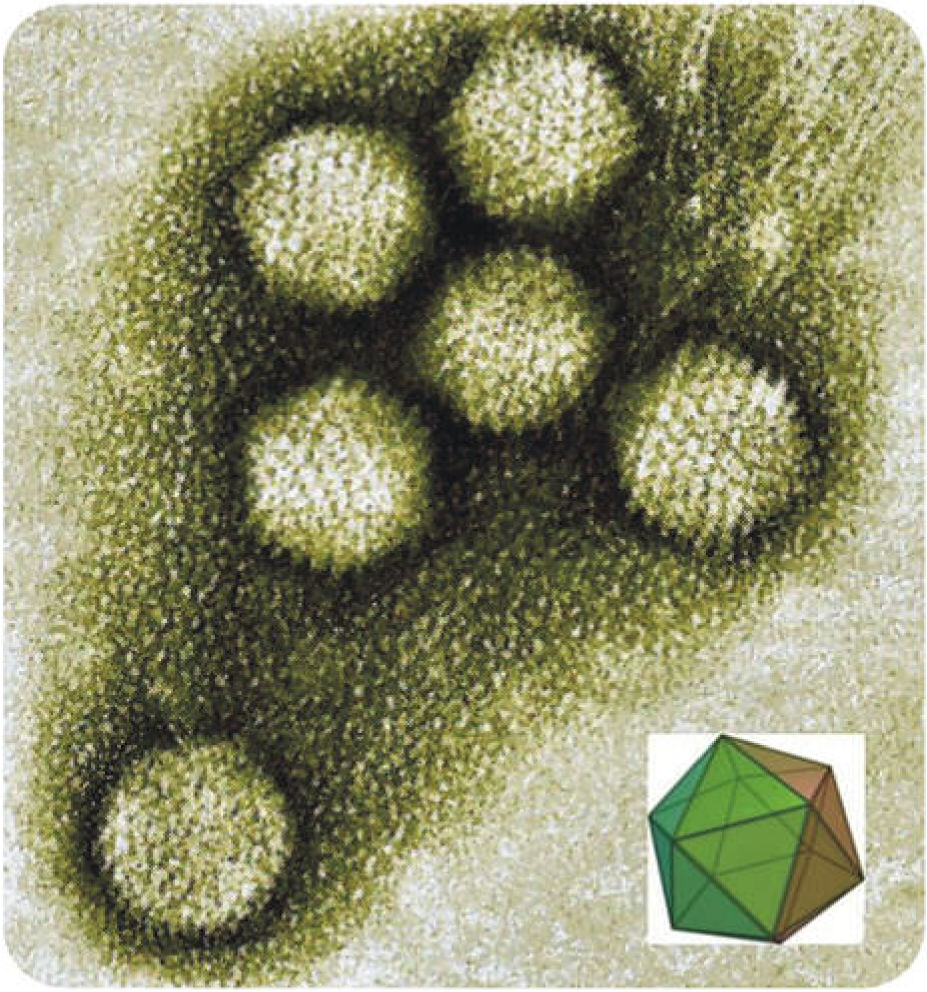


[Figure 3]

A helical virus, tobacco mosaic virus. Although their diameter may be very small, some helical viruses can be quite long, as shown here. 1. Nucleic acid; 2. Viral protein units, 3. Capsid. TMV causes tobacco mosaic disease in tobacco, cucumber, pepper, and tomato plants.

Icosahedral Viruses

icosahedral capsid symmetry gives viruses a spherical appearance at low magnification, but the protein subunits are actually arranged in a regular geometrical pattern, similar to a soccer ball; they are not truly spherical. An icosahedral shape is the most efficient way of creating a hardy structure from multiple copies of a single protein. This shape is used because it can be built from a single basic unit protein which is used over and over again. This saves space in the viral genome.

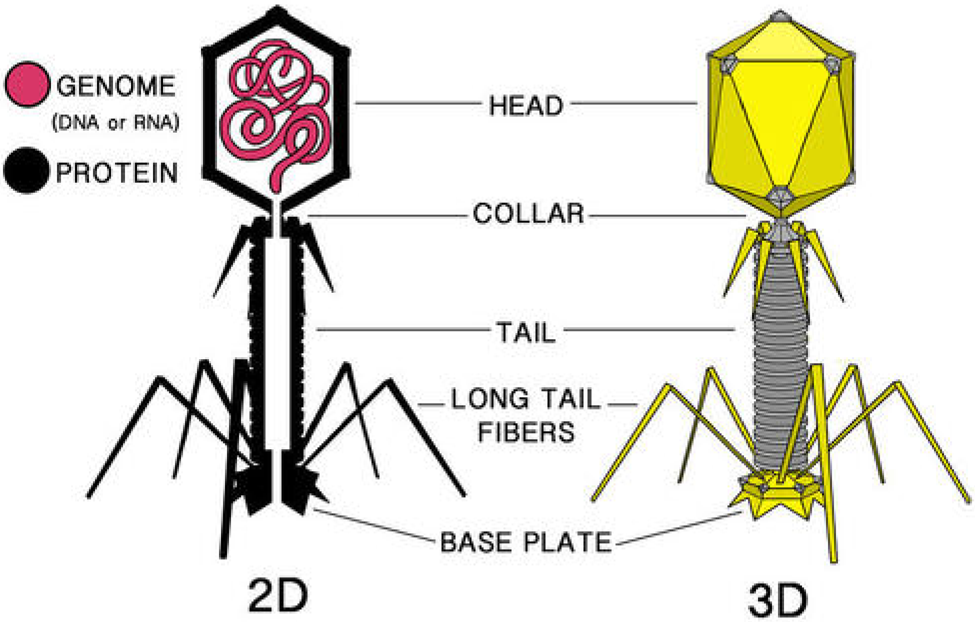


[Figure 4]

Adenovirus, an icosahedral virus. An icosahedron is a three-dimensional shape made up of 20 equilateral triangles. Viral structures are built of repeated identical protein subunits, making the icosahedron the easiest shape to assemble using these subunits.

Complex Viruses

complex virus possess a capsid which is neither purely helical, nor purely icosahedral, and which may have extra structures such as protein tails or a complex outer wall. Viral protein subunits will self-assemble into a capsid, but the complex viruses DNA also codes for proteins which help in building the viral capsid. Many phage viruses are complex-shaped; they have an icosahedral head bound to a helical tail. The tail may have a base plate with protein tail fibers. Some complex viruses do not have tail fibers.

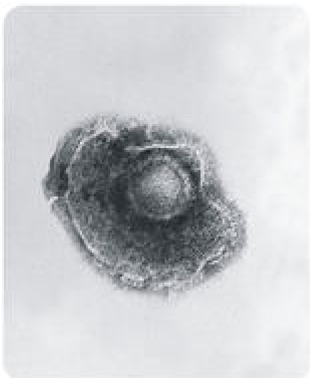


[Figure 5]

This “moon lander”-shaped complex virus infects *Escherichia coli* bacteria.

Enveloped Viruses

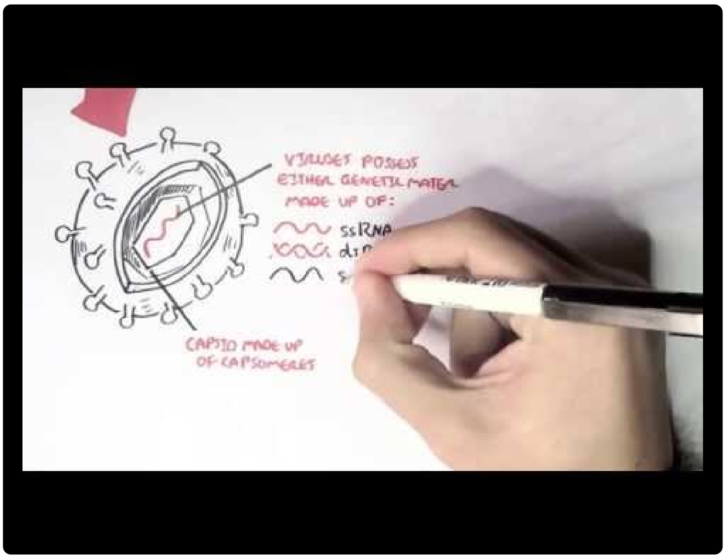
Some viruses are able to surround (envelop) themselves in a portion of the cell membrane of their host. The virus can use either the outer membrane of the host cell, or an internal membrane such as the nuclear membrane or endoplasmic reticulum. In this way the virus gains an outer lipid bilayer known as a **viral envelope**. This membrane is studded with proteins coded for by both the viral genome and the host genome. However, the lipid membrane itself and any carbohydrate present come entirely from the host cell. The influenza virus, HIV, and the varicella zoster virus (**Figure** below) are enveloped viruses.



[Figure 6]

An enveloped virus. Varicella zoster virus causes chicken pox and shingles.

The viral envelope can give a virus some advantages over other capsid-only viruses. For example, they have better protection from the host's immune system, enzyme and certain chemicals. The proteins in the envelope can include glycoproteins, which act as receptor molecules. These receptor molecules allow host cells to recognize and bind the virions, which may result in easier uptake of the virion into the cell. Most enveloped viruses depend on their envelopes to infect cells. However, because the envelope contains lipids, it makes the virus more susceptible to inactivation by environmental agents, such as detergents that disrupt lipids.



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Summary

- Viruses have different shapes. They can be cylindrical, icosahedral, complex, or enveloped.

Review

1. Describe variation in capsid shape in viruses.
2. Compare the structures of a prokaryote and a virus. If you prefer, you may draw a diagram of each and label the different parts of each structure.

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7.11 Virus Classification

FlexBooks 2.0 > Biology For High School Diploma > Virus Classification

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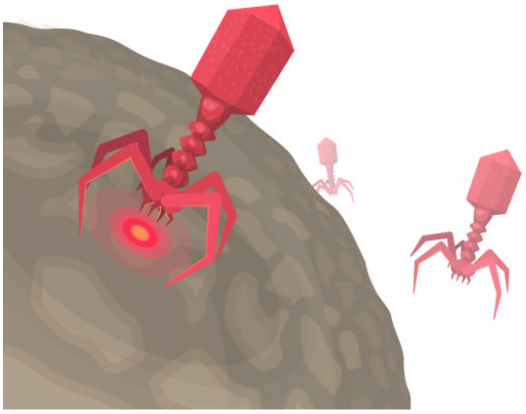


[Figure 1]

How are viruses classified?

In part by their shape. This picture represents a bacteriophage, a virus that infects bacterium. Notice the distinctive shape. This virus has a complex shape.

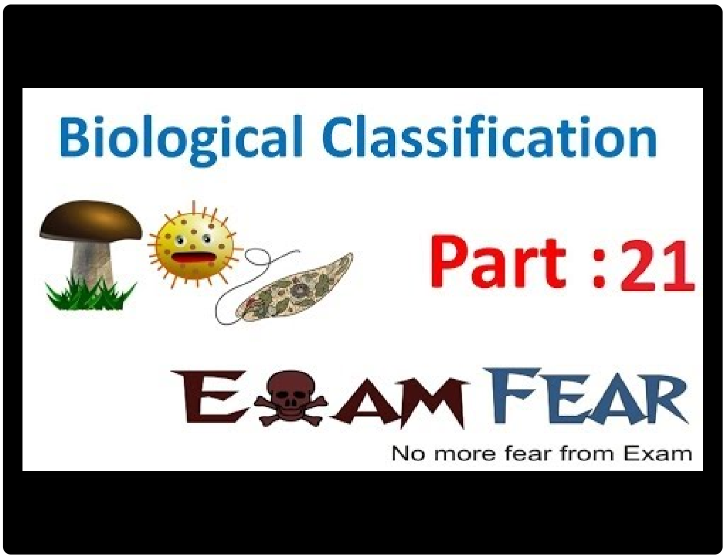
Classification of Viruses

Like the classification systems for cellular organism, virus classification is the subject of ongoing debate. This is largely due to the nature of viruses, which are not living organisms by the classic definition, but neither are they necessarily non-living. Therefore, viruses do not fit neatly into the biological classification system of cellular organisms, as plants and animal do.

Virus classification is based mainly on characteristics of the viral particles, including the **capsid** shape, the type of nucleic acid (DNA or RNA, double stranded (ds) or single stranded (ss)) within the capsid, the process of replication, their host organisms, or the type of disease they cause. The **Table** below lists characteristics such as capsid shape, presence of an envelope, and the diseases the viruses can cause.

Viruses

Virus Family	Virus	Envelope	Capsid shape	Nucleic Acid	Disease
Adenoviruses	Adenovirus	No	Icosahedral	dsDNA	upper respiratory infections
Parvoviruses	Parvovirus	No	Icosahedral	ssDNA	fifth disease, Canine parvovirus
Herpesviruses	Herpes simplex virus, Varicella zoster virus, Epstein Barr virus	Yes	Icosahedral	dsDNA	Herpes, chicken pox, shingles, infectious mononucleosis
Hepadnaviruses	hepatitis B virus	Yes	Icosahedral	dsDNA	Hepatitis B
Reoviruses	Rotavirus	No	Icosahedral	dsRNA	gastroenteritis
retrovirus	HIV, HTLV-I	Yes	Complex	ssRNA	HIV/AIDS, leukemia
Orthomyxoviruses	influenza viruses	Yes	Helical	ssRNA	Influenza (flu)
Rhabdoviruses	Rabies virus	Yes	Helical	ssRNA	Rabies
Coronaviruses	Corona virus	Yes	Complex	ssRNA	Common cold, severe acute respiratory syndrome (SARS)
Cystoviruses	Cystovirus	Yes	Icosahedral	dsRNA	Infects *Pseudomonas* bacteria



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Summary

- Viruses can be classified on the basis of capsid shape, presence or absence of an envelope, and type of nucleic acid.

Review

1. Describe how viruses are classified.
2. What is the difference between viruses in the Herpesvirus family and the Retrovirus family?

3. What are the four types of nucleic acid that may be present in a virus?
4. Give an example of a disease caused by a member of the Orthomyxoviruses.
5. Give an example of a disease caused by a retrovirus.

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7.12 Virus Origin

FlexBooks 2.0 > Biology For High School Diploma > Virus Origin

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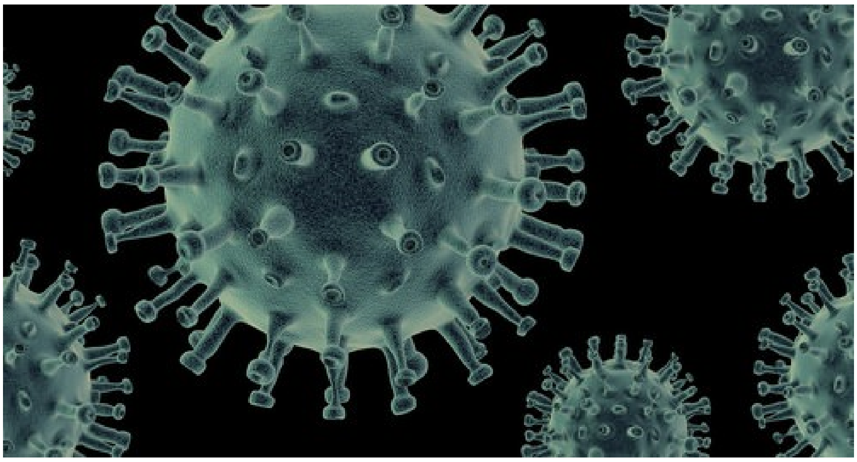


[Figure 1]

Can you "discover" something without actually seeing it?

Well, yes you can, and that's precisely how virus were discovered. Viruses are much smaller than bacterium, so special microscopes are needed to see them, but the existence of viruses was known prior to the development of these special microscopes.

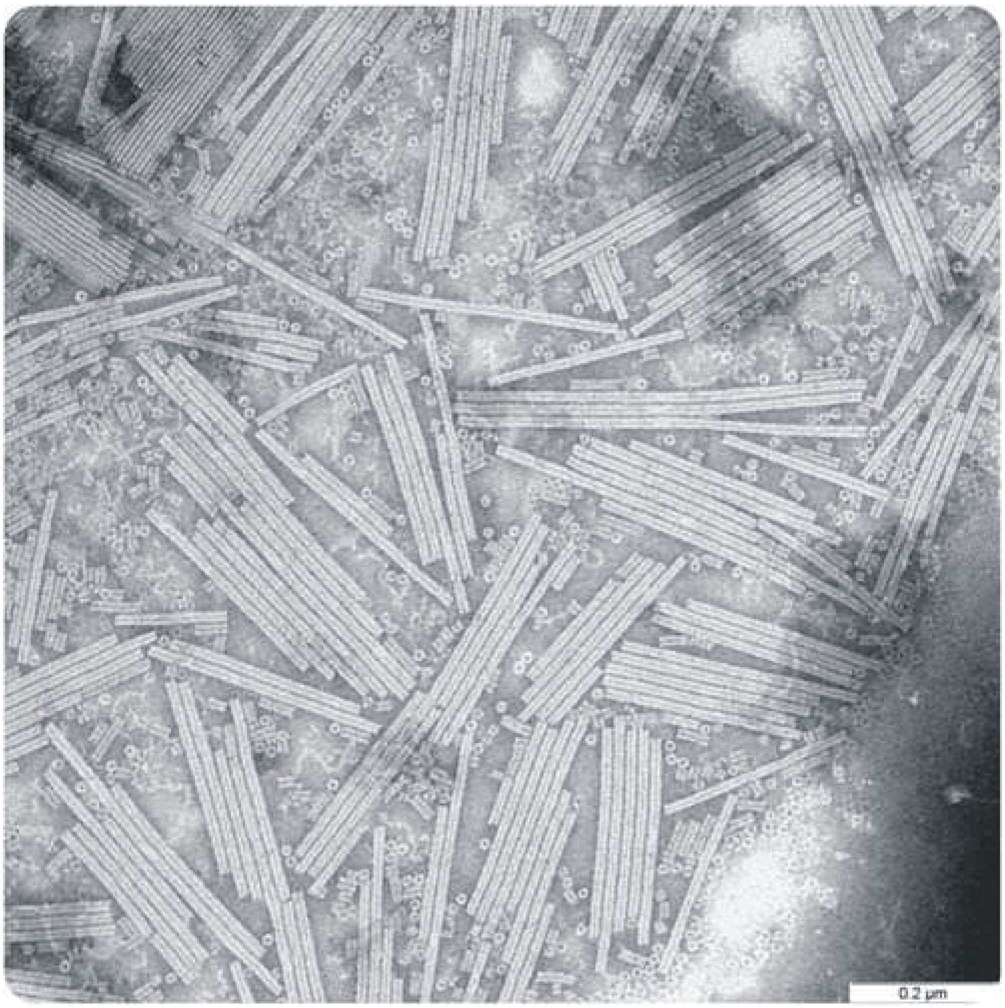
Discovery and Origin of Viruses

Viruses are so small that they can be seen only with an electron microscope. Before electron microscopes were invented, scientists knew viruses must exist. How did they know? They had demonstrated that particles smaller than bacteria cause disease.

Discovery of Viruses

Researchers used special filters to remove bacteria from tissue that were infected. If bacteria were causing the infection, the filtered tissues should no longer be able to make other organism sick. However, the filtered tissues remained infective. This meant that something even smaller than bacteria was causing the infection.

Scientists did not actually see viruses for the first time until the 1930s. That's when the **electron microscope** was invented. The **tobacco mosaic virus** shown in the **Figure** below was the first one to be seen. In 1915, English bacteriologist Frederick Twort discovered **bacteriophage**, the viruses that attack bacteria. He noticed tiny clear spots within bacterial colonies, and hypothesized that something was killing the bacteria.



[Figure 2]

Tobacco Mosaic Virus. This tobacco mosaic virus was the first virus to be discovered. It was first seen with an electron microscope in 1935.

Origin of Viruses

Where did viruses come from? How did the first viruses arise? The answers to these questions are not known for certain. Several hypothesis have been proposed. The two main hypotheses are stated below. Both may be valid and explain the origin of different viruses.

- Small viruses started as runaway pieces of nucleic acid that originally came from living cell such as bacteria.
- Large viruses were once parasitic cells inside bigger host cells. Over time, gene needed to survive and reproduce outside host cells were lost.

Summary

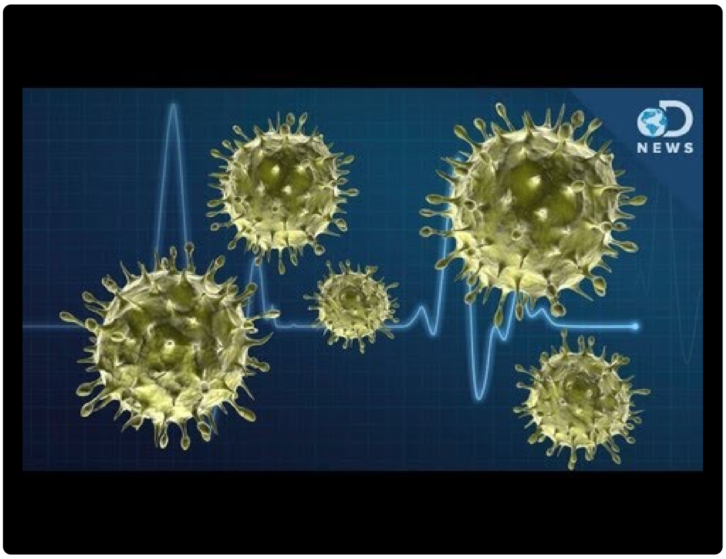
- Viruses were assumed to exist before they were first seen with an electron microscope in the 1930s.

- Multiple hypotheses for viral origins have been proposed.

Review

1. Why did scientists think viruses must exist even before they ever saw them with an electron microscope?
2. State two hypotheses for the origin of viruses.
3. What allowed scientists to see a virus for the first time?

Resources



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7.13 Virus Replication

FlexBooks 2.0 > Biology For High School Diploma > Virus Replication

Last Modified: Jul 04, 2019

[Figure 1]

Notice the viruses sitting on the bacteria?

Why is the virus sitting here? Remember, viruses are not living. So how do they replicate?

Replication of Viruses

population of viruses do not grow through cell division because they are not cell. Instead, they use the machinery and metabolism of a host cell to produce new copies of themselves. After infecting a host cell, a virion uses the cell's ribosome, enzyme, ATP, and other components to replicate. Viruses vary in how they do this. For example:

- Some **RNA virus** are translated directly into viral protein in ribosomes of the host cell. The host ribosomes treat the viral RNA as though it were the host's own mRNA.
- Some DNA virus are first transcribed in the host cell into viral mRNA. Then the viral mRNA is translated by host cell ribosomes into viral proteins.

In either case, the newly made viral proteins assemble to form new virions. The virions may then direct the production of an enzyme that breaks down the host cell wall. This allows the virions to burst out of the cell. The host cell is destroyed in the process. The newly released virus particles are free to infect other cells of the host.

Replication of RNA Viruses

An is a virus that has RNA as its **genetic material**. Their nucleic acid is usually single-stranded RNA, but may be double-stranded RNA. Important human pathogenic RNA viruses include the severe acute respiratory syndrome (SARS) virus, influenza virus, and Hepatitis C virus. animal RNA viruses can be placed into different groups depending on their type of replication.

- Some RNA viruses have their genome used directly as if it were mRNA. The viral RNA is translated directly into new viral proteins after infection by the virus.
- Some RNA viruses carry enzymes which allow their RNA genome to act as a template for the host cell to a form viral mRNA.
- **retrovirus** use DNA intermediates to replicate. **reverse transcriptase**, a viral enzyme that comes from the virus itself, converts the viral RNA into a complementary strand of DNA, which is copied to produce a double stranded molecule of viral DNA. This viral DNA is then transcribed and translated by the host machinery, directing the formation of new virions. Normal transcription involves the synthesis of RNA from DNA; hence, reverse transcription is the *reverse* of this process. This is an exception to the central dogma of molecular biology.

Replication of DNA Viruses

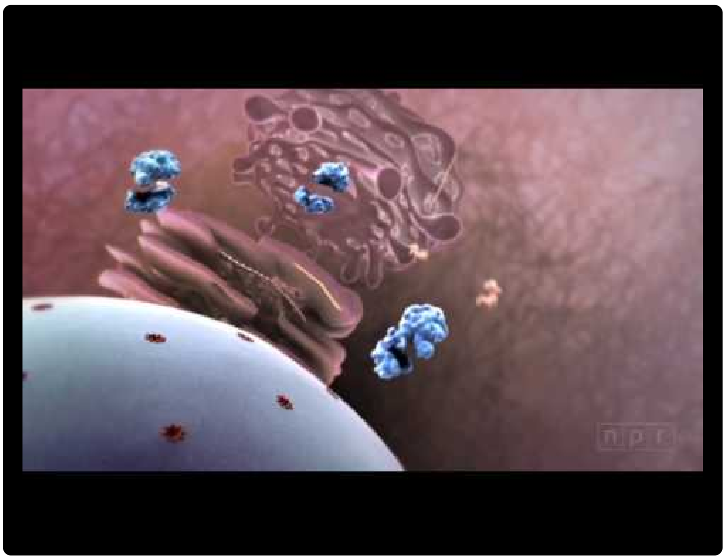
A is a virus that has DNA as its genetic material and replicates using a DNA-dependent DNA polymerase. The nucleic acid is usually double-stranded DNA but may also be single-stranded DNA. The DNA of DNA viruses is transcribed into mRNA by the host cell. The viral mRNA is then translated into viral proteins. These viral proteins then assemble to form new viral particles.

Reverse-Transcribing Viruses

A **reverse-transcribing virus** is any virus which replicates using reverse transcription, the formation of DNA from an RNA template. Some reverse-transcribing viruses have genomes made of single-stranded RNA and use a DNA intermediate to replicate. Others in this group have genomes that have double-stranded DNA and use an RNA intermediate during genome replication. The retroviruses, as mentioned above, are included in this group, of which HIV is a member. Some double-stranded DNA viruses replicate using reverse transcriptase. The hepatitis B virus is one of these viruses.

Bacteriophages

bacteriophage are viruses that infect bacterium. They bind to surface receptor molecules of the bacterial cell and then their genome enters the cell. The protein coat does not enter the bacteria. Within a short amount of time, in some cases, just minutes, bacterial polymerase starts translating viral mRNA into protein. These proteins go on to become either new virions within the cell, helper proteins which help assembly of new virions, or proteins involved in cell lysis. Viral enzymes aid in the breakdown of the cell membrane. With some phage, just over twenty minutes after the phage infects the bacterium, over three hundred phages can be assembled and released from the host.



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Summary

- After infecting a host cell, a virus uses the cell's machinery and metabolism to produce new copies of itself.

Review

1. In general terms, describe viral replication.
2. Describe how DNA viruses replicate.
3. What are reverse-transcribing viruses?

Report Content Errors

7.14 Viral Disease

FlexBooks 2.0 > Biology For High School Diploma > Viral Disease

Last Modified: Aug 25, 2021

[Figure 1]

Viral or bacterial?

Doesn't look like fun. The flu is caused by an influenza virus. And usually a slightly different virus every season.

Viruses and Human Disease

Viruses cause many human diseases. In addition to the flu and HIV, viruses cause rabies, measles, diarrheal diseases, hepatitis, polio, cold sores and other diseases (see **Figure** below). Viral diseases range from mild to fatal. One way viruses cause disease is by causing host cell to burst open and die. Viruses may also cause disease without killing host cells. They may cause illness by disrupting homeostasis in host cells.

[Figure 2]

Cold Sore. Cold sores are caused by a herpes virus.

Some viruses live in a dormant state inside the body. This is called **latency**. For example, the virus that causes chicken pox may infect a young child and cause the short-term disease chicken pox. Then the virus may remain latent in nerve cells within the body for decades. The virus may re-emerge later in life as the disease called shingles. In shingles, the virus causes painful skin rashes with blisters (see **Figure** below).

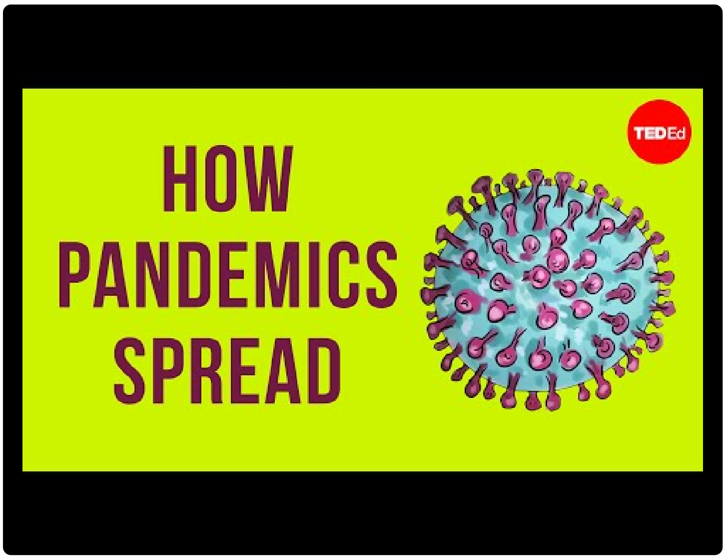
[Figure 3]

Shingles. Shingles is a disease caused by the same virus that causes chicken pox.

Some viruses can cause cancer. For example, human papillomavirus (HPV) causes cancer of the cervix in females. hepatitis B virus causes cancer of the liver. A viral cancer is likely to develop only after a person has been infected with a virus for many years.

The Flu

Influenza, or flu, is a contagious respiratory illness caused by influenza viruses. Influenza spreads around the world in seasonal **epidemic**. An **epidemic** is an outbreak of a disease within a population of people during a specific time. Every year in the United States, about 200,000 people are hospitalized and 36,000 people die from the flu. Flu pandemics can kill millions of people. A **pandemic** is an epidemic that spreads through human populations across a large region (for example a continent), or even worldwide. Three influenza pandemics occurred in the 20th century and killed tens of millions of people, with each of these pandemics being caused by the appearance of a new strain of the virus. Most influenza strains can be inactivated easily by disinfectants and detergents.



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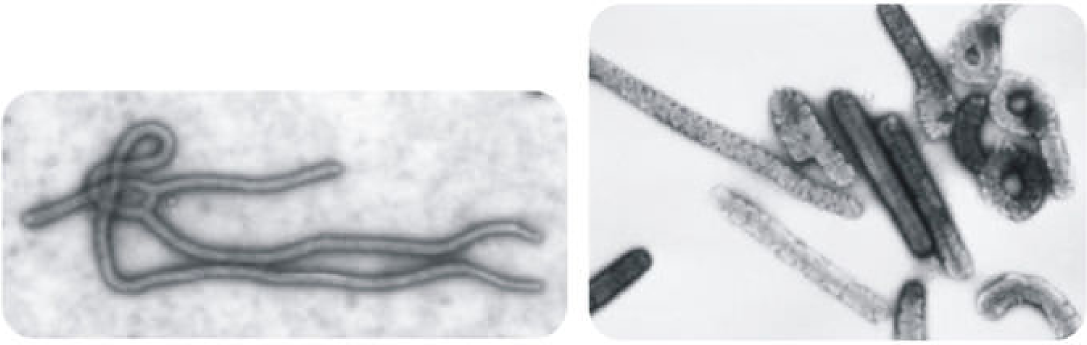
Emerging Viral Diseases

Modern modes of transportation allow more people and products to travel around the world at a faster pace. They also open the airways to the transcontinental movement of infectious disease vector. One example of this occurring is **West Nile Virus**, which scientists believe was introduced to the United States by an infected air traveler. With the use of air travel, people are able to go to foreign lands, contract a disease and not have any symptoms of illness until they get home, possibly exposing others to the disease along the way.

Often, new diseases result from the spread of an existing disease from animal to humans. A disease that can be spread from animals to humans is called a **zoonosis**. When a disease breaks out, scientists called **epidemiologist** investigate the outbreak, looking for its cause. Epidemiologists are like detectives trying to solve a crime. The information epidemiologists learn is important to understand the pathogen, and help prevent future outbreaks of disease.

A deadly strain of avian flu virus named H5N1 has posed the greatest risk for a new influenza pandemic since it first killed humans in Asia in the 1990s. The virus is passed from infected bird to humans. Fortunately, the virus has not mutated to a form that spreads easily between people.

Several lethal viruses that cause viral hemorrhagic fever have been discovered, two of which are shown in the **Figure** below. Ebola outbreaks have been limited mainly to remote areas of the world. However, they have gained extensive media attention because of the high mortality rate—23 percent to 90 percent—depending on the strain. The primary hosts of the viruses are thought to be apes in west central Africa, but the virus has also been isolated from bats in the same region.



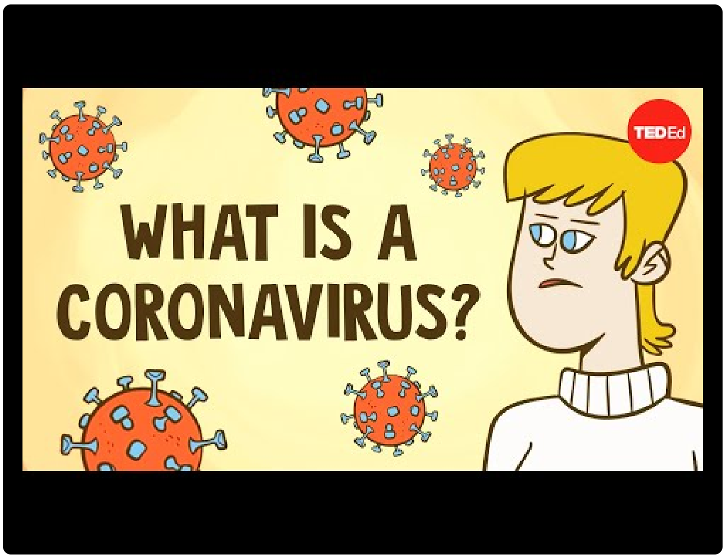
[Figure 4]

The Ebola virus (left), and Marburg virus (right), are viruses that cause hemorrhagic fevers that can cause multiple organ failure and death.

Ebola is a rare and deadly disease caused by infection with a strain of Ebola virus. The 2014 Ebola epidemic affected multiple countries in West Africa, including Guinea, Sierra Leone and Liberia. Ebola is spread through direct contact with blood and body fluids of a person infected by and already showing symptoms of Ebola. Ebola is not spread through the air, water, food, or mosquitoes.

People get exposed to new and rare zoonoses when they move into new areas and encounter wild animals. For example, **severe acute respiratory syndrome** (**SARS**) is a respiratory disease which is caused by the SARS coronavirus. An outbreak in China in 2003 was linked to the handling and consumption of wild civet cats sold as food in a market. In 2005, two studies identified a number of SARS-like coronaviruses in Chinese bats. It is likely that the virus spread from bats to civets, and then to humans.

A novel type of coronavirus was discovered in 2019, first in China and then globally. The novel virus is named Severe Acute Respiratory Syndrome - 2 (SARS-CoV-2). The disease itself is referred to as coronavirus disease 2019 (COVID-19).



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Summary

- Viruses cause many human diseases by killing host cells or disturbing their homeostasis.
- Viruses are not affected by antibiotics. Several viral diseases can be treated with antiviral drugs or prevented with vaccines.
- Several emerging viral diseases exist: West Nile Virus, Ebola, SARS, and COVID-19.

Explore More

Explore More I

Use the resource below to answer the questions that follow.

- Which is better: Soap or hand sanitizer?: https://www.youtube.com/watch?v=x7KKkElpyKQ

https://flexbooks.ck12.org/flx/render/embeddedobject/274270

1. What is the outer surface of the coronavirus that causes COVID-19 made of?
2. What are amphiphiles? Which biological molecules do they resemble?
3. Distinguish between how hand sanitizer versus soap and water disrupt the outer membrane of the coronavirus that causes COVID-19.
4. Is hand sanitizer or soap and water better to use to prevent the spread of COVID-19?
5. What are the benefits to using soap and water to prevent the spread of COVID-19?

Explore More II

Use the resource below to answer the questions that follow.

- U.S. Mortality: Death Certificates Listing Pneumonia, Influenza, and COVID-19:
  - Animated GIF: https://www.cdc.gov/coronavirus/2019-ncov/covid-data/images/us-mortality-graph-animated-may72020.gif
  - Static Image: https://www.cdc.gov/coronavirus/2019-ncov/covid-data/images/us-mortality-graph-may72020.jpg

1. The peak percent of deaths is observed as a result of what disease(s)?
2. What might you infer about the disease(s) that are causing the percent of deaths at this peak?
3. The graph indicates a peak in the percent of deaths ending the week of April 11, 2020. During this time in the US (March 2020 - May 2020), widespread stay-at-home policies were put into place with strict social distancing guidelines. According to the data provided, how do you think these measures impacted the percent of deaths during this time?

Review

1. How do viruses cause human disease?
2. What is an epidemic? Why can the flu be considered an epidemic?
3. What is latency? Give an example of a virus that undergoes this process.

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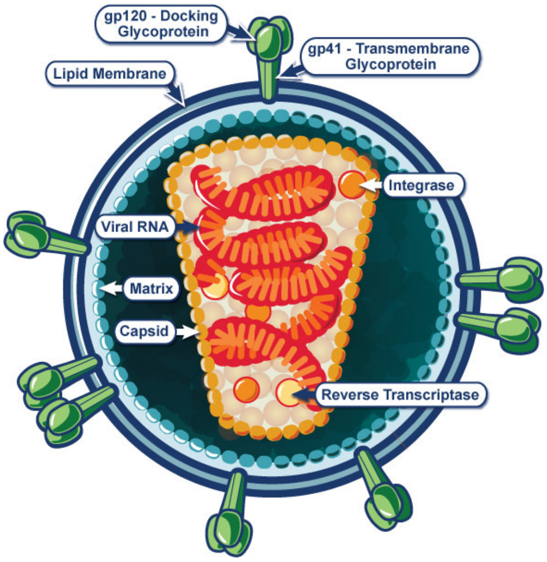
7.15 HIV

FlexBooks 2.0 > Biology For High School Diploma > HIV

Last Modified: Jul 04, 2019



[Figure 1]

Why is the shape of the virus important?

The AIDS virus. One of the most devastating viruses known. Why? Notice the intricate anatomy of the virus, both inside and outside. It is the constant changing of those outside markers that make producing a vaccine against this virus difficult.

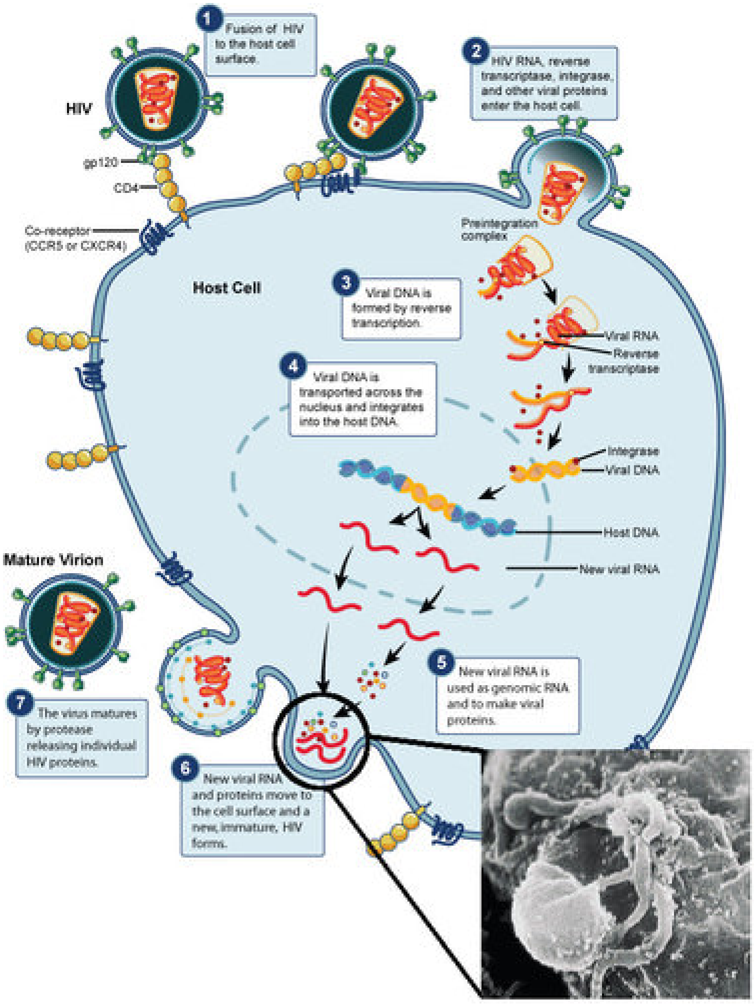
HIV

The **human immunodeficiency virus** (**HIV**) is the virus that causes **acquired immunodeficiency syndrome** (**AIDS**). Most researchers believe that the HIV originated in sub-Saharan Africa during the 20th century. HIV is transmitted by sexual contact and by contact with infected bodily fluids, such as blood, semen, breast milk, and vaginal secretions. It is also passed from mother to fetus. HIV is now a **pandemic**, with an estimated (as of 2008) 38.6 million people now living with the disease worldwide. It is estimated that AIDS has killed more than 25 million people since it was first recognized in 1981.

HIV is the retrovirus that destroys the immune system. HIV primarily infects helper T cell (specifically $CD4^+$ T cells), macrophages, and dendritic cell. HIV infection leads to low levels of $CD4^+$ T cell because the virus directly kills infected cells and the infected T cells are also attacked by the immune system. The infection of a CD4 cell is shown in the **Figure** below. When $CD4^+$ numbers decline below a certain critical level, cell-mediated immunity is lost, and the body becomes more prone to opportunistic infections. HIV infections will be discussed further in the immune system concepts.

If left untreated, most HIV-infected individuals will develop AIDS. AIDS is a collection of symptoms and infections resulting from the damage to the immune system by HIV. Because the immune systems of people with AIDS are so weak, bacterium and viruses that do not normally cause disease in healthy people can easily cause disease in an AIDS patient. Opportunistic infections associated with AIDS include:

- **pneumocystis pneumonia**: a form of pneumonia caused by a fungus.
- tuberculosis (TB), caused by the *Mycobacterium tuberculosis* bacteria.
- lung infections caused by Mycobacterium other than tuberculosis (MOTT).
- **Kaposi's sarcoma**: a type of cancer that is caused by Kaposi's sarcoma-associated herpesvirus (KSHV).



[Figure 2]

Lifecycle of HIV. The image at bottom right is an SEM of HIV budding from cultured lymphocyte. The many round bumps on the cell surface are sites of assembly and budding of virions.

An HIV Infection

An HIV infection of a CD4 cell can be summarized as follows:

1. First, the viral particle attaches to the CD4 receptor and other associated receptors on the cell membrane. The **viral envelope** then fuses with the cell membrane, and the viral capsid moves into the cell.
2. Once the viral capsid enters the cell, **reverse transcriptase** frees the single-stranded RNA from the viral protein and copies it into a complementary strand of DNA. This process of reverse transcription is error-prone and it is during this step that mutation may occur. Such mutations may cause drug resistance.
3. The reverse transcriptase then makes a complementary DNA strand to form a double-stranded viral DNA (vDNA).

4. The vDNA is then moved into the cell nucleus. The integration of the viral DNA into the host cell's genome is carried out by another viral enzyme called **integrase**. This integrated viral DNA may then lie dormant, during the latent stage of the HIV infection. Clinical latency for HIV can vary between two weeks and 20 years.
5. To actively produce viruses, certain cellular transcription factors need to be present. These transcription factors are plentiful in activated T cells. This means that those cells most likely to be killed by HIV are those currently fighting infection. The virus DNA is transcribed to mRNA which then leads to new virus protein and genome production.
6. Viral particles are assembled inside the cell and then exit the cell by budding. The virus gets its viral envelope from the cell's plasma membrane. The cycle begins again when the new particles infect another cell.

HIV infection is treated with a cocktail of several antiretroviral drug. The **antiretroviral drugs** prevent the virus from replicating and destroying more T cells, thus preventing the patients from developing AIDS. Treatment with antiretroviral drugs can dramatically increase the life expectancy of people with HIV.

https://flexbooks.ck12.org/flx/render/embeddedobject/170344

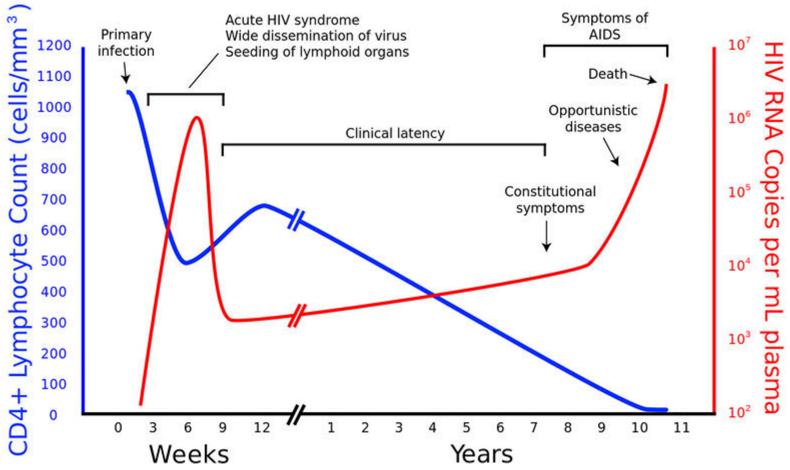
Summary

- HIV is the virus that causes AIDS. HIV destroys the immune system.
- Opportunistic infections lead to AIDS.

Review

1. Describe the relationship between HIV and AIDS.

The graph below shows the relationship between the number of HIV particles and CD4 lymphocyte counts over the course of an untreated HIV infection. Use the graph to answer the following questions:



[Figure 3]

2. How does the increase of the number of HIV particles relate to the path of the disease?

3. Outline what happens to the number of viruses and numbers of lymphocytes between three and six weeks after initial infection.

4. Can the development of AIDS symptoms be delayed? Explain your answer.

Report Content Errors

7.16 Virus Control

FlexBooks 2.0 > Biology For High School Diploma > Virus Control

Last Modified: Mar 10, 2020

[Figure 1]

What's the best part of going to the doctor?

Most people don't like having a shot at the doctor's office. But these are necessary. They protect you from some very dangerous virus.

Control of Viruses

People have been able to control the spread of viruses even before they knew they existed. In 1717, Mary Montagu, the wife of an English ambassador to the Ottoman Empire, observed local women inoculating their children against smallpox, a contagious viral disease that was often deadly. **inoculation** involves introducing a small amount of virus into a person's body to allow their body to build up **immunity** to the virus. This early smallpox inoculation involved putting smallpox crusts into the nostril of a healthy person.

Vaccines

Because viruses use the machinery of a host cell to reproduce and stay within them, they are difficult to get rid of without killing the host cell. **vaccine** were used to prevent viral infections long before the discovery of viruses. A **vaccine** is a mixture of antigenic material and other immune stimulant that will produce immunity to a certain pathogen or disease. The term "vaccine" comes from Edward Jenner's use of cowpox (*vacca* means cow in Latin), to immunize people against smallpox.

The material in the vaccine can either be weakened forms of a living pathogen or virus, dead pathogens (or inactivated viruses), purified material such as viral protein, or genetically engineered pieces of a pathogen. The material in the vaccine will cause the body to mount an immune response, so the person will develop **immunity** to the disease. Smallpox was the first disease people tried to prevent by purposely inoculating themselves with other types of infections such as cowpox. **vaccination** is an effective way of preventing viral infections. Vaccinations can be given in schools, shown in the **Figure** below, health clinics, and even at home. Their use has resulted in a dramatic decline in morbidity (illness) and mortality (death) associated with viral infections such as polio, measles, mumps, and rubella. Genetically engineered vaccines are produced through recombinant DNA technology. Most new vaccines are produced with this technology.

[Figure 2]

A young student receives a vaccine.

A worldwide vaccination campaign by the World Health Organization led to the eradication of smallpox in 1979. Smallpox is a contagious disease unique to humans and is caused by two *Variola* viruses. The eradication of smallpox was possible because humans are the only carriers of the virus. To this day, smallpox is the only human infectious disease to have been completely eradicated from nature. Scientists are hoping to eradicate polio next.

Antiviral Drugs

While people have been able to prevent certain viral diseases by vaccinations for many hundreds of years, the development of antiviral drug to treat viral diseases is a relatively recent development. **Antiviral drugs** are medications used specifically for treating the symptoms of viral infections. The first antiviral drug was **interferon**, a substance that is naturally produced by certain immune cells when an infection is detected. Over the past twenty years the development of antiretroviral drug (also known as antiretroviral therapy, or ART) has increased rapidly. This has been driven by the AIDS epidemic.

Like antibiotic, specific antivirals are used for specific viruses. They are relatively harmless to the host, and therefore can be used to treat infections. Most of the antiviral drugs now available are designed to help deal with HIV and herpes viruses. Antivirals are also available for the influenza viruses and the hepatitis B and C viruses, which can cause liver cancer.

Antiviral drugs are often imitation DNA building blocks which viruses incorporate into their genomes during replication. The life cycle of the virus is then halted because the newly synthesized DNA is inactive. Similar to antibiotics, antivirals are subject to drug resistance as the pathogens evolve to survive exposure to the treatment. HIV evades the immune system by constantly changing the amino acid sequence of the proteins on the surface of the virion. Researchers are now working to extend the range of antivirals to other families of **pathogens**.

Summary

- Several viral diseases can be treated with antiviral drugs or prevented with vaccines.

Review

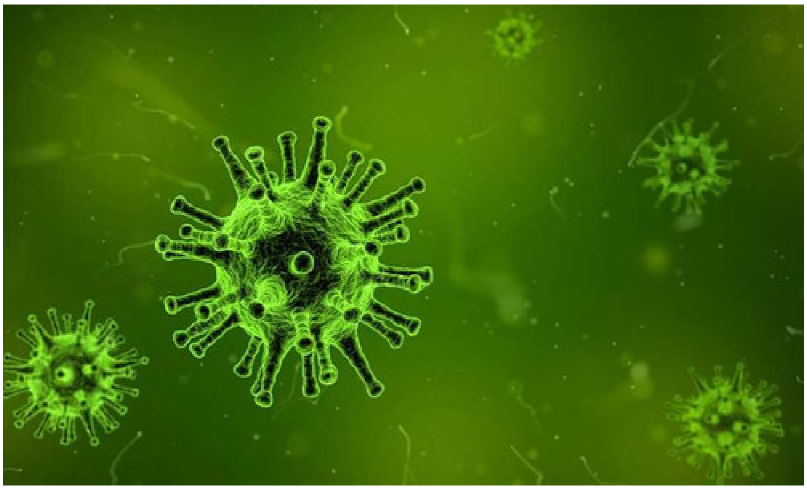
1. What is a vaccine?
2. Describe the relationship between vaccination and immunity.
3. What diseases can be controlled with vaccinations? List five.

Report Content Errors

7.17 Viruses in Research

FlexBooks 2.0 > Biology For High School Diploma > Viruses in Research

Last Modified: May 21, 2021



[Figure 1]

Can viruses be helpful, or just harmful?

virus are extensively used in research and medicine to both understand basic biology and to improve human health. Imagine having a tool that is able to inject its DNA into a host cell. The possibilities of using such a tool are endless. That tool would be a virus.

Viruses in Research

Viruses are an extremely important tool in the study of molecular and cellular biology. Since viruses infect cells by moving their genetic material into the host cell's nucleus, they are helpful in the investigation of the functions of cells. For example, the use of viruses in research has helped our understanding of the basics of molecular genetics, such as DNA replication, transcription, RNA processing, translation, protein transport, and immunology.

Viruses and Medicine

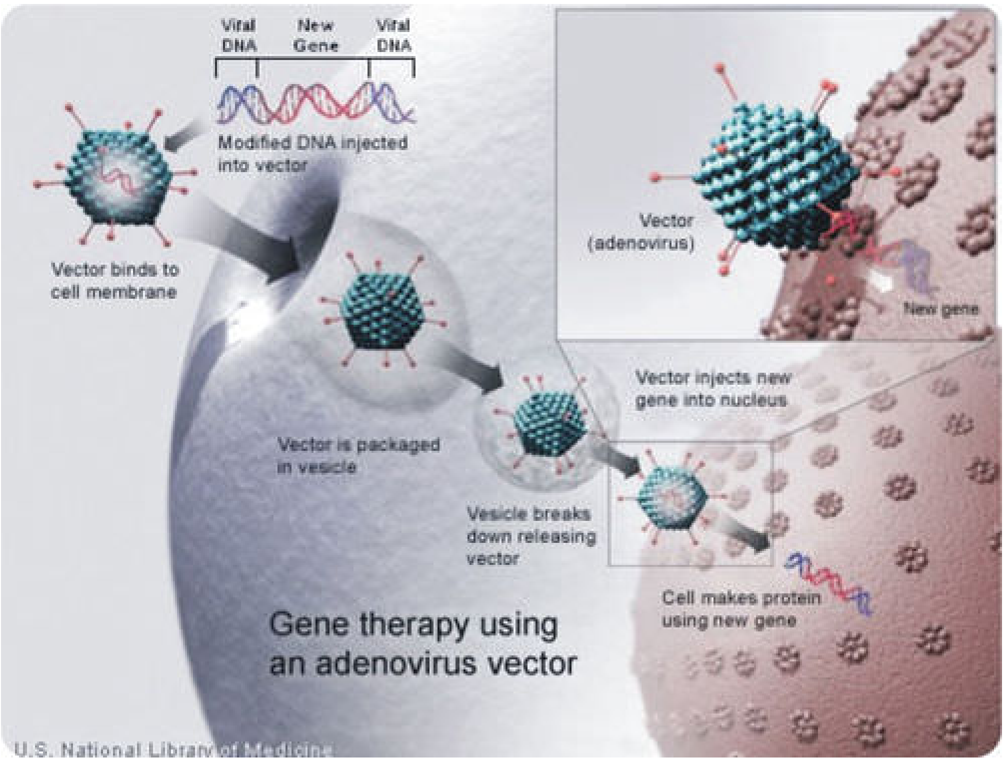
Geneticists often use viruses as vector to introduce gene into cells that they are studying. A **viral vector** is a tool commonly used by molecular biologists to place genetic material into cells. To be a useful viral vector, the virus is modified so that it will not cause disease, and it will infect only certain types of cells. **phage** are often used as vectors to genetically modify bacterium.

In a similar fashion, **viral therapy** uses viruses to genetically modify diseased cells and tissue. Viral therapy shows promise as a method of **gene therapy** and in the treatment of cancer. Gene therapy is the insertion of genes into a person’s cells and tissues to treat a disease. In the case of a genetic disease, the defective gene is replaced with a working gene. Although the technology is still new, it has been used with some success.

Scientists have focused on gene therapy for diseases caused by single-gene defects, such as cystic fibrosis, hemophilia, muscular dystrophy and sickle cell anemia. In gene therapy, the correct version of the gene is introduced to human cells by using a viral vector such as the adenovirus shown in the **Figure** below.

Phages have been used for over 60 years as an alternative to antibiotic in the former Soviet Union and Eastern Europe. They are seen as a hope against multi-drug-resistant strains of many bacteria because they can infect and kill these "superbugs". However, in the case of MRSA (Methicillin-resistant *Staphylococcus aureus*), a phage infecting the bacterium produces a toxin that makes the bacterium more virulent and difficult to contain.

Viruses that infect cancer cells are being studied for their use in cancer treatments. **oncolytic virus** are viruses that lyse and kill cancer cells. Some researchers are hoping to treat some cancers with these viruses.



[Figure 2]

Gene therapy using an Adenovirus vector. A new gene is inserted into an adenovirus vector, which is used to introduce the modified DNA into a human cell. If the treatment is successful, the new gene will get into the nucleus and into the target cell DNA to make a functional protein.

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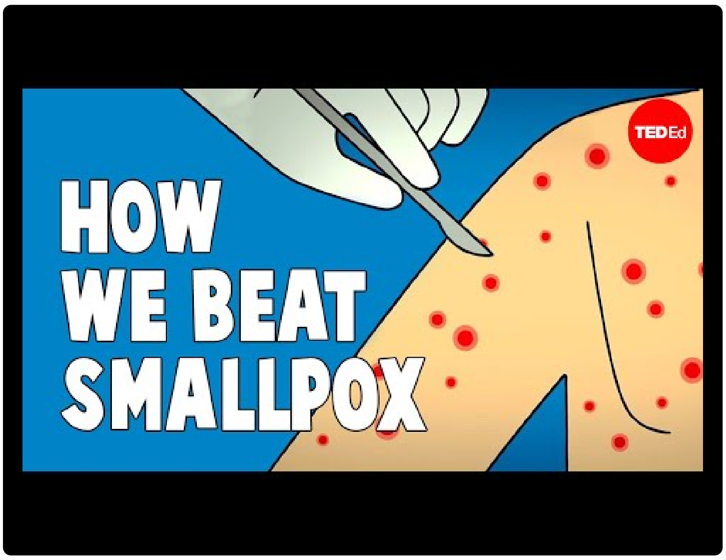
Summary

- Viruses are useful tools in scientific research and medicine.
- Viruses help us understand molecular biology. They are also used in gene therapy.

Review

1. Why are viruses especially useful tools for understanding molecular biology?
2. What have scientists learned by studying the viruses and their invasion of host cells?
3. What is a viral vector? Are they harmful?

Resources



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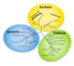	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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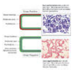
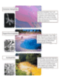
	**Credit:** Gram cell wall: User:JulianOnions/Wikimedia Commons; Gram-positive: JA Jernigan et al./Centers for Disease Control and Prevention; Gram-negative: William A. Clark/Centers for Disease and Control **Source:** Gram cell wall: http://commons.wikimedia.org/wiki/File:Gram-Cell-Wall.jpg; Gram-positive: http://www.cdc.gov/ncidod/EID/vol7no6/jerniganG2.htm; Gram-negative: http://commons.wikimedia.org/wiki/File:Bacillus_coagulans_01.jpg **License:** Public Domain
	**Credit:** From left to right, top to bottom: NASA; Tom Hilton; PMEL/National Oceanic and Atmospheric Administration; US Geological Survey; NASA; Environmental Protection Agency **Source:** From left to right, top to bottom: http://science.nasa.gov/science-news/science-at-nasa/2004/10sep_radmicrobe/; http://www.flickr.com/photos/tomhilton/4689387475/; http://www.pmel.noaa.gov/vents/nemo1999/images/bugtem.gif; http://wwwbrr.cr.usgs.gov/projects/GWC_chemtherm/; http://astrobiology.nasa.gov/articles/is-there-life-on-mars-ask-a-magnet/; http://water.epa.gov/polwaste/nps/acid_mne.cfm **License:** From left to right, top to bottom: Public Domain; CC BY 2.0; Public Domain; Public Domain; Public Domain; Public Domain
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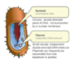
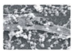
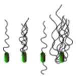
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Courtesy of Janice Carr/Centers for Disease Control and Prevention **Source:** http://commons.wikimedia.org/wiki/File:Staphylococcus_on_catheter.png **License:** Public Domain
	**Credit:** User:Adenosine/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Flagella.svg **License:** CC BY 3.0
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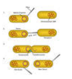	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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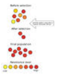
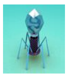
	**Credit:** User:Wykis/Wikimedia Commons, modified by CK-12 Foundation **Source:** http://commons.wikimedia.org/wiki/File:Antibiotic_resistance.svg **License:** Public Domain
	**Credit:** Oona Räisänen **Source:** https://commons.wikimedia.org/wiki/File:T4_rendered.jpg **License:** Public Domain
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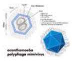	**Credit:** User:Xanthine/Wikipedia **Source:** http://commons.wikimedia.org/wiki/File:Mimivirus.jpg **License:** CC BY 2.5
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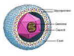
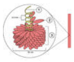
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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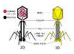
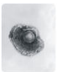
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Courtesy of Centers for Disease Control and Prevention/Dr. Erskine Palmer/B.G. Partin **Source:** http://commons.wikimedia.org/wiki/File:Varicella_%28Chickenpox%29_Virus_PHIL_1878_lores.jpg **License:** Public Domain
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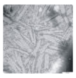	**Credit:** T. Moravec **Source:** http://commons.wikimedia.org/wiki/File:TMV.jpg **License:** Public Domain
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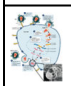
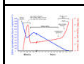
	**Credit:** Diagram: Courtesy of the NIAID; SEM image: Courtesy of CDC/C. Goldsmith, P. Feorino, E. L. Palmer, W. R. McManus **Source:** Diagram: http://www.niaid.nih.gov/topics/HIVAIDS/Understanding/Biology/pages/hivreplicationcycle.aspx; SEM image: http://commons.wikimedia.org/wiki/File:HIV-budding.jpg **License:** Public Domain
	**Credit:** User:Sigve/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Hiv-timecourse_copy.svg **License:** Public Domain
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CHAPTER 8

Protists and Fungi

Chapter Outline

8.1 Protists

FlexBooks 2.0 > Biology For High School Diploma > Protists

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[Figure 1]

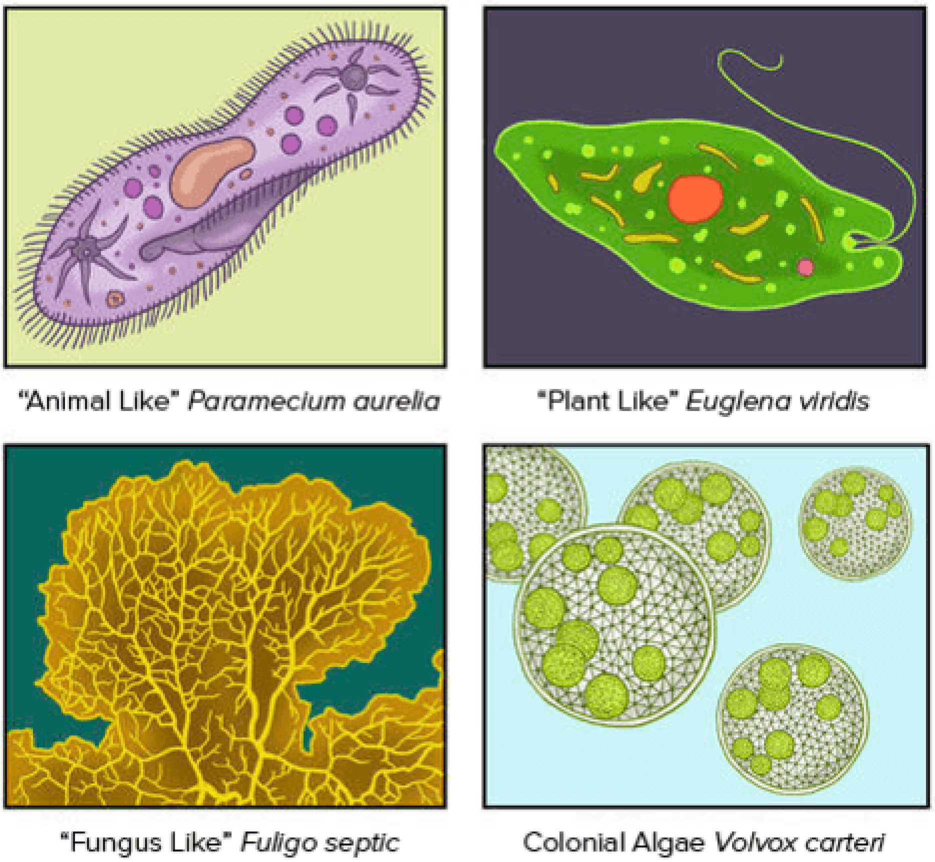
prokaryote or eukaryote?

This organism consists of a single cell with several flagellum. Is it a prokaryote, such as a bacterium? Actually, it's larger than a prokaryotic cell, and it also has a nucleus. Therefore, this organism belongs to the domain Eukarya, the domain that includes humans. This particular eukaryote is one of the smallest, simplest organisms in the domain, called a protist. It's scientific name is *Giardia lamblia.* As a human parasite, it can make us sick.

Kingdom Protista

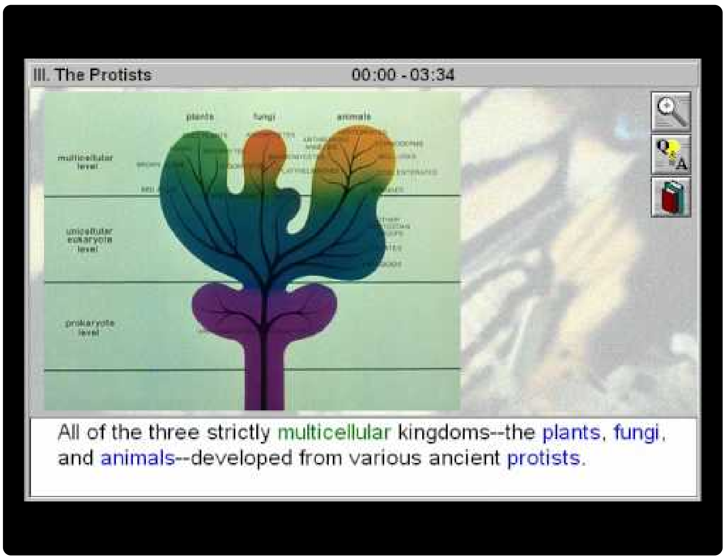
Protists are a group of all the eukaryotes that are not fungus, animal, or plants. As a result, it is a very diverse group of organisms. The eukaryotes that make up this kingdom, Kingdom **Protista**, do not have much in common besides a relatively simple organization. Protists can look very different from each other. Some are tiny and unicellular, like an **amoeba**, and some are large and multicellular, like **seaweed**. However, multicellular protists do not have highly specialized tissue or organ. This simple cellular-level organization distinguishes protists from other eukaryotes, such as fungi, animals, and plants. There are thought to be between 60,000 and 200,000 protist species, and many have yet to be identified. Protists live in almost any environment that contains liquid water. Many protists, such as the **alga**, are photosynthetic and are vital primary producer in ecosystem. Other protists are responsible for a range of serious human diseases, such as **malaria** and sleeping sickness.

The term protista was first used by Ernst Haeckel in 1866. Protists were traditionally placed into one of several groups based on similarities to a plant, animal, or fungus: the animal-like **protozoan**, the plant-like **protophyta** (mostly algae), and the fungus-like **slime mold** and **water molds**. These traditional subdivisions, which were largely based on non-scientific characteristics, have been replaced by classifications based on **phylogenetics** (evolutionary relatedness among organisms). However, the older terms are still used as informal names to describe the general characteristics of various protists.



[Figure 2]

Protists range from single-celled amoebas to multicellular seaweed. Protists may be similar to animals, plants, or fungi.



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Summary

- Kingdom Protista includes all eukaryotes that are not animals, plants, or fungi.
- Kingdom Protista is very diverse. It consists of both single-celled and multicellular organisms.

Review

1. What are protists?
2. How are unicellular protists and multicellular protists similar?
3. How are protists classified? What are the main categories of protists?

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8.2 Protist Evolution

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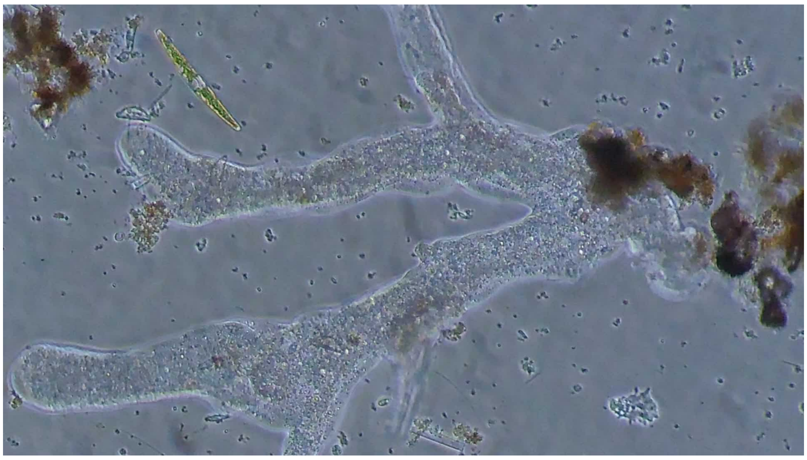


[Figure 1]

What's the difference between a bacterium and a simple protist?

Were simple protist the first eukaryotic organism to evolve? Probably. A protist is a eukaryote, so each cell has a nucleus. Otherwise, simple protists, like the Paramecium and amoeba, can be fairly similar to bacterium.

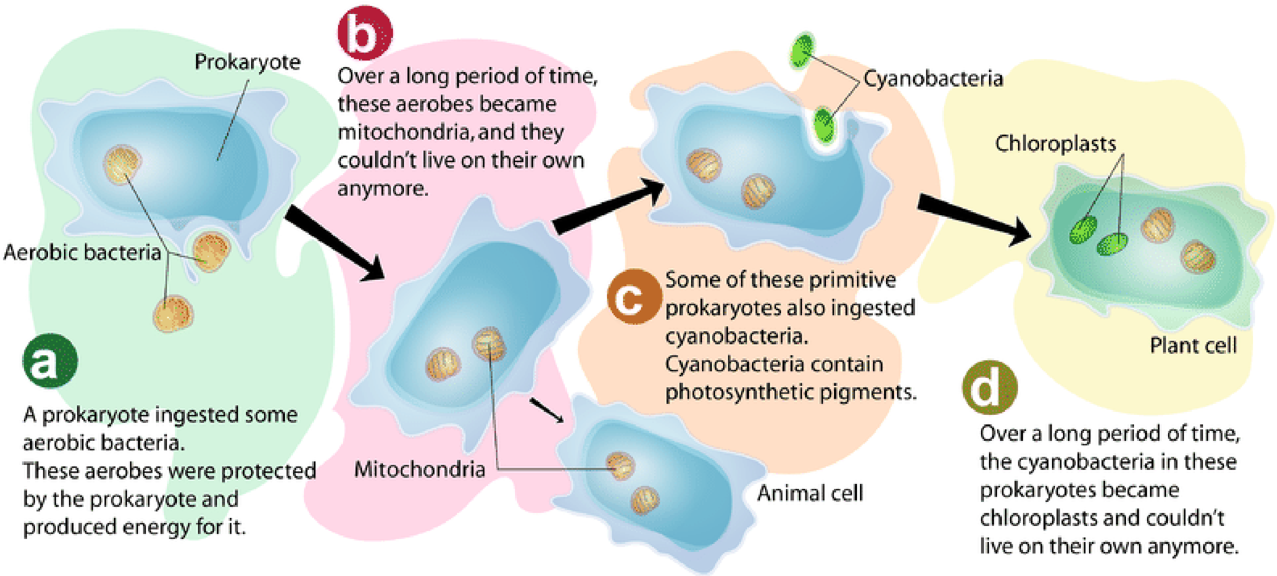
Evolution of Protists

Scientists think that protists are the oldest eukaryotes. If so, they must have evolved from prokaryotic cell. How did this happen? The **endosymbiotic theory** provides the most widely-accepted explanation. That's because it is well supported by evidence.

The First Eukaryotic Cells

According to the endosymbiotic theory, the first eukaryotic cell evolved from a **symbiotic relationship** between two or more prokaryotic cells. Smaller prokaryotic cells were engulfed by (or invaded) larger prokaryotic cells. The small cells (now called **endosymbiont**) benefited from the relationship by getting a safe home and nutrient. The large cells (now called **hosts**) benefited by getting some of the organic molecule or energy released by the endosymbionts. Eventually, the endosymbionts evolved into **organelle** of the host cells. After that, neither could live without the other.

As shown in **Figure** below, some of the endosymbionts were aerobic bacteria. They were specialized to break down chemicals and release energy. They evolved into the mitochondrion of eukaryotic cells. Some of the small cells were cyanobacterium. They were specialized for photosynthesis. They evolved into the chloroplast of eukaryotic cells.



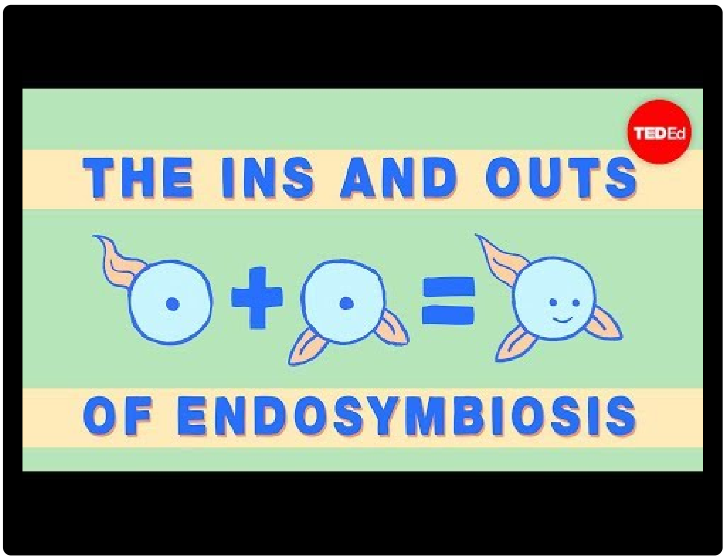
[Figure 2]

Endosymbiotic theory explains how eukaryotic cells arose.

Evidence for the Endosymbiotic Theory

Many pieces of evidence support the endosymbiotic theory. For example:

- Mitochondria and chloroplasts contain DNA that is different from the DNA found in the cell nucleus. Instead, it is similar to the circular DNA of bacteria.
- Mitochondria and chloroplasts are surrounded by their own plasma membranes, which are similar to bacterial membranes.
- New mitochondria and chloroplasts are produced through a process similar to **binary fission**. Bacteria also reproduce through binary fission.
- The internal structure and biochemistry of chloroplasts is very similar to that of cyanobacteria.



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Summary

- Scientists think that protists are the oldest eukaryotes.
- Protists most likely evolved from prokaryotic cells, as explained by the endosymbiotic theory. This theory is well-supported by evidence.

Review

1. How did the first eukaryotic cells evolve, according to endosymbiotic theory?
2. Identify two pieces of evidence for endosymbiotic theory. Explain how this evidence supports the theory.
3. How are additional mitochondria produced?

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8.3 Protist Characteristics

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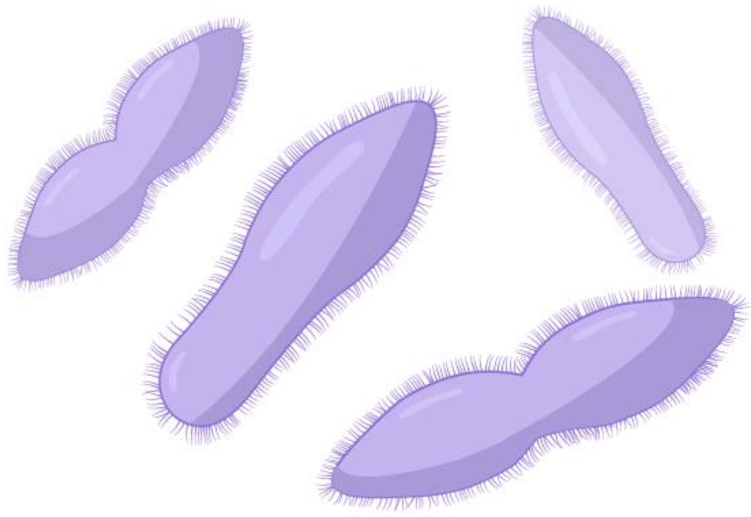


[Figure 1]

Sexual or asexual reproduction for protists?

Notice how the Paramecium is dividing into two cell. This, obviously, is a form of asexual reproduction. But, remember that protist are an extremely diverse kingdom, and some protists can also reproduce sexually.

Characteristics of Protists

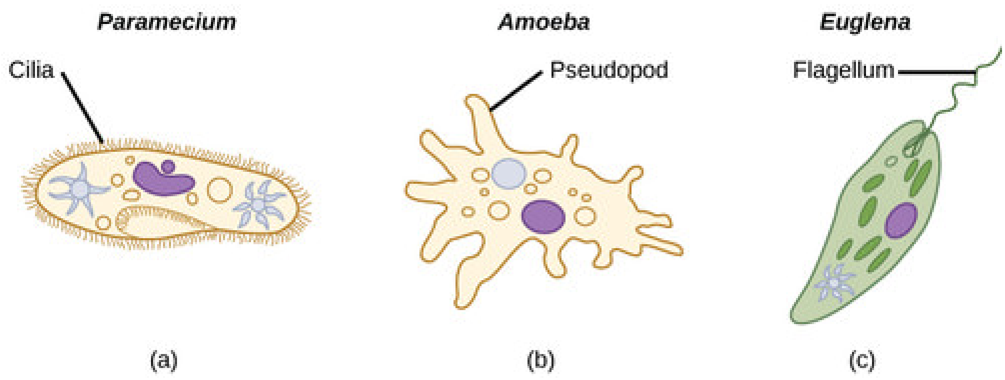
Like all other eukaryote, protists have a nucleus containing their DNA. They also have other membrane-bound organelle, such as mitochondrion and the endoplasmic reticulum. Most protists are single-celled. Some are multicellular. Because the protist kingdom is so diverse, their ways of getting food and reproducing vary widely.

Protist Habitats

Most protists are aquatic organism. They need a moist environment to survive. They are found mainly in damp soil, marshes, puddles, lakes, and the ocean. Some protists are free-living organisms. Others are involved in **symbiotic** relationships. They live in or on other organisms, including humans.

Motility of Protists

Most protists have **motility**. This is the ability to move. Protists have three types of appendage for movement. As shown in **Figure** below, they may have **flagellum, cilia**, or **pseudopods** ("false feet"). There may be one or more whip-like flagella. Cilia are similar to flagella, except they are shorter and there are more of them. They may completely cover the surface of the protist cell. Pseudopods are temporary, foot-like extensions of the cytoplasm.

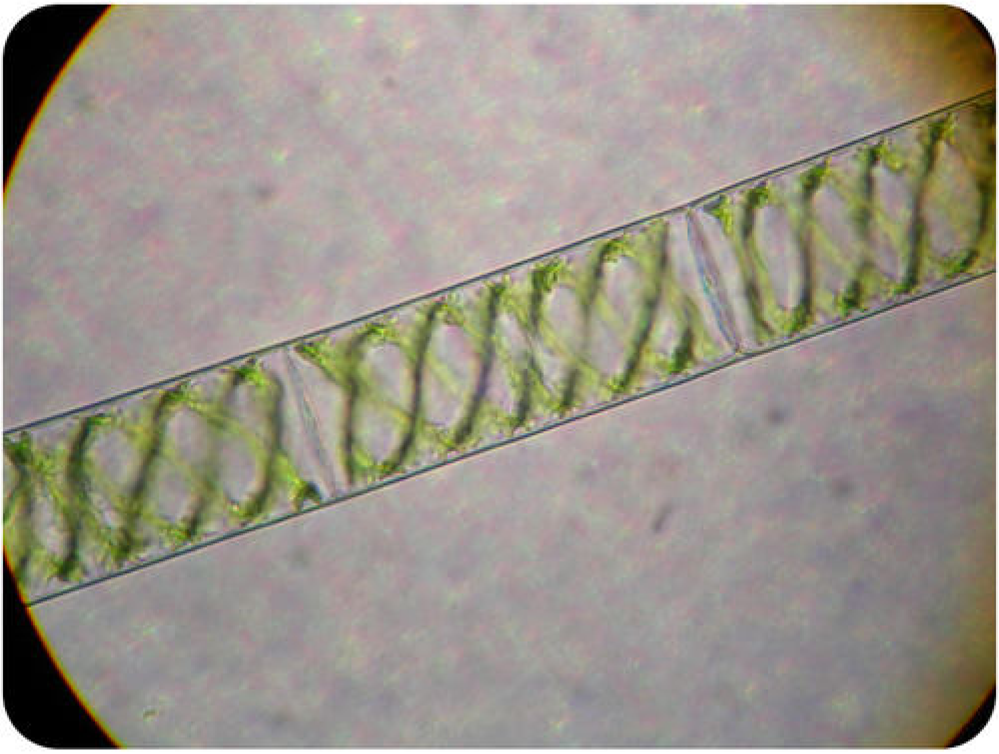


[Figure 2]

Protists use cilia, pseudopods, or flagella to move.

Protist Reproduction

Protists have complex life cycles. Many have both asexual and sexual reproduction. An example is a protist called *Spirogyra*, a type of alga, shown **Figure** below. It usually exists as haploid cells that reproduce by binary fission. In a stressful environment, such as one that is very dry, *Spirogyra* may produce tough spores that can withstand harsh conditions. **Spores** are reproductive cells produced by protists and various other organisms. If two protist spores are close together, they can fuse to form a diploid zygote. This is a type of sexual reproduction. The zygote then undergoes meiosis, producing haploid cells that repeat the cycle.



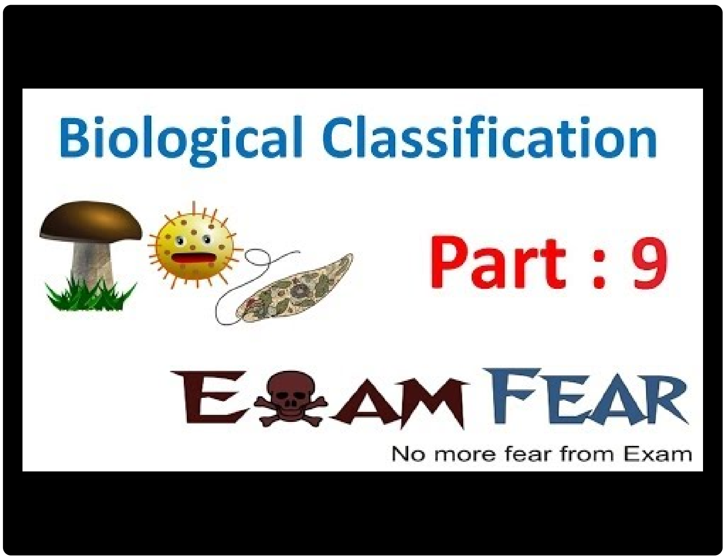
[Figure 3]

Spirogyra is a genus of algae with a complex life cycle. Each organism consists of rectangular cells connected end-to-end in long filaments.

Protist Nutrition

Protists get food in one of three ways. They may ingest, absorb, or make their own organic molecule.

- Ingestive protists ingest, or engulf, bacterium and other small particles. They extend their cell wall and cell membrane around the food item, forming a food **vacuole**. Then enzyme digest the food in the vacuole.
- Absorptive protists absorb food molecules across their cell membranes. This occurs by **diffusion**. These protists are important decomposer.
- Photosynthetic protists use light energy to make food. They are major producer in aquatic ecosystem.



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Summary

- Protists have nuclear membranes around their DNA. They also have other membrane-bound organelles.
- Many protists live in aquatic habitats, and most are motile, or able to move.
- Protists have complex life cycles that may include both sexual and asexual reproduction.
- Protists get food through ingestion, absorption, or photosynthesis.

Review

1. Identify three structures that protists use to move.
2. Describe three ways that protists get food.
3. Describe asexual and sexual reproduction in protists.

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8.4 Protozoa

FlexBooks 2.0 > Biology For High School Diploma > Protozoa

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[Figure 1]

What's like an animal, but not an animal?

An animal-like protist, or a protozoa. These protists have the ability to move, usually with some sort of cilia or flagellum, and must obtain their energy from other sources. But obviously, they are much simpler than animal.

Animal-Like Protists: Protozoa

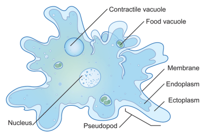
Animal-like protists are commonly called **protozoa** (singular, protozoan). Most protozoa consist of a single cell. They are animal-like because they are heterotroph, and are capable of moving. Although protozoa are not animals, they are thought to be the ancestors of animals.

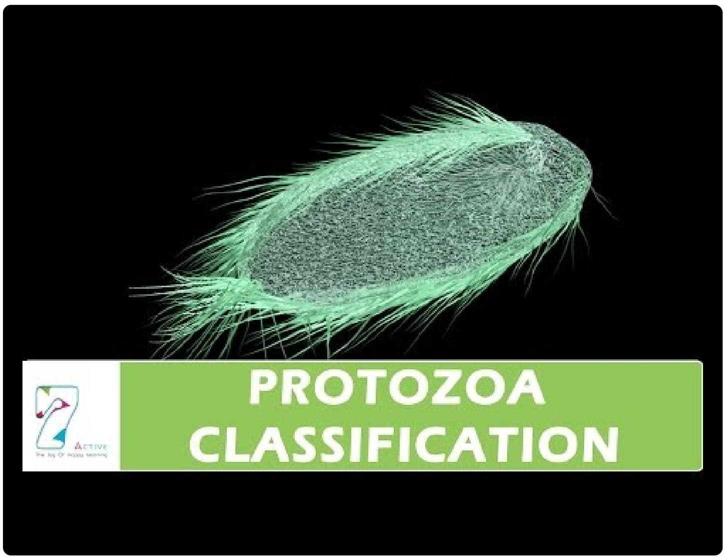
Ecology of Protozoa

Protozoa generally feed by engulfing and digesting other organism. As consumers, they have various roles in food chain and webs. Some are predator. They prey upon other single-celled organisms, such as bacterium. In fact, protozoa predators keep many bacterial population under control. Other protozoa are herbivore. They graze on alga. Still others are decomposer. They consume dead organic matter. There are also parasitic protozoa that live in or on living hosts. For example, the protozoan that causes malaria lives inside a human host. Protozoa are also important food sources for many larger organisms, including insects and worms.

Classification of Protozoa

Protozoa can be classified on the basis of how they move. As shown in **Table** below, protozoa move in three different ways. Only sporozoa cannot move. Note that this classification is based only on differences in movement. It does not represent phylogenetic relationships.

Type of Protozoa	How It Moves	Example (Genus)
amoeboid	pseudopods	*amoeba*  [Figure 2]
ciliate	cilia	*Paramecium*  [Figure 3]
flagellate	flagella	*Giardia*  [Figure 4]
Sporozoan	does not move (as adult)	*Plasmodium*  [Figure 5]



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Summary

- Animal-like protists are called protozoa. Most consist a single cell.
- Like animals, protozoa are heterotrophic and capable of moving.
- Examples of protozoa include amoebas and paramecia.

Review

1. How are protozoa similar to animals?
2. What roles do protozoa play in food chains and webs?
3. What type of protozoa is a *Paramecium?*
4. What type of protozoa is a *Giardia?*

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8.5 Algae

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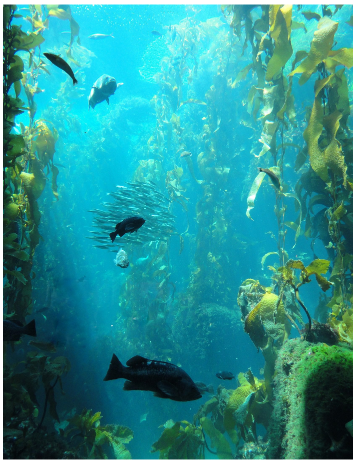


[Figure 1]

Many people, if not most, believe seaweed to be a plant. Is it?

seaweed is actually a plant-like protist, which are also known as algae. The green color is due to what pigment? Algae, like plants, obtain their energy through photosynthesis.

Plant-Like Protists: Algae

Plant-like protists are called **algae** (singular, alga). They are a large and diverse group. Some algae, the **diatom**, are single-celled. Others, such as **seaweed**, are multicellular (see **Figure** below).

[Figure 2]

Diatoms are single-celled algae. Other forms of algae are multicellular.

Why are algae considered plant-like? The main reason is that they contain **chloroplast** and produce food through **photosynthesis**. However, they lack many other structures of true plants. For example, algae do not have roots, stem, or leaves. Some algae also differ from plants in being motile. They may move with pseudopods or flagellum. Although not plants themselves, algae were probably the ancestors of plants.

Ecology of Algae

Algae play significant roles as producer in aquatic ecosystem. Microscopic forms live suspended in the water column. They are the main component of **phytoplankton**. As such, they contribute to the food base of most marine ecosystems.

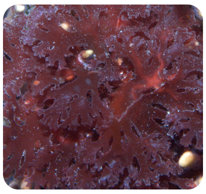
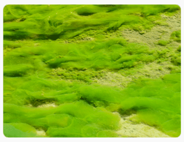
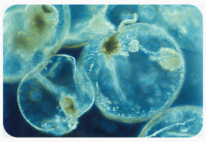
Multicellular seaweeds called **kelp** may grow as large as trees. They are the food base of ecosystems called **kelp forest** (see **Figure** below). Kelp forests are found throughout the ocean in temperate and arctic climates. They are highly productive ecosystems.

[Figure 3]

Kelp Forest. This kelp forest supports a large community of many other types of organisms.

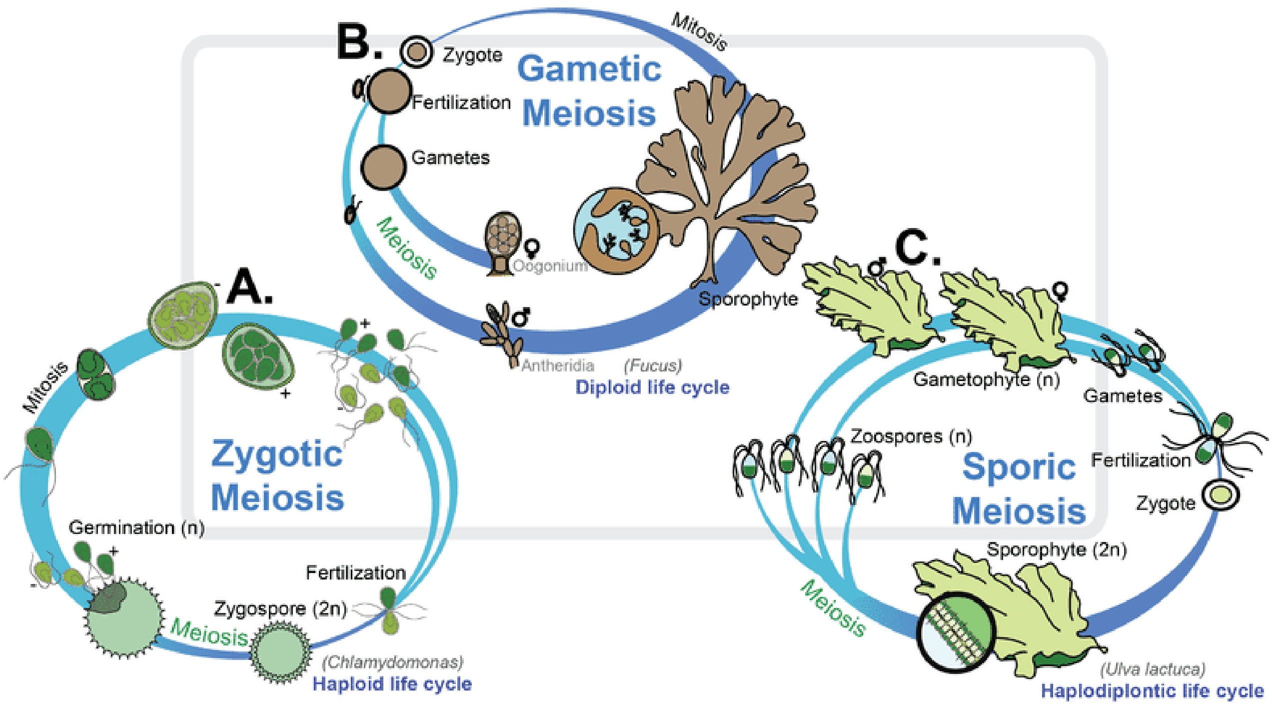
Classification of Algae

Types of algae include red and green algae, and **euglenid**, and **dinoflagellate** (see **Table** below for examples). Scientists think that red and green algae evolved from endosymbiotic relationships with cyanobacterium. Their chloroplasts have two membranes because the cell membrane of the cyanobacteria became additional plasma membranes of the chloroplasts. Scientists think that euglenids and dinoflagellates evolved later, from endosymbiotic relationships with green and red algae. This is why their chloroplasts have three membranes. Differences in the types of chlorophyll in the four types of algae also support the hypothesized evolutionary relationships.

Type of Algae	Origin of Chloroplast	Type of Chloroplast
Red algae  [Figure 4]	cyanobacteria	two membranes, chlorophyll like the majority of cyanobacteria
Green algae  [Figure 5]	cyanobacteria	two membranes, chlorophyll like a minority of cyanobacteria
Euglenids  [Figure 6]	green algae	three membranes, chlorophyll like green algae
Dinoflagellates  [Figure 7]	red algae	three membranes, chlorophyll like red algae

Reproduction of Algae

Algae have varied life cycles. Two examples are shown in **Figure** below. Both cycles include phases of asexual reproduction (haploid, *n*) and sexual reproduction (diploid, *2n*). Why go to so much trouble to reproduce? Asexual reproduction is fast, but it doesn't create new genetic variation. Sexual reproduction is more complicated and risky, but it creates new gene combinations. Each strategy may work better under different conditions. Rapid population growth (asexual reproduction) is adaptive when conditions are favorable. Genetic variation (sexual reproduction) helps ensure that some organism will survive if the environment changes.



[Figure 8]

Life Cycles of Algae: Zygotic Meiosis (A), Gametic Meiosis (B) and Sporic Meiosis (C). In life cycle A (left), diploid (2n) zygotes result from fertilization and then undergo meiosis to produce haploid (n) gametes. The gametes undergo mitosis and produce many additional copies of themselves. How are life cycles B and C different from life cycle A?

Summary

- Plant-like protists are called algae. They include single-celled diatoms and multicellular seaweed.
- Like plants, algae contain chlorophyll and make food by photosynthesis.
- Types of algae include red and green algae, euglenids, and dinoflagellates.

Review

1. Compare and contrast algae and plants.
2. State pros and cons of asexual and sexual reproduction in algae.
3. Explain why dinoflagellates and euglenids have chloroplasts with three membranes instead of two.

Report Content Errors

8.6 Mold

FlexBooks 2.0 > Biology For High School Diploma > Mold

Last Modified: Jul 04, 2019

[Figure 1]

What grows just about anywhere there is decaying material?

Mold. This **slime mold**, shown growing on dead wood, is a fungus-like protist. Though this mold does not have a mouth, essentially it is still "eating" this decaying material.

Fungus-Like Protists: Molds

Fungus-like protists are **molds**. They are absorptive feeders on decaying organic matter. They resemble fungus, and they reproduce with **spores** as fungi do. However, in other ways, they are quite different from fungi and more like other protists. For example, they have cell wall made of **cellulose**, whereas fungi have cell walls made of chitin. Like other protists, they have complicated life cycles with both asexual and sexual reproduction. They are motile during some stages of their life cycle. Two major types of fungus-like protists are slime molds and water molds.

Slime Molds

Slime molds are fungus-like protists commonly found on rotting logs and compost. They move very slowly in search of decaying matter to eat. When food is scarce, individual cell swarm together to form a blob-like mass, like the "dog vomit" slime mold in the **Figure**

below. The mass glides along on its own secretions, engulfing decaying organic matter as it moves over it.

[Figure 2]

“Dog Vomit” Slime Mold. This slime mold looks like its name.

There are two types of slime molds when it comes to how they swarm: acellular and cellular.

- When acellular slime molds swarm, they fuse together to form a single cell with many nucleus.
- When cellular slime molds swarm, they remain as distinct cells.

Cellular slime molds are used as model organism in molecular biology and genetics. They may be the key to how multicellular organism evolved. Can you explain why?

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Water Molds

Water molds are commonly found in moist soil and surface water. Many are plant pathogen that destroy crops. They infect plants such as grapes, lettuce, corn, and potatoes. Some water molds are parasite of fish and other aquatic organisms.

Science Friday: The Road Best Traveled

A Tale of Ants, Slime Mold and the New Jersey Turnpike For most people, getting stuck in a traffic jam on the New Jersey Turnpike is a grueling lesson in futility. However, in this video by science Friday, Simon Garnier examines our collective behavior and how relatively simple organisms organize themselves so dynamically.

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Summary

- Fungus-like protists are molds.
- Molds are absorptive feeders, found on decaying organic matter. They resemble fungi and reproduce with spores as fungi do.
- Examples of fungus-like protists include slime molds and water molds.

Review

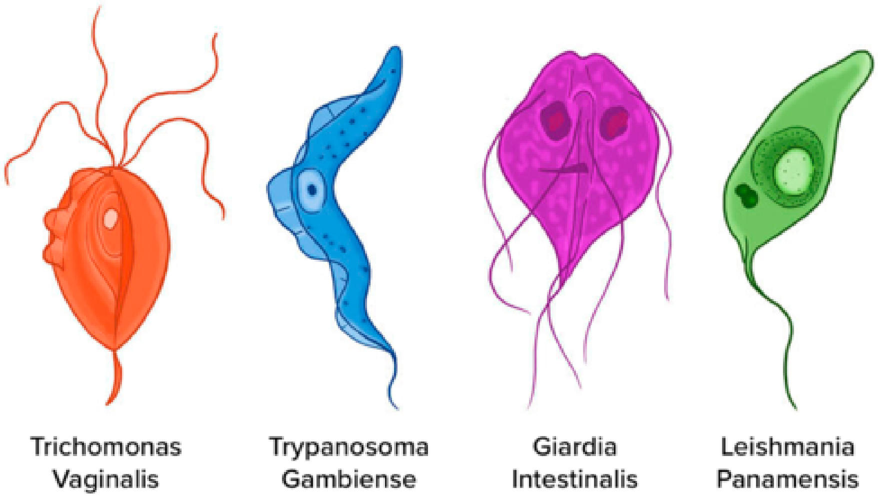
1. How are fungus-like protists similar to fungi? What is one way they are different?
2. Why might cellular slime molds, but not acellular slime molds, be the key to how multicellular organisms evolved?

Report Content Errors

8.7 Protists and Disease

FlexBooks 2.0 > Biology For High School Diploma > Protists and Disease

Last Modified: Feb 03, 2021



[Figure 1]

Can such little creatures make you sick?

They sure can. Not all of them, but some of them. And without proper medical treatment, the person may never recover.

Protists and Human Disease

Most protist diseases in humans are caused by animal-like protists, or **protozoan**. Protozoa make us sick when they become human **parasite**. Three examples of parasitic protozoa are described below.

Trypanosoma Protozoa

Members of the genus *Trypanosoma* are flagellate protozoa that cause **sleeping sickness**, which is common in Africa. They also cause **Chagas disease**, which is common in South America. The parasites are spread by insect vector. The vector for Chagas disease is shown in **Figure** below. *Trypanosoma* parasites enter a person's blood when the vector bites. Then they spread to other tissue and organ. The diseases may be fatal without medical treatment.

[Figure 2]

Vector for Chagas Disease. In Chagas disease, the Trypanosoma parasite is spread by an insect commonly called the "kissing bug." A bite from this bug could be the kiss of death.

The discovery of Chagas disease is unique in the history of medicine. That's because a single researcher—a Brazilian physician named Carlos Chagas—single-handedly identified and explained the new infectious disease. In the early 1900s, Chagas did careful lab and field studies. He determined the pathogen, vector, host, symptoms, and mode of transmission of the disease that is now named for him.

Giardia Protozoa

Giardia are flagellate protozoa that cause **giardiasis**. The parasites enter the body through food or water that has been contaminated by feces of infected people or animal. The protozoa attach to the lining of the host's small intestine, where they prevent the host from fully absorbing nutrient. They may also cause diarrhea, abdominal pain, and fever. A picture of a *Giardia* protozoan opens this concept.

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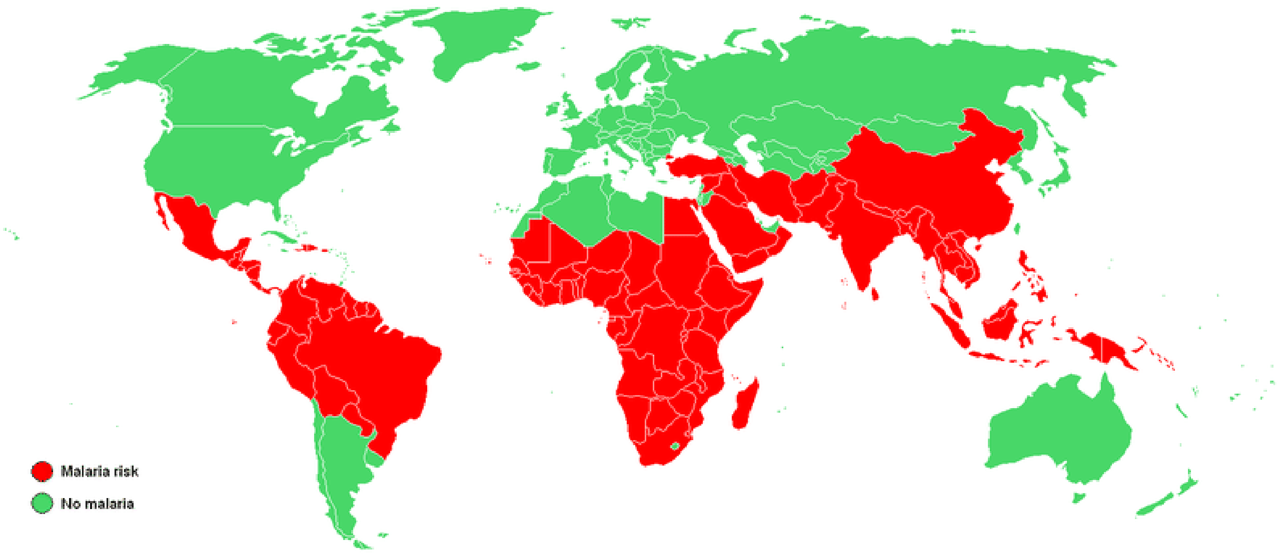
Plasmodium Protozoa

Plasmodium protozoa cause **malaria**. The parasites are spread by a mosquito vector. Parasites enter a host's blood through the bite of an infected mosquito. The parasites infect the host's red blood cell, causing symptoms such as fever, joint pain, anemia, and fatigue.

Malaria is common in tropical and subtropical climates throughout the world (see **Figure** below). In fact, malaria is one of the most common infectious diseases on the planet. Malaria is also a very serious disease. It kills several million people each year, most of them children. A vaccine to malaria is a possibility.



[Figure 3]

Worldwide Distribution of Malaria. This map shows where malaria is found. The area is determined by the mosquito vector. The mosquito can live year-round only in the red-shaded areas.

https://flexbooks.ck12.org/flx/render/embeddedobject/190227

Summary

- Most protist diseases in humans are caused by protozoa. Protozoa make humans sick when they become human parasites.
- *Trypanosoma* protozoa cause Chagas disease and sleeping sickness.
- *Giardia* protozoa cause giardiasis, and *Plasmodium* protozoa cause malaria.

Review

1. Describe how the protozoa that cause Chagas disease are spread to human hosts.
2. State why malaria is commonly found only in tropical and subtropical regions of the world.
3. Terri lost her water bottle while hiking in Canada. It was a hot day, so she drank water from a stream to stay hydrated. A few days later, Terri became ill with abdominal pain, fever, and diarrhea. Her doctor thinks she has a protozoan infection. Which type of protozoa do you think is most likely responsible for Terri's illness? How do you think Terri became infected?

Report Content Errors

8.8 Fungi

FlexBooks 2.0 > Biology For High School Diploma > Fungi

Last Modified: Jul 04, 2019

[Figure 1]

What exactly is a fungus?

They're not animal or plants, and definitely not protist. So they cannot photosynthesize or eat. And they are much more than mushroom.

Characteristics of Fungi

Do you see the organism growing on the bread in the **Figure** below? They belong to the kingdom **Fungi**. **Molds** growing on foods are some of the most common fungi in our everyday lives. These organisms may seem useless, gross, and costly. But fungi play very important roles in almost every terrestrial ecosystem on Earth.

[Figure 2]

The mold growing on this bread is a common fungus.

Fungi (singular, fungus) are a kingdom in the domain Eukarya. The fungi kingdom may contain more than a million species, but fewer than 100,000 have been identified. As shown in the **Figure** below, fungi include mushrooms and yeasts in addition to molds.

[Figure 3]

Several examples of fungi are pictured here.

Most fungi are multicellular, but some exist as single cell. Single-celled fungi are known as **yeasts.** Fungi spend most of their life cycle in the haploid state. They form diploid cells only during sexual reproduction. Like the cells of protists and plants, the cells of fungi have cell wall. But fungi are unique in having cell walls made of **chitin** instead of cellulose. **Chitin** is a tough carbohydrate that also makes up the exoskeleton (outer skeleton) of insects and related organisms.

Habitats of Fungi

Fungi are found all around the world, and grow in a wide range of habitat, including deserts. Most grow in terrestrial environments, but several species live only in aquatic habitats. Most fungi live in soil or dead matter, and in symbiotic relationships with plants, animals, or other fungi. Fungi, along with bacterium that are found in soil, are the primary decomposer of organic matter in terrestrial ecosystems. The decomposition of dead organisms returns nutrient to the soil, and the environment.

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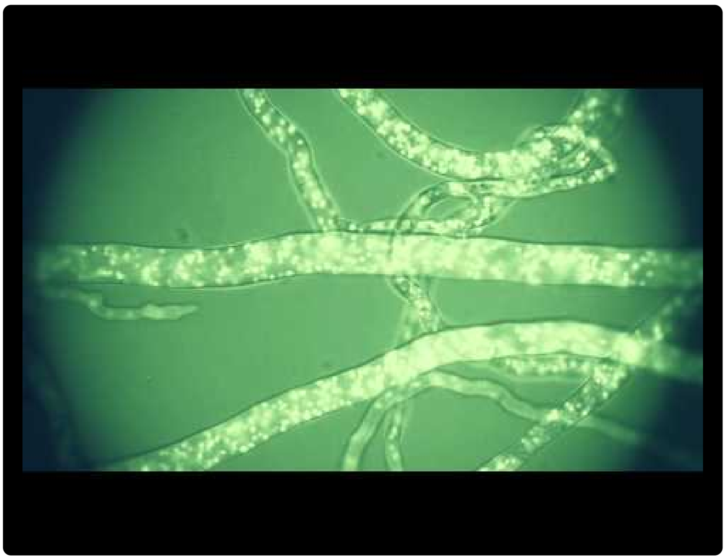
Science Friday: Fungal Freeways

Fungus use fluid networks, similar to roads and freeways, to move nutrients and nucleus through their cells. In the video by science Friday, Dr. Marcus Roper explains how these networks function with remarkable efficiency and prevent microscopic traffic jams.



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Summary

- Fungi are a kingdom in the domain Eukarya that includes molds, mushrooms, and yeasts.
- Most fungi are multicellular. They are unique in having cell walls made of chitin.
- Most fungi live on dead matter or soil. Some live in aquatic habitats. Many are involved in symbiotic relationships.

Review

1. What are fungi? Give two examples of fungi.
2. Explain the significance of the chitin cell wall of fungi.
3. List two habitats where fungi live.

Report Content Errors

8.9 Fungi Structure

FlexBooks 2.0 > Biology For High School Diploma > Fungi Structure

Last Modified: May 16, 2021

[Figure 1]

Is the structure important?

Of course. Though **mushroom** may be the most common type of fungus, fungi also include rusts, smuts, puffballs, truffles, morels, molds, and yeasts, as well as many less well-known organism. And, except for yeast cell, they all have similar structures, which are usually hidden deep within their food source.

Structure of Fungi

Except for yeasts, which grow as single cells, most fungi grow as thread-like filaments, like those shown in **Figure** below. The filaments are called **hypha** (singular, hypha). Each hypha consists of one or more cells surrounded by a tubular cell wall. A mass of hyphae make up the body of a fungus, which is called a **mycelium** (plural, mycelia).

The hyphae of most fungi are divided into cells by internal walls called **septum** (singular, septum). Septa usually have little pores that are large enough to allow ribosome, mitochondrion and sometimes nucleus to flow among cells. Hyphae that are divided into cells are called **septate hyphae**. However, the hyphae of some fungi are not separated by septa. Hyphae without septae are called **coenocytic hypha**. Coenocytic hyphae are big, multinucleated cells.

[Figure 2]

These branches are hyphae, or filaments, of fungi.

A mycelium may range in size from microscopic to very large. In fact, one of the largest living organisms on Earth is the mycelium of a single fungus. A small part of a similar fungus is pictured in **Figure** below. The giant fungus covers 8.9 square kilometers (3.4 square miles) in an Oregon forest. That's about the size of a small city. The fungus didn't grow that large overnight. It's estimated to be 2,400 years old, and it's still growing!

[Figure 3]

The fungus shown here has been dubbed the "humongous fungus" because it covers such a large area.

Fruiting Bodies

Some fungi become noticeable only when producing spores (fruiting), either as mushrooms or molds. For example, you can see the fruiting bodies of the *Armillaria* fungus in the **Figure** above, but the large "body" of the fungus, the mycelium, is hidden underground. This fruiting body, known as the **sporocarp**, is a multicellular structure on which spore-producing structures form. The fruiting body is part of the sexual phase of a fungal life cycle. The rest of the life cycle is characterized by the growth of mycelia.

Dimorphic Fungi

Some fungi take on different shapes, depending on their environmental conditions. These fungi are called **dimorphic fungus**, because they have "two forms." For example, the fungus *Histoplasma capsulatum*, which causes the disease histoplasmosis, is thermally dimorphic; it has two forms that are dependent on temperature. In temperatures of about 25°C, it grows as a brownish mycelium, and looks like a mass of threads. At body temperature (37°C in humans), it grows as single, round yeast cells.

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Summary

- Most fungi grow as thread-like filaments called hyphae.
- A mass of hyphae make up the body of a fungus, called a mycelium.

Review

1. Describe the general structure of multicellular fungi.
2. What is a fruiting body?
3. Relate the structures of hyphae, mycelia, and fruiting bodies to one another.

Report Content Errors

8.10 Fungi Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Fungi Reproduction

Last Modified: May 16, 2021

[Figure 1]

How do fungi reproduce? Sexually or asexually?

How about both? That would suggest that fungus can produce both diploid and haploid cell, which they can. Shown above are fungi hypha and haploid spores. Spores allow fungi to reproduce through unfavorable conditions.

Reproduction of Fungi

The majority of fungi can reproduce both asexually and sexually. This allows them to adjust to conditions in the environment. They can spread quickly through asexual reproduction when conditions are stable. They can increase their genetic variation through sexual reproduction when conditions are changing and variation may help them survive.

Asexual Reproduction

Almost all fungi reproduce asexually by producing spores. A fungal **spore** is a haploid cell produced by mitosis from a haploid parent cell. It is genetically identical to the parent cell.

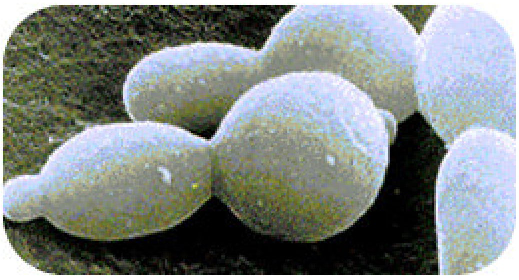
Fungal spores can develop into new haploid individuals without being fertilized.

Spores may be dispersed by moving water, wind, or other organism. Some fungi even have "cannons" that "shoot" the spores far from the parent organism. This helps to ensure that the offspring will not have to compete with the parent for space or other resources. You are probably familiar with puffballs, like the one in **Figure** below. They release a cloud of spores when knocked or stepped on. Wherever the spores happen to land, they do not germinate until conditions are favorable for growth. Then they develop into new **hyphae**.

[Figure 2]

Puffballs release spores when disturbed.

Yeasts do not produce spores. Instead, they reproduce asexually by **budding**. **Budding** is the pinching off of an offspring from the parent cell. The offspring cell is genetically identical to the parent. Budding in yeast is pictured in **Figure** below.

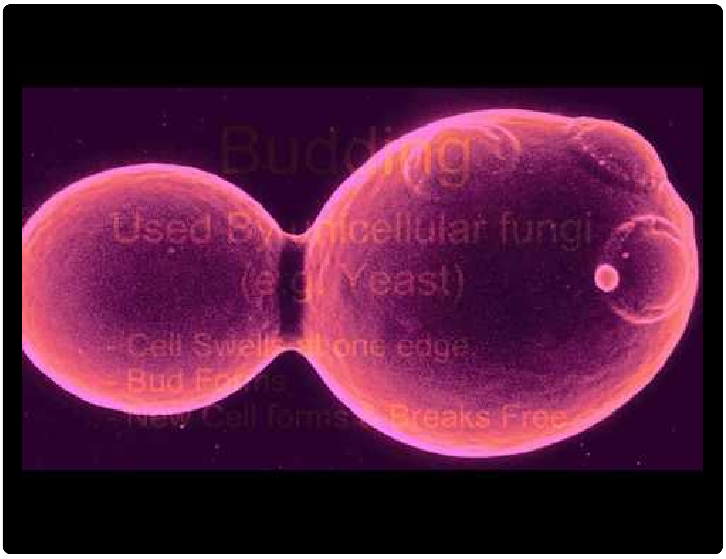


[Figure 3]

Yeast reproduce asexually by budding.

Sexual Reproduction

Sexual reproduction also occurs in virtually all fungi. This involves mating between two haploid hyphae. During mating, two haploid parent cells fuse, forming a diploid spore called a **zygospore**. The zygospore is genetically different from the parents. After the zygospore germinates, it can undergo meiosis, forming haploid cells that develop into new hyphae.



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Summary

- The majority of fungi can reproduce both asexually and sexually. This allows them to adjust to conditions in the environment.
- Yeast reproduce asexually by budding. Other fungi reproduce asexually by producing spores.
- Sexual reproduction occurs when spores from two parents fuse and form a zygospore.

Review

1. Explain the advantages of fungal spores.
2. Identify ways that fungal spores may be dispersed.
3. Compare and contrast a fungal spore and zygospore.

Report Content Errors

8.11 Fungi Evolution

FlexBooks 2.0 > Biology For High School Diploma > Fungi Evolution

Last Modified: May 21, 2021

[Figure 1]

What were early fungi like?

Early fungus probably lived in water. And they were most likely single-celled organism. Maybe they lived on dead and decaying material. Obviously, at least in overall size and structure, a mold is very different than a mushroom. Could early fungi have been similar to a mold?

Evolution of Fungi

DNA evidence suggests that almost all **fungi** have a single common ancestor. The earliest fungi may have evolved about 600 million years ago or even earlier. They were probably aquatic organisms with a flagellum. Fungi first colonized the land at least 460 million years ago, around the same time as plants. fossil of terrestrial fungi date back almost 400 million years (see **Figure** below). Starting about 250 million years ago, the fossil record shows fungi were abundant in many places. They may have been the dominant life forms on Earth at that time.

[Figure 2]

This rock contains fossilized fungi. The fungi lived 396 million years ago in what is now Scotland. They were preserved when they were covered with lava from a volcano. The lava cooled and hardened into rock.

Summary

- Almost all fungi have a single common ancestor.
- The earliest fungi may have evolved about 600 million years ago.
- Fungi colonized land at least 460 million years ago.
- By 250 million years ago, they may have been the dominant life forms on Earth.

Review

1. Summarize the evolution of fungi.

Report Content Errors

8.12 Fungi Classification

Last Modified: Jul 04, 2019

[Figure 1]

What type of fungus is this?

Obviously a mold. But what type of mold? There are thousands of known species of molds. How are they classified?

Classification of Fungi

For a long time, scientists considered fungus to be members of the plant kingdom because they have obvious similarities with plants. Both fungi and plants are immobile, have cell wall, and grow in soil. Some fungi, such as **lichens**, even look like plants (see **Figure** below).

[Figure 2]

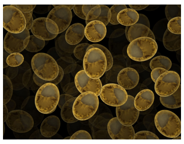
Moss (Plant) and Lichen Growing on Tree Bark. Both fungi and moss are growing on this tree. Can you tell them apart?

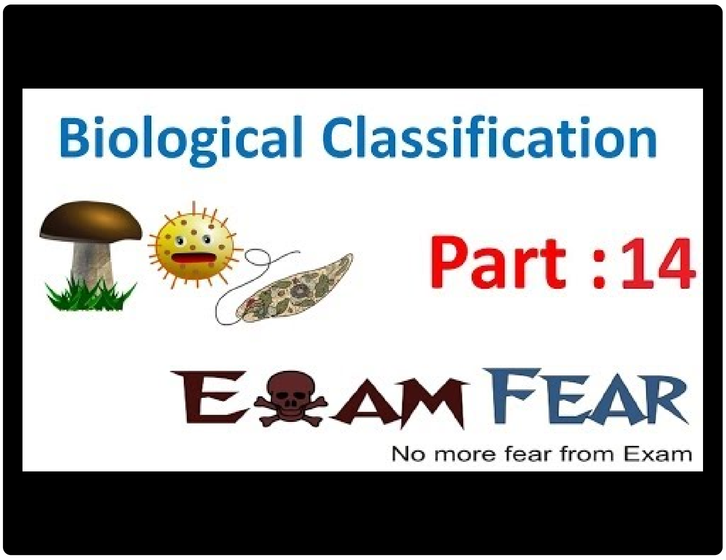
The Kingdom Fungi

Today, fungi are no longer classified as plants. We now know that they have unique physical, chemical, and genetic traits that set them apart from plants and other eukaryote. For example, the cell walls of fungi are made of **chitin**, not cellulose. Also, fungi absorb nutrient from other organism, whereas plants make their own food. These are just a few of the reasons fungi are now placed in their own kingdom.

Fungal Phyla

Classification of fungi below the level of the kingdom is controversial. There is no single, widely-accepted system of fungal classification. Most classifications include several phyla (the next major taxon below the kingdom). Three of the most common phyla are compared in **Table** below.

Phylum	Description	Example
Zygomycota	mainly terrestrial, live in soil and compost and on foods such as bread	black bread mold  [Figure 3]
Basidiomycota	have many different shapes, considerable variation exists even within species	button mushroom  [Figure 4]
Ascomycota	found in all terrestrial ecosystem world-wide, even in Antarctica, often involved in symbiotic relationships	baker's yeast  [Figure 5]



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Summary

- Fungi used to be classified as plants. Now, they are known to have unique traits that set them apart from plants. For example, fungal cell walls contain chitin, not cellulose, and fungi absorb food rather than make their own.

- Below the level of the kingdom, classification of fungi is controversial.

Review

1. State why fungi were once classified as plants.
2. Explain the significance of the chitin cell wall of fungi.
3. Mushrooms belong to what phylum of fungi?

Report Content Errors

8.13 Fungi Nutrition

FlexBooks 2.0 > Biology For High School Diploma > Fungi Nutrition

Last Modified: Jul 04, 2019

[Figure 1]

So what do fungi "eat"?

Just about anything. From dead plants to rotting fruit. Shown here are fungus sprouting from dead material in the woods. Fungi perform an essential role in the decomposition of organic matter and have fundamental roles in nutrient cycling and exchange.

Nutrition

Fungi get their nutrition by absorbing organic compound from the environment. Fungi are **heterotrophic**: they rely solely on carbon obtained from other organism for their metabolism and nutrition. Fungi have evolved in a way that allows many of them to use a large variety of organic substrate for growth, including simple compounds such as nitrate, ammonia, acetate, or ethanol. Their mode of nutrition defines the role of fungi in their environment.

Fungi obtain nutrients in three different ways:

1. They decompose dead organic matter. A **saprotroph** is an organism that obtains its nutrients from non-living organic matter, usually dead and decaying plant or animal matter, by absorbing soluble organic compounds. Saprotrophic fungi play very important roles as recyclers in ecosystem energy flow and biogeochemical cycle. Saprophytic fungi, such as shiitake (*Lentinula edodes*) and oyster mushroom (*Pleurotus ostreatus*), decompose dead plant and animal tissue by releasing enzyme from hyphal

tips. In this way they recycle organic materials back into the surrounding environment. Because of these abilities, fungi are the primary decomposer in forests (see **Figure** below).

2. They feed on living hosts. As **parasite**, fungi live in or on other organisms and get their nutrients from their host. Parasitic fungi use enzymes to break down living tissue, which may causes illness in the host. Disease-causing fungi are parasitic. Recall that parasitism is a type of symbiotic relationship between organisms of different species in which one, the parasite, benefits from a close association with the other, the host, which is harmed.
3. They live mutualistically with other organisms. Mutualistic fungi live harmlessly with other living organisms. Recall that mutualism is an interaction between individuals of two different species, in which both individuals benefit.

Both parasitism and mutualism are classified as symbiotic relationships, but they are discussed separately here because of the different effect on the host.

[Figure 2]

Forest Decomposers. These forest mushrooms may look fragile, but they do a powerful job. They decompose dead wood and other tough plant material.

Fungal hypha are adapted to efficient absorption of nutrients from their environments, because hyphae have high surface area-to-volume ratios. These adaptation are also complemented by the release of **hydrolytic enzyme** that break down large organic molecule such as polysaccharide, protein, and lipid into smaller molecules. These molecules are then absorbed as nutrients into the fungal cell. One enzyme that is secreted by fungi is **cellulase**, which breaks down the polysaccharide **cellulose**. Cellulose is a major component of plant cell wall. In some cases, fungi have developed specialized structures for nutrient uptake from living hosts, which penetrate into the host cells for nutrient uptake by the fungus.

[Figure 3]

Fungal mycelia. Fungi absorb nutrients from the environment through mycelia. The branching mycelia have a high surface-area-to-volume ratio which allows for efficient absorption of nutrients. Some fungi digest nutrients by releasing enzymes into the environment.

Mycorrhiza

A **mycorrhiza** (Greek for "fungus roots") is a symbiotic association between a fungus and the roots of a plant. In a mycorrhizal association, the fungus may colonize the roots of a host plant by either growing directly into the root cells, or by growing around the root cells. This association provides the fungus with relatively constant and direct access to glucose, which the plant produces by photosynthesis. The mycelium of the fungi increase the surface area of the plant's root system. The larger surface area improves water and mineral nutrient absorption from the soil.

https://flexbooks.ck12.org/flx/render/embeddedobject/185281

Summary

- Fungi are heterotrophic. They get their nutrition by absorbing organic compounds from the environment.
- Fungi, along with bacteria that are found in soil, are the primary decomposers of organic matter in terrestrial ecosystems.

Review

1. Describe how fungi obtain nutrients.
2. Explain the role of saprotrophic fungi? Give an example of this role.
3. What is a mycorrhiza? What are the advantages of a mycorrhiza?

8.14 Fungi Symbiosis

FlexBooks 2.0 > Biology For High School Diploma > Fungi Symbiosis

Last Modified: Dec 14, 2021

[Figure 1]

Do all fungi feed only on dead organisms?

Not all. This is a unique organism called a **lichen**. It is a symbiotic relationship between a fungus and a photosynthetic bacterium or alga. The cell from the alga or bacterium live inside the fungus. Besides providing a home, the fungus also provides nutrient. In turn, the bacterium or the alga provides energy to the fungus by performing photosynthesis.

Symbiotic Relationships of Fungi

Not all fungi feed on dead organisms. Many are involved in symbiotic relationships, including **parasitism** and **mutualism**.

Fungi as Parasites

In a parasitic relationship, the parasite benefits while the host is harmed. Parasitic fungi live in or on other organisms and get their nutrients from them. Fungi have special structures for penetrating a host. They also produce enzyme that break down the host's tissue.

Parasitic fungi often cause illness and may eventually kill their host. They are the major cause of disease in agricultural plants. Fungi also parasitize animal, such as the insect pictured in **Figure** below. Fungi even parasitize humans. Did you ever have athelete's foot? If so, you were the host of a parasitic fungus.

[Figure 2]

Parasitic Fungus and Insect Host. The parasitic fungus named Cordyceps is shown here growing on its host—a fly.

Mutualism in Fungi

Fungi have several mutualistic relationships with other organisms. In mutualism, both organisms benefit from the relationship. Two common mutualistic relationships involving fungi are **mycorrhiza** and lichen.

- A **mycorrhiza** is a mutualistic relationship between a fungus and a plant. The fungus grows in or on the plant roots. The fungus benefits from the easy access to food made by the plant. The plant benefits because the fungus puts out mycelium that help absorb water and nutrients. Scientists think that a symbiotic relationship such as this may have allowed plants to first colonize the land.
- A **lichen** is an organism that results from a mutualistic relationship between a fungus and a photosynthetic organism. The other organism is usually a cyanobacterium or green alga. The fungus grows around the bacterial or algal cells. The fungus benefits from the constant supply of food produced by the photosynthesizer. The photosynthesizer

benefits from the water and nutrients absorbed by the fungus. **Figure** below shows lichen growing on a rock.

[Figure 3]

Lichen Growing on Rock. Unlike plants, lichen can grow on bare rocks because they don't have roots. That's why lichens are often pioneer species in primary ecological succession. How do lichen get water and nutrients without roots?

Some fungi have mutualistic relationships with insects. For example:

- Leafcutter ants grow fungi on beds of leaves in their nests. The fungi get a protected place to live. The ants feed the fungi to their larva.
- Ambrosia beetles bore holes in tree bark and "plant" fungal spores in the holes. The holes in the bark give the fungi an ideal place to grow. The beetles harvest fungi from their "garden."

https://flexbooks.ck12.org/flx/render/embeddedobject/185299

Summary

- Many fungi are involved in symbiotic relationships.
- Some fungi are parasites. They are specialized to penetrate a host and break down the host's tissues. Parasitic fungi often cause illness and may eventually kill their host.
- Two common mutualistic relationships involving fungi are mycorrhiza (fungi and plant roots) and lichen (fungi and either cyanobacteria or green algae).
- Some fungi also have mutualistic relationships with insects.

Review

1. How significant are fungi as plant parasites?
2. Describe an example of a mutualistic relationship between fungi and insects.
3. Assume that you notice a fungus growing on a plant. What possible relationships might exist between the fungus and the plant? What type of evidence might help you identify which is the correct relationship?
4. Compare and contrast mycorrhiza and lichen.

Report Content Errors

8.15 Use of Fungi

FlexBooks 2.0 > Biology For High School Diploma > Use of Fungi

Last Modified: Jul 04, 2019

[Figure 1]

What's growing on this lemon?

Would you believe **penicillin**? Penicillin is a mold, which of course is a fungus, one that has helped millions, if not billions, of people.

Human Uses of Fungi

Whenever you eat pizza, you eat fungi, even if you don't like your pizza with mushroom. That's because pizza dough contains **yeast**. Do you know other foods that are made with fungi?

Fungi for Food

Humans have collected and grown **mushrooms** for food for thousands of years. **Figure** below shows some of the many types of mushrooms that people eat. Yeasts are used in bread baking and brewing alcoholic beverages. Other fungi are used in fermenting a wide variety of foods, including soy sauce, tempeh, and cheeses. Blue cheese has its distinctive appearance and flavor because of the fungus growing though it (see **Figure** below).

[Figure 2]

These are just a few of the many species of edible mushrooms consumed by humans.

[Figure 3]

Blue Cheese. The dark blue strands running through this cheese are a fungus. In fact, this cheese is moldy! The fungus is *Penicillium roqueforti*, a type of mold.

https://flexbooks.ck12.org/flx/render/embeddedobject/185309

Fungi for Pest Control

Harmless fungi can be used to control pathogenic bacterium and insect pests on crops. Fungi compete with bacteria for nutrient and space, and they parasitize insects that eat plants. Fungi reduce the need for pesticides and other toxic chemicals.

Other Uses of Fungi

Fungi are useful for many other reasons.

- They are a major source of citric acid (vitamin C).
- They produce antibiotic such as **penicillin**, which has saved countless lives.
- They can be genetically engineered to produce insulin and other human hormone.
- They are model research organism.

https://flexbooks.ck12.org/flx/render/embeddedobject/190235

Summary

- Humans use fungi for many purposes, including as food or in the preparation of food.
- Humans also use fungi for pest control.
- In addition, fungi can be used to produce citric acid, antibiotics, and human hormones.
- Fungi are model research organisms as well.

Review

1. Describe two ways that humans use fungi.
2. How are fungi used to control pests?

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8.16 Fungi Diseases

FlexBooks 2.0 > Biology For High School Diploma > Fungi Diseases

Last Modified: Feb 26, 2022

[Figure 1]

Would you eat these mushrooms?

It would not be recommended. But certain red mushroom, *Ganoderma Lucidum*, have been found to be good for you. Red Mushrooms comprise a family of more than 200 mushroom species, which are good for our health. Of these, 6 species have a particularly high therapeutic effect.

Fungi and Human Disease

fungus cause human illness in three different ways: poisonings, parasitic infections, and allergic reactions. *science on the SPOT: Fungus Fair* explores some of these dangerous but also tasty and weirdly wonderful fungi.

Fungal Poisoning

Many fungi protect themselves from parasite and predator by producing toxic chemicals. If people eat toxic fungi, they may experience digestive problems, hallucinations, organ failure, and even death. Most cases of mushroom poisoning are due to mistaken identity. That's because many toxic mushrooms look very similar to safe, edible mushrooms. An example is shown in **Figure** below.

[Figure 2]

Poisonous or Edible? The destroying angel mushroom on the left causes liver and kidney failure. The puffball mushroom on the right is tasty and harmless. Do you think you could tell these two species of mushrooms apart?

Fungal Parasites

Some fungi cause disease when they become human parasites. Two examples are fungi in the genera *Candida* and *Trichophyton*.

- *Candida* are yeast that cause **candidiasis**, commonly called a "yeast infection." The yeast can infect the mouth or the vagina. If yeast enter the blood, they cause a potentially life threatening illness. However, this is rare, except in people with a depressed immune system.
- *Trichophyton* are fungi that cause **ringworm**. This is a skin infection characterized by a ring-shaped rash. The rash may occur on the arms, legs, head, neck, or trunk. The same fungi cause **athlete's foot** when they infect the skin between the toes. Athlete's foot is the second most common skin disease in the U.S.

Figure below shows signs of these two infections.

[Figure 3]

Ringworm produces a ring-shaped rash, but it isn't caused by a worm. It's caused by the same fungus that causes athlete's foot.

Fungal Allergies

mold allergy are very common. They are caused by airborne mold spores. When the spores enter the respiratory tract, the immune system responds to them as though they were harmful microbes. Symptoms may include sneezing, coughing, and difficulty breathing. The symptoms are likely to be more severe in people with asthma or other respiratory diseases. Long-term exposure to mold spores may also weaken the immune system.

Molds grow indoors as well as out. Indoors, they grow in showers, basements, and other damp places. Homes damaged in floods and hurricanes may have mold growing just about everywhere (see **Figure** below). Indoor mold may cause more health problems than outdoor mold because of the closed, confined space. Most people also spend more time indoors than out.

[Figure 4]

The mold growing on the walls and ceiling of this storm-damaged home may be harmful to human health.

Summary

- Fungi cause three different types of human illness: poisonings, parasitic infections, and allergies.
- Many poisonous mushrooms are eaten by mistake because they look like edible mushrooms.
- Parasitic yeasts cause candidiasis, ringworm, and athlete's foot.
- Mold allergies are very common.

Review

1. Explain why you should never eat mushrooms you find in the woods unless you know for certain which type of mushrooms they are.
2. Compare and contrast ringworm and athlete's foot.
3. How does mold cause allergies?
4. State why indoor mold may cause more health problems than outdoor mold.

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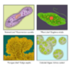	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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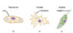	**Credit:** Miranda Dudzik **Source:** http://cnx.org/content/m48073/latest/#fig-ch23_02_02 **License:** CC BY 3.0
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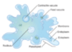	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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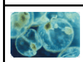	**Credit:** Maria Antónia Sampayo, Instituto de Oceanografia, Faculdade Ciências da Universidade de Lisboa **Source:** https://commons.wikimedia.org/wiki/File:Noctiluca_scintillans_varias.jpg **License:** CC BY 3.0
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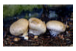	**Credit:** Bernard Spragg **Source:** https://www.flickr.com/photos/88123769@N02/40349064585 **License:** Public Domain
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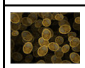	**Credit:** Zappy's **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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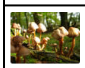	**Credit:** A Bremner **Source:** http://www.flickr.com/photos/scoobygirl/271283243/ **License:** CC BY 2.0
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CHAPTER 9

Plants

Chapter Outline

9.1 Plant Characteristics

FlexBooks 2.0 > Biology For High School Diploma > Plant Characteristics

Last Modified: Jul 04, 2019

[Figure 1]

What are plants?

Autumn. A time when leaves turn amazing colors. Of course, leaves are part of plants. But what are plants? What separates a plant from a fungus or protist? Or animal?

Plants

Imagine that human life cycles resembled those of the earliest plants. If you think about this analogy, you may begin to realize that many plants, which appear so inert to our roving eyes and active minds, actually lead secret lives of surprising variety.

You know that humans develop, or gradually change, from infant to quite different, sexually mature adults. You also know that meiosis in your own ovary or testis produces haploid egg or sperm, which must join in fertilization to become a new individual. Each of us, of course, began as that single cell made when a sperm united with an egg. Now, through mitosis and the miracle of development, we are made of trillions of cells organized into tissue, organ, and organ system, which make us complex, amazing, active, individual beings. None of us would doubt that we have changed significantly since we began as single cells. Each of us has a unique identity that we keep throughout our entire lives, until death marks our end. We may give birth to other individuals by producing eggs or sperm, but only if they join with other sperm or eggs to produce new, separate lives.

If, however, we lived like some plants, your father would not have produced the sperm cell destined to provide half of your gene, although there would be such a sperm cell. Your mother would not have produced the egg cell destined to produce the other half. In fact, your parents, and you, would not be distinguishable as male or female. Instead, both parents (or maybe just one parent) would have released thousands of haploid spore cells, each of which would grow, by mitosis, into a new individual being, entirely different in form and habitat from its parents - and you. Small spores would become males, and large spores females, but as if sperm and egg had decided to postpone their "marriage" and grow up on their own, these beings would live very different, "non-human" lives.

Who are these beings? You are certainly not one of them, because you begin only when egg meets sperm. Their differences from you would be far greater than the differences between tadpole and frog, or caterpillar and butterfly, because every individual butterfly or frog could (theoretically) identify exactly which individual caterpillar or tadpole it used to be. Not so with these haploid creatures.

At some time during their relatively long lives, the male and female beings would produce sperm cells and egg cells by mitosis. Fertilization would not involve mating, of course. Depending on which kind of plant we chose as our model, sperm might swim on their own (with two or more flagella) from male to female being, or they might be blown by the wind, or carried by an animal. After sperm and egg join, you would begin your life as a single cell, and grow into an "adult," eventually producing your own haploid spores. But you would never be able to identify your parents – if indeed you had two – nor would you know your children, because entire haploid lives would separate you. Why do plants lead such complex, multiple lives?

Most of the plants you are probably familiar with produce flower. However, plants existed for hundreds of millions of years before they evolved flowers. In fact, the earliest plants were different from most modern plants in several important ways. They not only lacked flowers, but also lacked leaves, roots, and stem. You might not even recognize them as plants. So why are the earliest plants placed in the plant kingdom? What traits define a plant?

What are Plants?

Plants are multicellular eukaryotic organism with **cell wall** made of **cellulose**. Plant cells also have **chloroplast**. In addition, plants have specialized reproductive organs. These are structures that produce reproductive cells. Male reproductive organs produce sperm, and female reproductive organs produce eggs. Male and female reproductive organs may be on the same or different plants.

How Do Plants Obtain Food?

Almost all plants make food by **photosynthesis**. Only about 1 percent of the estimated 300,000 species of plants have lost the ability to photosynthesize. These other species are consumers, many of them predator. How do plants prey on other organisms? The Venus fly trap in **Figure** below shows one way this occurs.

[Figure 2]

Venus fly trap plants use their flowers to trap insects. The flowers secrete enzymes that digest the insects, and then they absorb the resulting nutrient molecules.

What Do Plants Need?

Plants need temperatures above freezing while they are actively growing and photosynthesizing. They also need sunlight, carbon dioxide, and water for photosynthesis. Like most other organisms, plants need oxygen for cellular respiration and mineral to build protein and other organic molecule. Most plants support themselves above the ground with stiff stems in order to get light, carbon dioxide, and oxygen. Most plants also grow roots down into the soil to absorb water and minerals. And, of course, we need the energy stored in plants through photosynthesis to survive. Life as we know it would not be possible without plants.

Summary

- Plants are multicellular eukaryotes. They have organelles called chloroplasts and cell walls made of cellulose.
- Plants also have specialized reproductive organs.
- Almost all plants make food by photosynthesis.
- Life as we know it would not be possible without plants.

Review

1. What traits do all plants share?
2. How do almost all plants obtain food?
3. What do plants need? Why do they need these items?

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9.2 Importance of Plants

FlexBooks 2.0 > Biology For High School Diploma > Importance of Plants

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[Figure 1]

What is so special about this particular plant?

Look at this plant. You could say it has some interesting fruit. Some might say the fruit does not even look that tasty. However, this is a cacao tree, and its seed are the source of chocolate. So, there are some people who would argue that this is one of the most important plants in the whole plant kingdom.

The Importance of Plants

The importance of plants to humans and just about all other life on Earth is staggering. Life as we know it would not be possible without plants. Why are plants so important?

- Plants supply food to nearly all terrestrial organism, including humans. We eat either plants or other organisms that eat plants.
- Plants maintain the atmosphere. They produce oxygen and absorb carbon dioxide during **photosynthesis**. Oxygen is essential for cellular respiration for all aerobic organisms. It also maintains the ozone layer that helps protect Earth's life from damaging UV radiation. Removal of carbon dioxide from the atmosphere reduces the greenhouse effect and global warming.
- Plants recycle matter in biogeochemical cycle. For example, through **transpiration**, plants move enormous amounts of water from the soil to the atmosphere. Plants such as peas

host bacterium that fix nitrogen. This makes nitrogen available to all plants, which pass it on to consumers.

- Plants provide many products for human use, such as firewood, timber, fibers, medicines, dyes, pesticides, oils, and rubber.
- Plants create habitat for many organisms. A single tree may provide food and shelter to many species of insects, worms, small mammal, bird, and reptile (see **Figure** below).

[Figure 2]

Red-eyed tree frogs like this one live in banana trees.

We obviously can't live without plants, but sometimes they cause us problems. Many plants are **weed**. **Weeds** are plants that grow where people don't want them, such as gardens and lawns. They take up space and use resources, hindering the growth of more desirable plants. People often introduce plants to new habitats where they lack natural predator and parasite. The introduced plants may spread rapidly and drive out native plants. Many plants produce **pollen**, which can cause allergy. Plants may also produce toxins that harm human health (see **Figure** below).

[Figure 3]

Poison ivy causes allergic skin rashes. It's easy to recognize the plant by its arrangement of leaves in groups of three. That's the origin of the old saying, "leaves of three, leave it be."

Why Study Plants?

Members of the plant kingdom play many crucial and sometimes surprising roles in the drama of life on Earth. You are probably familiar with some reasons plants are important. Why should you understand how plants live? Because plants play many roles, including but certainly not limited to:

1. Supplying Food and energy
2. Maintaining Earth's Atmosphere
3. Cycling Water and Nurturing Soils
4. Contributing to Nitrogen and Other Biogeochemical Cycles
5. interdependence with animal
6. Interdependence with fungus
7. Interdependence Among Plants
8. Resources for Humans
9. Aesthetics for Humans
10. Scientific Use by Humans
11. Causing Problems

More than 100,000 natural compounds come from plants, and most of these have yet to be explored. Some of the most powerful and useful compounds come from plants. Who knew they could help us unlock some of the biology's mysteries - all using an approach of mapping biological pathways.

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Summary

- Life as we know it would not be possible without plants.

Review

1. List three reasons that plants are important to life on Earth.
2. When is a plant considered a weed?

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9.3 Plant Life Cycle

FlexBooks 2.0 > Biology For High School Diploma > Plant Life Cycle

Last Modified: Jul 04, 2019

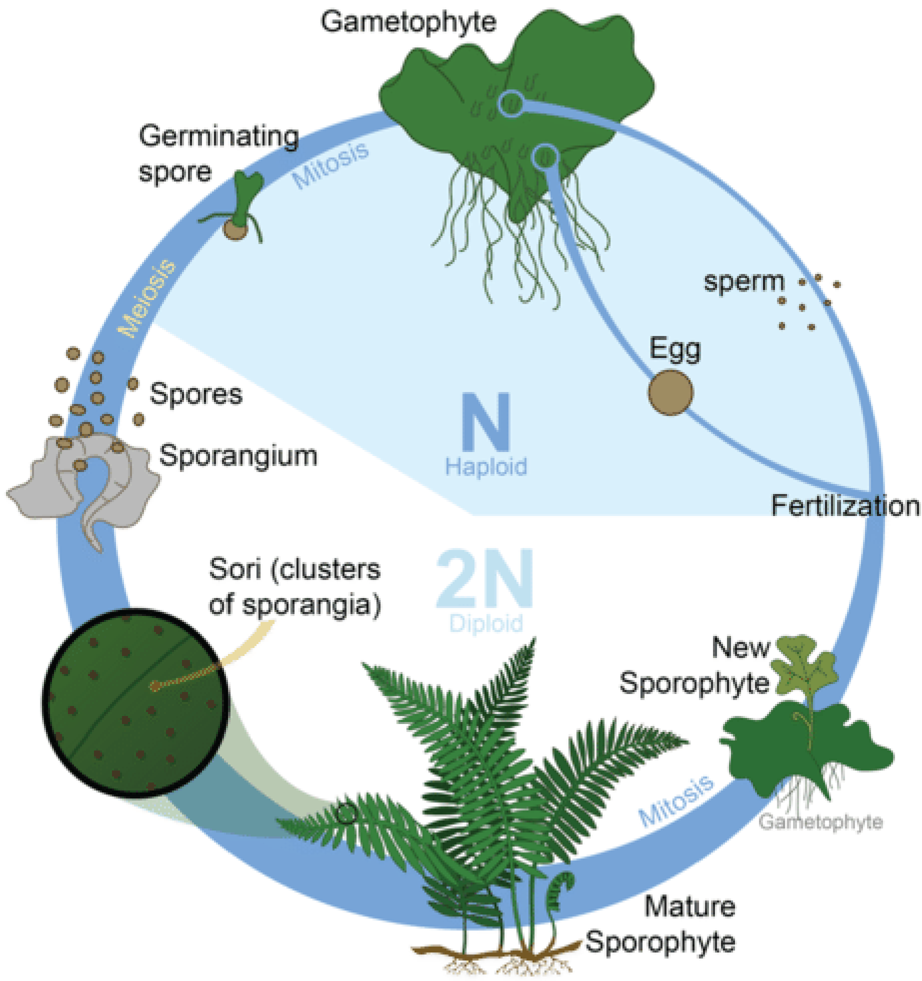
[Figure 1]

How do plants reproduce?

Is it really due to the bird and the bees? Not always. Even though it is spotted, this plant is known as the kangaroo fern, not the cheetah fern. And all those spots are spores. So what's a spore? Each spore can grow into a new individual without the need for fertilization.

Life Cycle of Plants

All plants have a characteristic **life cycle** that includes **alternation of generations**. Plants alternate between haploid and diploid generations. Alternation of generations allows for both asexual and sexual reproduction. Beginning with the diploid **sporophyte**, **spores** form from meiosis. asexual reproduction with spores produces haploid individuals called **gametophyte**, which produce haploid gamete by mitosis. Sexual reproduction with gametes and fertilization produces the diploid sporophyte. A typical plant’s life cycle is diagrammed in **Figure** below.



[Figure 2]

Life Cycle of Plants. This diagram shows the general life cycle of a plant.

Early plants reproduced mainly with spores and spent most of their life cycle as haploid gametophytes. Spores require little energy and matter to produce, and they grow into new individuals without the need for fertilization. In contrast, most modern plants reproduce with gametes using pollen and seed, and they spend most of their life cycle as diploid sporophytes. Many modern plants can also reproduce asexually using roots, stem, or leaves. This is called **vegetative reproduction**. One way this can occur is shown in **Figure** below.

[Figure 3]

Strawberry plants have horizontal stems called stolons that run over the ground surface. If they take root, they form new plants.

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Summary

- All plants have a characteristic life cycle that includes alternation of generations.
- Asexual reproduction with spores produces a haploid gametophyte generation.
- Sexual reproduction with gametes and fertilization produces a diploid sporophyte generation.

Review

1. Define alternation of generations.
2. What type of reproduction occurs in an alternation of generations life cycle?
3. Draw a diagram of a typical plant life cycle that illustrates the concept of alternation of generations.

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9.4 Plant Evolution

FlexBooks 2.0 > Biology For High School Diploma > Plant Evolution

Last Modified: Jul 04, 2019

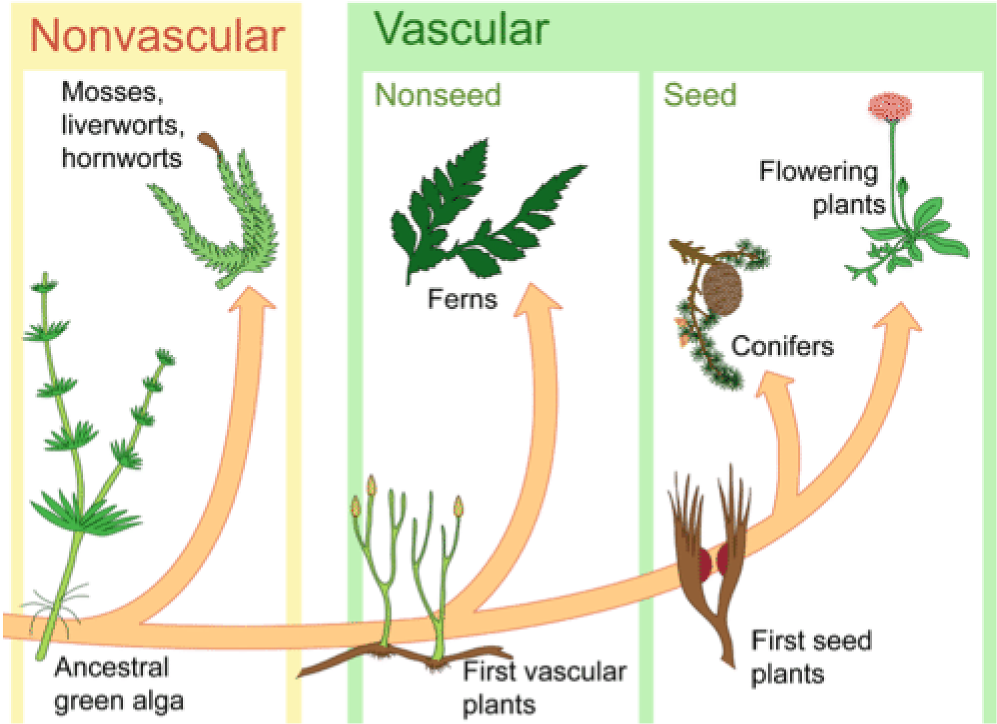
[Figure 1]

Which moved onto land first, plants or animals?

This fossilized fern may be millions of years old. Over 200 million years ago, the first evidence of ferns related to several modern families appeared. The "great fern radiation" occurred in the late-Cretaceous, which ended 65 million years ago, when many modern families of ferns first appeared. And if animal were the first on land, would many have starved?

Evolution of Plants

As shown in **Figure** below, plants are thought to have evolved from an aquatic green alga protist. Later, they evolved important adaptation for land, including **vascular tissue**, seed, and flower. Each of these major adaptations made plants better suited for life on dry land and much more successful.



[Figure 2]

From a simple, green alga ancestor that lived in the water, plants eventually evolved several major adaptations for life on land.

The Earliest Plants

The earliest plants were probably similar to the **stonewort**, an aquatic algae pictured in **Figure** below. Unlike most modern plants, stoneworts have stalks rather than stiff stem, and they have hair-like structures called **rhizoid** instead of roots. On the other hand, stoneworts have distinct male and female reproductive structures, which is a plant characteristic. For fertilization to occur, sperm need at least a thin film of moisture to swim to egg. In all these ways, the first plants may have resembled stoneworts.

[Figure 3]

Modern stoneworts may be similar to the earliest plants. Shown is a field of modern stoneworts (right), and an example from the Charophyta, a division of green algae that includes the closest relatives of the earliest plants (left).

Life on Land

By the time the earliest plants evolved, animals were already the dominant organism in the ocean. Plants were also constrained to the upper layer of water that received enough sunlight for photosynthesis. Therefore, plants never became dominant marine organisms. But when plants moved onto land, everything was wide open. Why was the land devoid of other life? Without plants growing on land, there was nothing for other organisms to feed on. Land could not be colonized by other organisms until land plants became established.

Plants may have colonized the land as early as 700 million years ago. The oldest fossil of land plants date back about 470 million years. The first land plants probably resembled modern plants called **liverwort**, like the one shown in **Figure** below.

[Figure 4]

The first land plants may have been similar to liverworts like this one.

Colonization of the land was a huge step in plant evolution. Until then, virtually all life had evolved in the ocean. Dry land was a very different kind of place. The biggest problem was the dryness. Simply absorbing enough water to stay alive was a huge challenge. It kept early plants small and low to the ground. Water was also needed for sexual reproduction, so sperm could swim to eggs. In addition, temperatures on land were extreme and always changing. Sunlight was also strong and dangerous. It put land organisms at high risk of mutation.

Vascular Plants Evolve

Plants evolved a number of adaptations that helped them cope with these problems on dry land. One of the earliest and most important was the evolution of vascular tissues. **Vascular tissues** form a plant's "plumbing system." They carry water and mineral from soil to leaves for photosynthesis. They also carry food (sugar dissolved in water) from photosynthetic cell to other cells in the plant for growth or storage. The evolution of vascular tissues revolutionized the plant kingdom. The tissue allowed plants to grow large and endure periods of drought in harsh land environments. Early vascular plant probably resembled the fern shown in **Figure** below.

[Figure 5]

Early vascular plants may have looked like this modern fern.

In addition to vascular tissues, these early plants evolved other adaptations to life on land, including **lignin**, leaves, roots, and a change in their life cycle.

- **Lignin** is a tough carbohydrate molecule that is hydrophobic ("water fearing"). It adds support to vascular tissues in stems. It also waterproofs the tissues so they don't leak, which makes them more efficient at transporting fluids. Because most other organisms cannot break down lignin, it helps protect plants from herbivore and parasite.
- Leaves are rich in chloroplast that function as solar collectors and food factories. The first leaves were very small, but leaves became larger over time.
- **Roots** are vascular organ that can penetrate soil and even rock. They absorb water and minerals from soil and carry them to leaves. They also anchor a plant in the soil. Roots evolved from rhizoids, which nonvascular plant had used for absorption.
- Land plants evolved a dominant diploid sporophyte generation. This was adaptive because diploid individuals are less likely to suffer harmful effects of mutations. They have two copies of each gene, so if a mutation occurs in one gene, they have a backup copy. This is extremely important on land, where there's a lot of solar radiation.

With all these advantages, it's easy to see why vascular plants spread quickly and widely on land. Many nonvascular plants went extinct as vascular plants became more numerous. Vascular plants are now the dominant land plants on Earth.

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Summary

- The earliest plants are thought to have evolved in the ocean from a green alga ancestor.
- Plants were among the earliest organisms to leave the water and colonize land.
- The evolution of vascular tissues allowed plants to grow larger and thrive on land.

Review

1. What were the first plants to evolve?
2. What are vascular tissues of a plant? What is their function?
3. Explain why life on land was difficult for early plants.

4. Why did plants need to become established on land before animals could colonize the land?

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9.5 Seed Plant Evolution

FlexBooks 2.0 > Biology For High School Diploma > Seed Plant Evolution

Last Modified: Jul 04, 2019

[Figure 1]

Why are they called sunflowers?

When the plant is in the bud stage, the **flower** tends to track the movement of the sun across the horizon, hence the name sunflower. Flowering plants were the last group of plants to evolve. The flower contains both the male and female reproductive structures, and these plants have become tremendously successful. But these plants could not have evolved without the prior evolution of the **seed**. So what exactly is a seed?

Seed Plants Emerge

For reproduction, early vascular plant still needed moisture. sperm had to swim from male to female reproductive organ for fertilization. Spores also needed some water to grow and often to disperse as well. Of course, dryness and other harsh conditions made it very difficult for tiny new offspring plants to survive. With the evolution of **seeds** in vascular plants, all that changed. Seed plants evolved a number of adaptation that made it possible to reproduce without water. As a result, seed plants were wildly successful. They exploded into virtually all of Earth's habitat.

Why are seeds so adaptive on land? A seed contains an embryo and a food supply enclosed within a tough coating. An embryo is a zygote that has already started to develop and grow. Early growth and development of a plant embryo in a seed is called **germination**. The seed protects and nourishes the embryo and gives it a huge head start in the "race" of life. Many seeds can wait to germinate until conditions are favorable for growth. This increases the offspring's chance of surviving even more.

Other reproductive adaptations that evolved in seed plants include **ovule**, **pollen**, pollen tubes, and pollination by animal.

- An **ovule** is a female reproductive structure in seed plants that contains a tiny female gametophyte. The gametophyte produces an egg cell. After the egg is fertilized by sperm, the ovule develops into a seed.
- A grain of **pollen** is a tiny male gametophyte enclosed in a tough capsule (see **Figure** below). It carries sperm to an ovule while preventing it from drying out. Pollen grains can't swim, but they are very light, so the wind can carry them. Therefore, they can travel through air instead of water.
- Wind-blown pollen might land anywhere and be wasted. Another adaptation solved this problem. Plants evolved traits that attract specific animal **pollinator**. Like the bee in **Figure** below, a pollinator picks up pollen on its body and carries it directly to another plant of the same species. This greatly increases the chance that fertilization will occur.
- Pollen also evolved the ability to grow a tube, called a **pollen tube**, through which sperm could be transferred directly from the pollen grain to the egg. This allowed sperm to reach an egg without swimming through a film of water. It finally freed up plants from depending on moisture to reproduce.

[Figure 2]

Individual grains of pollen may have prickly surfaces that help them stick to pollinators such as bees. What other animals pollinate plants?

Seed Plants Diverge

The first seed plants formed seeds in **cone**. **Cones** are made up of overlapping scales, which are modified leaves (see **Figure** below). Male cones contain pollen, and female cones contain eggs. Seeds also develop in female cones. Modern seed plants that produce seeds in cones are called **gymnosperm**.

[Figure 3]

Gymnosperms produce seeds in cones (left). Each scale has a seed attached (right).

Later, seed plants called **angiosperm** evolved. They produce **flowers**, which consist of both male and female reproductive structures. The female reproductive structure in a flower includes an organ called an **ovary**. Eggs form in ovules inside ovaries, which also enclose and protect developing seeds after fertilization occurs. In many species of flowering plants, ovaries develop into **fruit**, which attract animals that disperse the seeds.

Summary

- The evolution of seeds and pollen allowed plants to reproduce on land without moisture.
- Flowering plants evolved flowers with ovaries that formed fruits. They have been the most successful plants of all.

Review

1. What is a seed?
2. Describe cones.
3. Compare and contrast gymnosperms and angiosperms, and give an example of each.

4. Which major plant adaptation—vascular tissues or seeds—do you think was more important in the evolution of plants? Choose one of the two adaptations, and write a logical argument to support your choice.

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9.6 Plant Classification

FlexBooks 2.0 > Biology For High School Diploma > Plant Classification

Last Modified: Nov 23, 2021

[Figure 1]

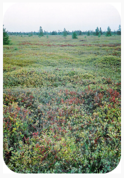
How do you know which group one particular plant belongs to?

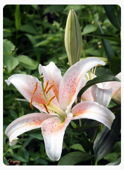
So many different types of plants. Does the plant have roots? Or **flower**? Or just **seed**? Or roots and stem but not seeds? These are all characteristics used to classify plants. How many different types of plants do you see in this Japanese garden?

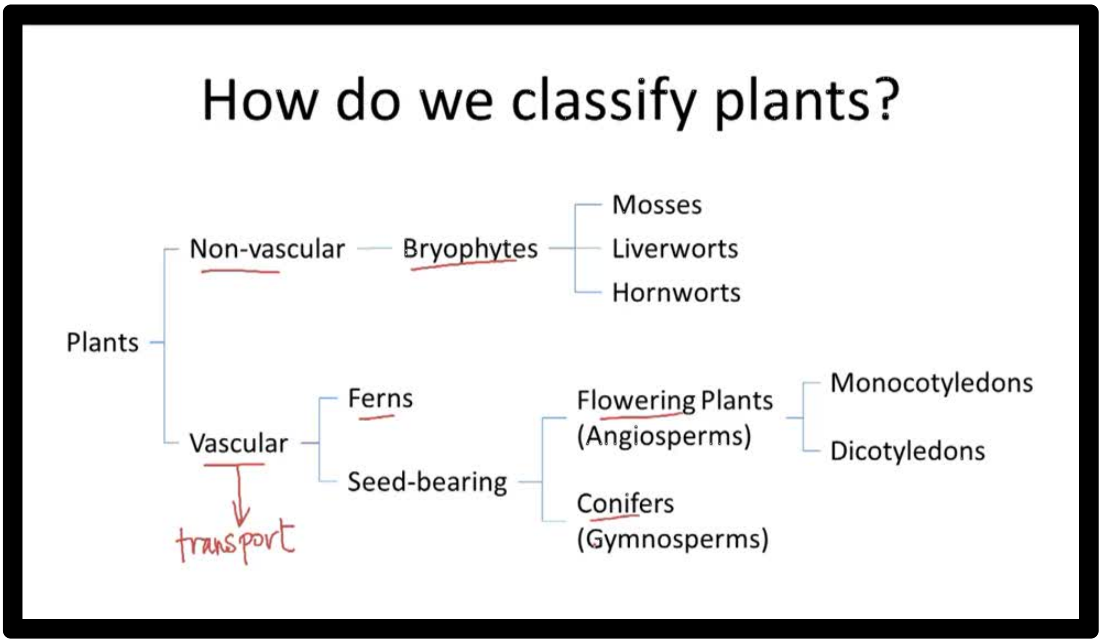
Classification of Plants

The scientific classification of modern land plants is under constant revision. Informally, land plants can be classified into the groups listed in **Table** below. Major divisions and types of modern land plants are organized in this table. Why do the first five types of plants require a moist habitat?

The most basic division is between **nonvascular plant** and **vascular plant**. Vascular plants are further divided into those that reproduce without **seeds** and those that reproduce with seeds. Seed plants, in turn, are divided into those that produce seeds in **cone** and those that produce seeds in the ovary of flowers. Seed plants are called **gymnosperm**. Seed plants called **angiosperm** produce seeds in the ovaries of **flowers**.

Major Division	Types of Plants	No. of Living Species	Description
Nonvascular Plants			
 [Figure 2]	liverwort	7,000	Most possess leaf-like, lobed, or ribbon-like photosynthetic tissue rather than leaves. They have very fine rhizoid, lack stems, and they are generally less than 10 centimeters (4 inches) tall. They often grow in colonies that carpet the ground.
 [Figure 3]	hornwort	150	Minute nonvascular plants, similar in size to liverworts. They have very fine rhizoids and lack stems. Their sporophyte are long and pointed, like tiny horns, which rise several centimeters above the gametophyte of the plant.
 [Figure 4]	**moss**	10,000	They lack leaves and roots. They have no stems, so they grow low to the ground. They reproduce with spores. They need a moist habitat.
Vascular Plants			
 [Figure 5]	clubmoss	1,200	They have roots and tiny leaves. They have no stems, so they grow low to the ground. They reproduce with spores. They need a moist habitat.
 [Figure 6]	fern	11,000	They have large leaves in frond. They have stiff stems, so they are tall growing; some are trees. They reproduce with spores. They need a moist habitat.
 [Figure 7]	**ginkgo**	1	There is only one living species (Ginkgo biloba); some living trees are more than 2000 years old; they originated in Asia but now are cultivated all over the world; they have been used for medicines for thousands of years.
 [Figure 8]	**cycad**	300	Most are trees with stout trunks and fern-like leaves; they live only in tropical and subtropical climates; they have large, brightly-colored seed cones to attract animal pollinator.
	conifer	700	There are more than 700 living species; most are trees such as pines with needle-like leaves; they are often the dominant plants in their habitats; they are valuable to humans for paper and timber.

[Figure 9]			
 [Figure 10]	Gnetae	70	Most are woody vines with evergreen leaves; they live mainly in tropical climates; they are the least well known gymnosperms but the most similar to angiosperms.
 [Figure 11]	Flowering Plants	258,650	They have tremendous diversity in size, shape, and other characteristics. They reproduce with seeds and pollen. They produce seeds in the ovaries of flowers. Ovaries may develop into fruit, which enhance seed dispersal.



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Summary

The most basic division of living plants is between nonvascular and vascular plants.

- Vascular plants are further divided into seedless and seed plants.

- Seed plants called gymnosperms produce seeds in cones.
- Seed plants called angiosperms produce seeds in the ovaries of flowers.

Review

1. Compare the different types of plants in the **Table** above. Which type of plants would you say is most successful? Support your answer with data from the table.

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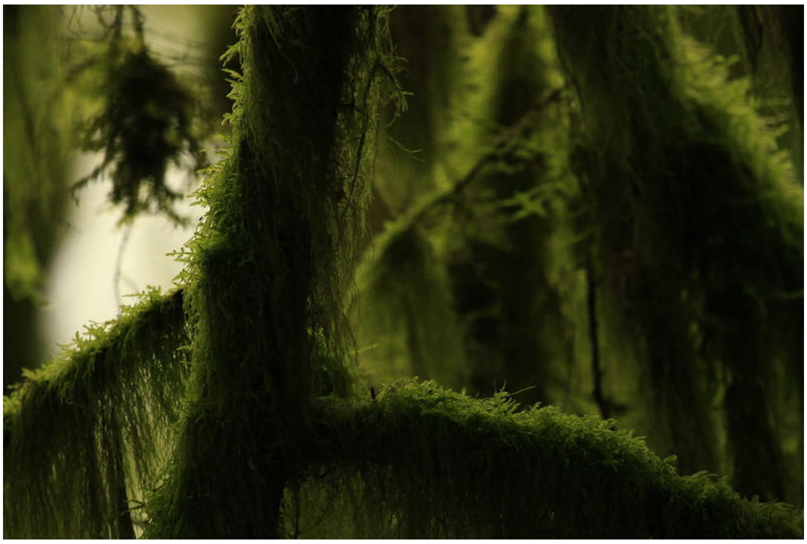
9.7 Nonvascular Plants

FlexBooks 2.0 > Biology For High School Diploma > Nonvascular Plants

Last Modified: Jul 04, 2019



[Figure 1]

Do all plants have roots?

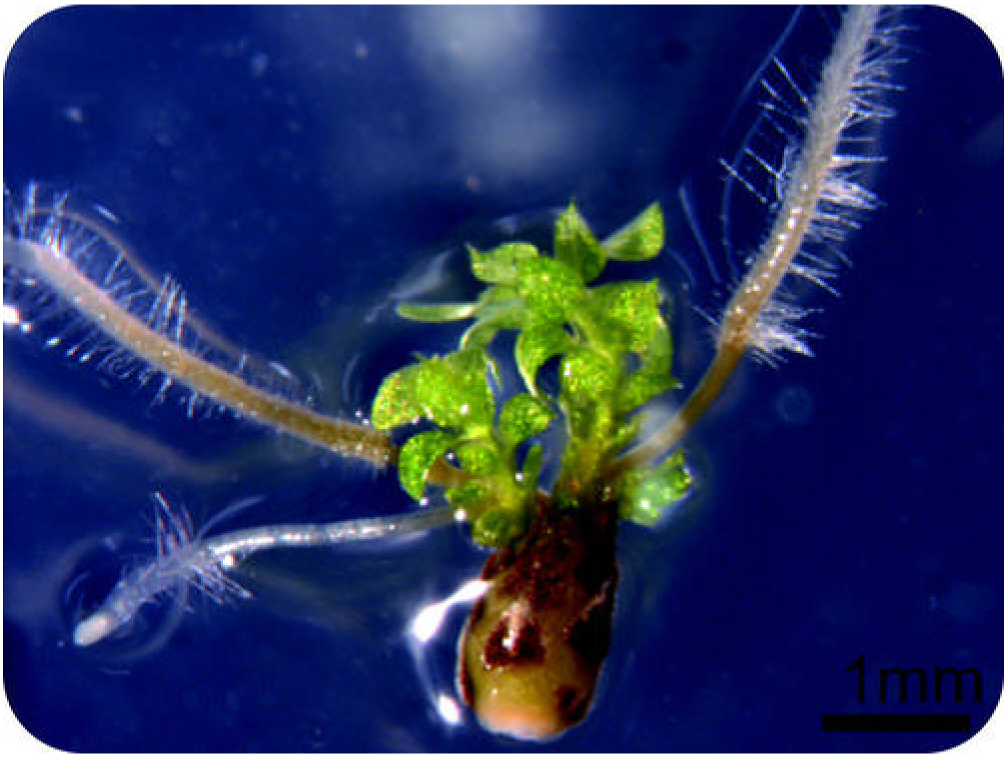
The massive **moss** covering these branches seems to be dominating its habitat. And maybe it is. Mosses, being nonvascular plants, don't need roots to grow, so they can easily cover moist areas. Mosses commonly grow close together in clumps or mats in damp or shady locations. You may even have mats of moss growing in your backyard.

Nonvascular Plants

Nonvascular plants are **bryophyte**. Despite the dominance of vascular plant today, more than 17,000 species of bryophytes still survive. They include **liverwort, hornwort,** and **mosses.**

Characteristics of Nonvascular Plants

Most bryophytes are small. They not only lack vascular tissue; they also lack true leaves, seed, and flower. Instead of roots, they have hair-like **rhizoid** to anchor them to the ground and to absorb water and mineral (see **Figure** below). Bryophytes occupy niches in moist habitats, but, as they lack vascular tissue, they are not very efficient at absorbing water.



[Figure 2]

The rhizoids of a bryophyte may be so fine that they are just one cell thick.

Bryophytes also depend on moisture to reproduce. sperm produced by a male gametophyte must swim through a layer of rainwater or dew to reach an egg produced by a female gametophyte. The tiny, diploid sporophyte generation then undergoes meiosis to produce haploid spores. The spores may also need moisture to disperse.

Evolution of Nonvascular Plants

Nonvascular plants were the first plants to evolve. Compared to other plants, their small size and lack of specialized structures, such as vascular tissue, stem, leaves, or flowers, explains why these plants evolved first. The first nonvascular plants to evolve were the liverworts. The hornworts evolved somewhat later, and mosses apparently evolved last. Of all the bryophytes, mosses are most similar to vascular plants. Presumably, they share the most recent common ancestor with vascular plants.

Diversity of Nonvascular Plants

The three types of modern nonvascular plants are pictured in **Figure** below.

- Liverworts are tiny nonvascular plants that have leaf-like, lobed, or ribbon-like photosynthetic tissue rather than leaves. Their rhizoids are very fine, they lack stems, and they are generally less than 10 centimeters (4 inches) tall. They often grow in colonies that carpet the ground.

- Hornworts are minute nonvascular plants, similar in size to liverworts. They also have very fine rhizoids and lack stems. Their sporophytes are long and pointed, like tiny horns. They rise several centimeters above the gametophytes of the plant.
- Mosses are larger nonvascular plants that have coarser, multicellular rhizoids that are more like roots. They also have tiny, photosynthetic structures similar to leaves that encircle a central stem-like structure. Mosses grow in dense clumps, which help them retain moisture.

[Figure 3]

Liverworts, hornworts, and mosses are modern bryophytes. Liverworts are named for the liver-shaped leaves of some species. Hornworts are named for their horn-like sporophytes.

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Summary

- Nonvascular plants are called bryophytes.
- Nonvascular plants include liverworts, hornworts, and mosses. They lack roots, stems, and leaves.
- Nonvascular plants are low-growing, reproduce with spores, and need a moist habitat.

Review

1. Describe nonvascular plants.
2. What is a rhizoid?
3. Why were nonvascular plants the first plants to evolve?

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9.8 Vascular Plants

FlexBooks 2.0 > Biology For High School Diploma > Vascular Plants

Last Modified: Nov 23, 2021

[Figure 1]

How does water move from the roots to the top of these trees?

Redwood trees found in Yosemite National Park in California. Big? Of course. How do these trees grow so tall? It has a lot to do with a very efficient system to move water, sugars and other nutrient. But the first plants to have such a "vascular system" were not tall trees, but much smaller plants.

Vascular Plants

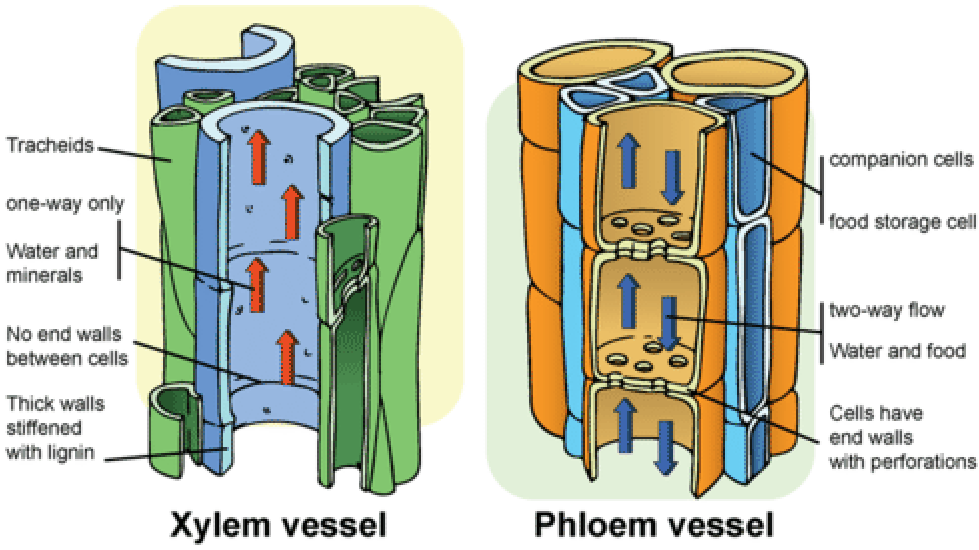
Vascular plants are known as **tracheophytes**, which literally means “tube plants.” The earliest vascular plants quickly came to dominate terrestrial ecosystem. Why were they so successful? It was mainly because of their tube-like vascular tissue.

Vascular Tissues

The vascular tissues for which these plants are named are specialized to transport fluid. They consist of long, narrow cell arranged end-to-end, forming tubes. There are two different types of vascular tissues, called xylem and phloem. Both are shown in **Figure** below.

- **Xylem** is vascular tissue that transports water and dissolved mineral from roots to stem and leaves. This type of tissue consists of dead cells that lack end walls between adjacent cells. The side walls are thick and reinforced with lignin, which makes them stiff and water proof.

- **Phloem** is vascular tissue that transports food (sugar dissolved in water) from photosynthetic cells to other parts of the plant for growth or storage. This type of tissue consists of living cells that are separated by end walls with tiny perforations, or holes.



[Figure 2]

Xylem and phloem are the two types of vascular tissues in vascular plants.

Evolution of Vascular Plants

The first vascular plants evolved about 420 million years ago. They probably evolved from moss-like bryophyte ancestors, but they had a life cycle dominated by the diploid sporophyte generation. As they continued to evolve, early vascular plants became more plant-like in other ways as well.

- Vascular plants evolved true **roots** made of vascular tissues. Compared with rhizoid, roots can absorb more water and minerals from the soil. They also anchor plants securely in the ground, so plants can grow larger without toppling over.
- Vascular plants evolved **stems** made of vascular tissues and **lignin**. Because of lignin, stems are stiff, so plants can grow high above the ground where they can get more light and air. Because of their vascular tissues, stems keep even tall plants supplied with water so they don't dry out in the air.
- Vascular plants evolved **leaves** to collect sunlight. At first, leaves were tiny and needle-like, which helped reduce water loss. Later, leaves were much larger and broader, so plants could collect more light.

With their vascular tissues and other adaptation, early vascular plants had the edge over nonvascular plant. They could grow tall and take advantage of sunlight high up in the air. Bryophytes were the photosynthetic pioneers onto land, but early vascular plants were the photosynthetic pioneers into air.

Diversity of Seedless Vascular Plants

Surviving descendants of early vascular plants include **clubmoss** and **fern**. There are 1,200 species of clubmoss and more than 20,000 species of fern. Both types of vascular plants are seedless and reproduce with spores. Two examples are pictured in **Figures** below and below.

- Clubmosses look like moss and grow low to the ground. Unlike mosses, they have roots, stems, and leaves, although the leaves are very small.
- Ferns look more like "typical" plants. They have large leaves and may grow very tall. Some even develop into trees.

[Figure 3]

Clubmosses like these are often confused with mosses.

[Figure 4]

There's no confusing ferns with mosses. Why do these ferns look more plant-like?

Summary

- Vascular plants are known as tracheophytes.
- Vascular tissues include xylem and phloem. They allow plants to grow tall in the air without drying out.
- Vascular plants also have roots, stems, and leaves.

Review

1. Compare xylem to phloem.
2. How did vascular tissues and lignin allow vascular plants to be "photosynthetic pioneers into air"?
3. Why are roots more advantageous to a plant than rhizoids?
4. What benefits do stems provide to a plant?

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9.9 Seed Plants

FlexBooks 2.0 > Biology For High School Diploma > Seed Plants

Last Modified: Nov 09, 2021

[Figure 1]

How old can a plant be?

This is obviously a seed plant. It is a Gingko tree, which is an unique species in that there are no close living relatives. Gingkoes can live for a very long time. Some specimens of this species are thought to be over 2,500 years old. The **ginkgo** is also known as a living fossil, with fossils related to modern Ginkgo from the Permian period, dating back 270 million years.

Seed Plants

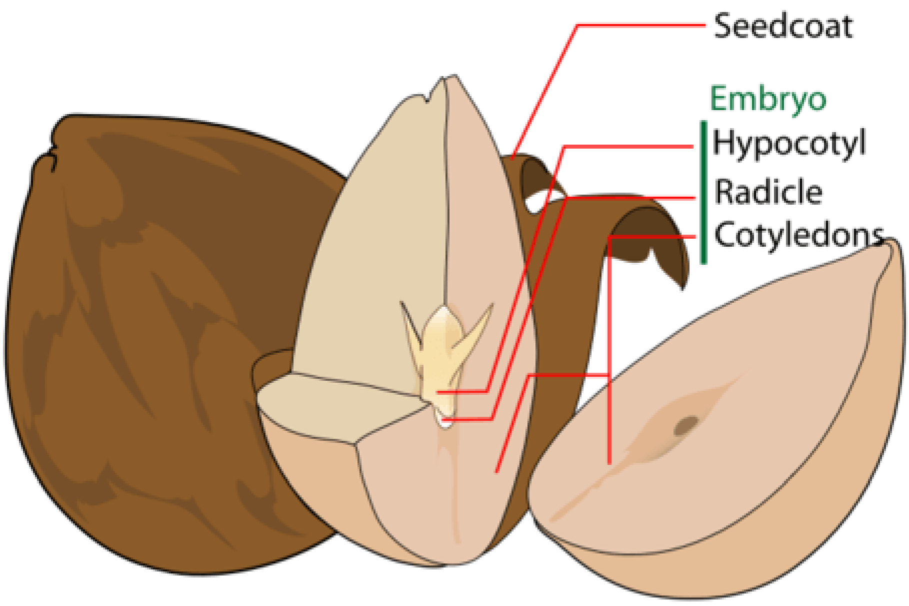
Seed plants are called **spermatophytes**. The evolution of seeds by vascular plants was a very big deal. In fact, it was arguably as important as the evolution of vascular tissue. Seeds solved the problem of releasing offspring into a dry world. Once seeds evolved, vascular seed plants and their descendants diversified to fill terrestrial niches everywhere. Today, vascular seed plants dominate Earth.

Parts of a Seed

As shown in **Figure** below, a seed consists of at least three basic parts: the embryo, **seed coat**, and stored food.

- The **embryo** develops from a fertilized egg. While still inside the seed, the embryo forms its first leaf (**cotyledon**) and starts to develop a stem (hypocotyl) and root (radicle).

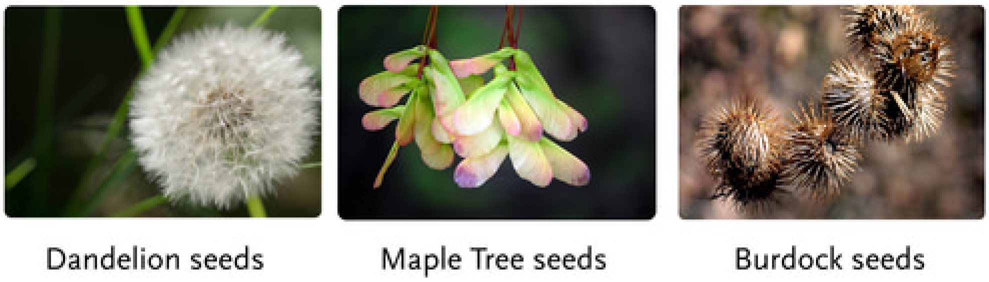
- The tough **seed coat** protects the embryo and keeps it from drying out until conditions are favorable for germination.
- The stored food in a seed is called **endosperm**. It nourishes the embryo until it can start making food on its own.



[Figure 2]

A typical plant seed, like this avocado seed, contains an embryo, seed coat, and endosperm. How does each part contribute to the successful development of the new plant?

Many seeds have additional structures that help them disperse. Some examples are shown in **Figure** below. Structures may help them travel in the wind or stick to animals. dispersal of seeds away from parent plants helps reduce competition with the parents and increases the chance of offspring surviving.

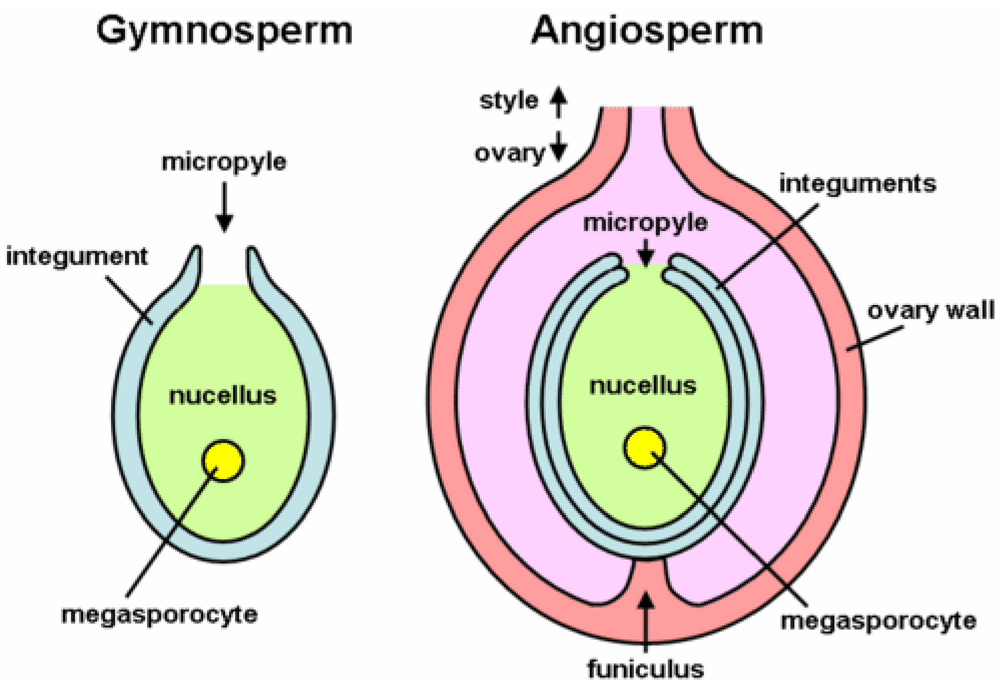


[Figure 3]

Dandelion seeds have tiny "parachutes." Maple seeds have "wings" that act like little gliders. Burdock seeds are covered with tiny hooks that cling to animal fur.

Classification of Seed Plants

The two major types of seed plants are the **gymnosperm** (seeds in cones) and **angiosperm** (seeds in ovary of flowers). **Figure** below shows how the seeds of gymnosperms and angiosperms differ. Do you see the main difference between the two seeds? The angiosperm seed is surrounded by an **ovary**.



[Figure 4]

In gymnosperms, a seed develops on the scale of a cone. Only an angiosperm seed develops inside an ovary.

There are only about 1,000 living species of gymnosperms, whereas there are hundreds of thousands of living species of angiosperms. Living gymnosperms are typically classified in the divisions described in the **Table** below. Most modern gymnosperms are trees with woody trunks. The majority are conifer such as pine trees.

	Division	Description
 [Figure 5]	Ginkgoes	There is only one living species (Ginkgo biloba); some living trees are more than 2000 years old; they originated in Asia but now are cultivated all over the world; they have been used for medicines for thousands of years.
 [Figure 6]	Conifers	There are more than 700 living species; most are trees such as pines with needle-like leaves; they are often the dominant plants in their habitat; they are valuable to humans for paper and timber.
 [Figure 7]	**cycad**	There are about 300 living species; they are typically trees with stout trunks and fern-like leaves; they live only in tropical and subtropical climates; they have large, brightly-colored seed cone to attract animal pollinator.
 [Figure 8]	Gnetae	There are fewer than 100 living species; most are woody vines with evergreen leaves; they live mainly in tropical climates; they are the least well known gymnosperms but the most similar to angiosperms.

Evolution of Seed Plants

The earliest seed plants probably evolved close to 300 million years ago. They were similar to modern ginkgoes and reproduced with pollen and seeds in cones. Early seed plants quickly came to dominate forests during the Mesozoic Era, or Age of the Dinosaurs, about 250 to 65 million years ago.

As seed plants continued to evolve, Earth's overall climate became drier, so early seed plants evolved adaptation to help them live with low levels of water. Some also evolved adaptations to cold. They had woody trunks and needle-like, evergreen leaves covered with a thick coating of waxy cuticle to reduce water loss. Some of the trees were huge, like today's giant sequoia, a modern conifer (see **Figure** below).

The person standing at the foot of this giant sequoia shows just how enormous the tree is. Some early seed plants also grew very large.

Eventually, some gymnosperms started to evolve angiosperm-like traits. For example, cycad ancestors were the first plants to use insects as pollinators. They also used birds and monkeys to disperse their brightly colored seeds. Of modern gymnosperms, Gnetae probably share the most recent common ancestor with angiosperms. Among other similarities, Gnetae produce **nectar**, a sweet, sugary liquid that attracts insect pollinators. Most modern flowering plants also produce nectar.

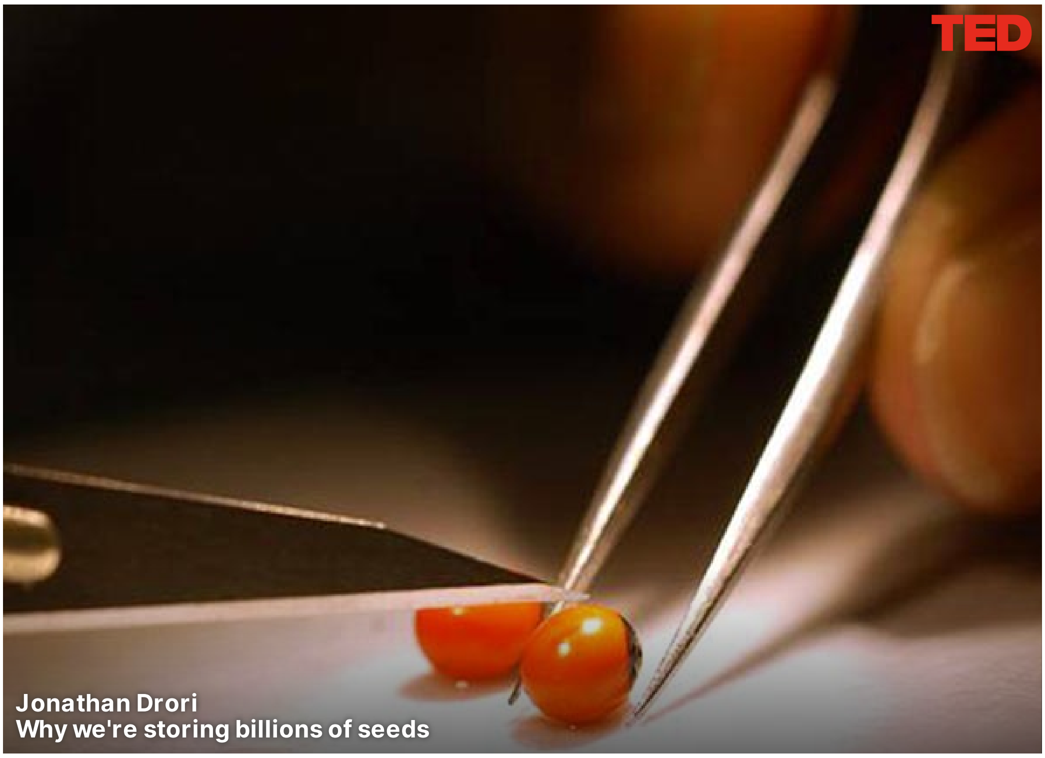
Summary

- Most vascular plants are seed plants, or spermatophytes. They reproduce with seeds and pollen.
- Some modern seed plants are gymnosperms that produce seeds in cones.

Review

1. Identify the parts of a seed and the role of each part.
2. Name and describe the divisions of gymnosperms.

Resources



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9.10 Angiosperm

FlexBooks 2.0 > Biology For High School Diploma > Angiosperm

Last Modified: Sep 28, 2021

[Figure 1]

So what exactly is a flower?

This closeup view of a lily flower shows the fine detail of this structure. Why are flowers so colorful? What is the purpose of all the parts? They were one of the last adaptation of the plant kingdom, suggesting immense evolutionary significance.

Flowering Plants

Angiosperms, or flowering seed plants, form seeds in ovary. As the seeds develop, the ovaries may develop into fruit. Flowers attract pollinator, and fruits encourage animal to disperse the seeds.

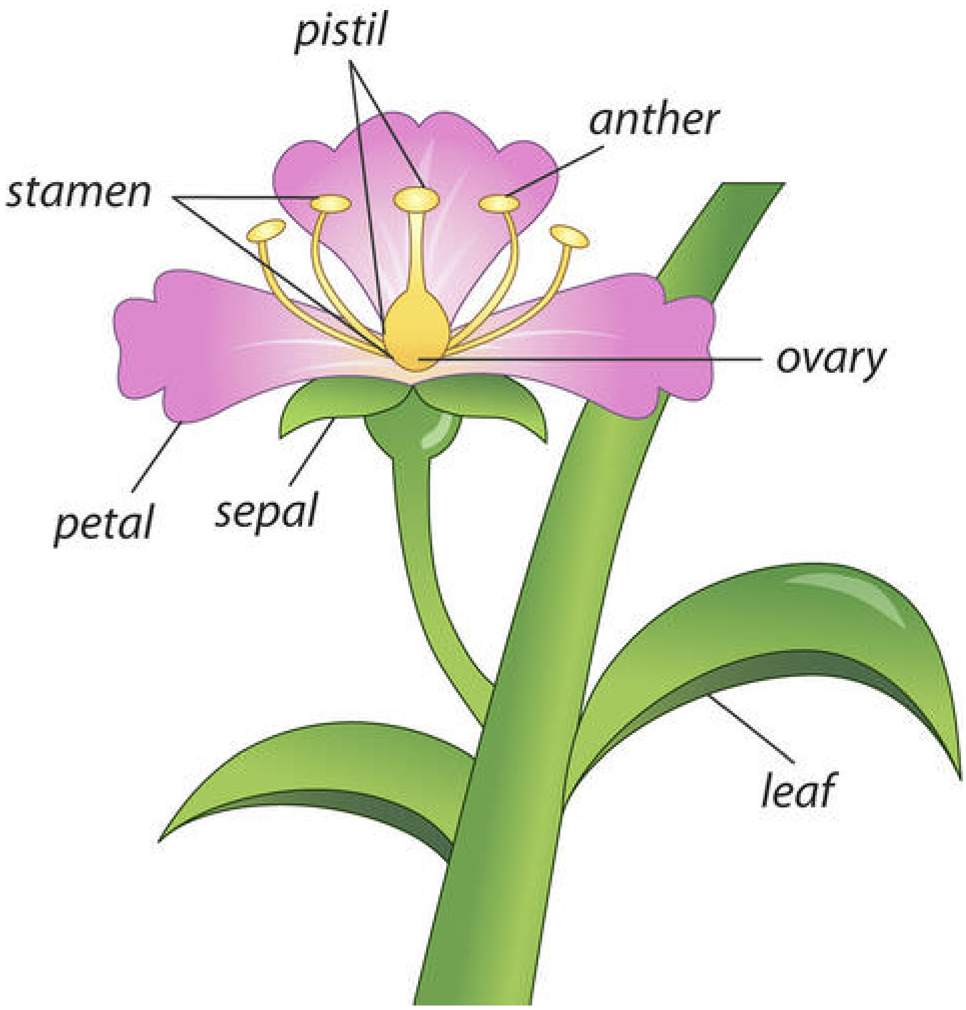
Parts of a Flower

A flower consists of male and female reproductive structures. The main parts of a flower are shown in **Figure** below. They include the **stamen**, **pistil**, **petal**, and **sepal**.

- The **stamen** is the male reproductive structure of a flower. It consists of a stalk-like filament that ends in an **anther**. The anther contains pollen sacs, in which meiosis occurs and pollen grains form. The filament raises the anther up high so its **pollen** will be more likely to blow in the wind or be picked up by an animal pollinator.
- The **pistil** is the female reproductive structure of a flower. It consists of a **stigma, style**, and **ovary**. The stigma is raised and sticky to help it catch pollen. The style supports the

stigma and connects it to the ovary, which contains the egg. **Petals** attract pollinators to the flower. Petals are often brightly colored so pollinators will notice them.

- **Sepals** protect the developing flower while it is still a bud. Sepals are usually green, which camouflages the bud from possible consumers.



[Figure 2]

A flower includes both male and female reproductive structures.

Flowers and Pollinators

Many flowers have bright colors, strong scents, and sweet nectar to attract animal pollinators. They may attract insects, bird, mammal, and even reptile. While visiting a flower, a pollinator picks up pollen from the anthers. When the pollinator visits the next flower, some of the pollen brushes off on the stigma. This allows cross-pollination, which increases genetic diversity.

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Other Characteristics of Flowering Plants

Although flowers and their components are the major innovations of angiosperms, they are not the only ones. Angiosperms also have more efficient vascular tissue. Additionally, in many flowering plants the ovaries ripen into fruits. Fruits are often brightly colored, so animals are likely to see and eat them and disperse their seeds (see **Figure** below).

[Figure 3]

Brightly colored fruits attract animals that may disperse their seeds. It's hard to miss the bright red apples on these trees.

Evolution of Flowering Plants

Flowering plants are thought to have evolved at least 200 million years ago from gymnosperm like Gnetae. The earliest known fossil of flowering plants are about 125 million years old. The fossil flowers have male and female reproductive organ but no petals or sepals.

Scientists think that the earliest flowers attracted insects and other animals, which spread pollen from flower to flower. This greatly increased the efficiency of fertilization over wind-spread pollen, which might or might not actually land on another flower. To take better advantage of this “animal labor,” plants evolved traits such as brightly colored petals to attract pollinators. In exchange for pollination, flowers gave the pollinators nectar.

Giving free nectar to any animal that happened to come along was not an efficient use of resources. Much of the pollen might be carried to flowers of different species and therefore wasted. As a result, many plants evolved ways to “hide” their nectar from all but very specific pollinators, which would be more likely to visit only flowers of the same species. For their part, animal pollinators co-evolved traits that allowed them to get to the hidden nectar. Two examples of this type of co-evolution are shown in **Figure** below.

[Figure 4]

The sphinx moth has a long narrow proboscis to reach nectar at the bottom of the tube-shaped flowers. The bat is active at night, so bright white, night-blooming flowers attract it. In each case, the flowering plant and its pollinator co-evolved to become better suited for their roles in the symbiotic relationship.

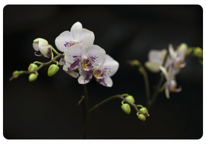
Some of the most recent angiosperms to evolve are grasses. Humans started domesticating grasses such as wheat about 10,000 years ago. Why grasses? They have many large, edible seeds that contain a lot of nutritious stored food. They are also relatively easy to harvest. Since then, humans have helped shaped the evolution of grasses, as illustrated by the example in **Figure** below. Grasses supply most of the food consumed by people worldwide. What other grass seeds do you eat?

[Figure 5]

The plant on the left, called teosinte, is the ancestor of modern, domesticated corn, shown on the right. An intermediate stage is pictured in the middle. How were humans able to change the plant so dramatically?

Classification of Flowering Plants

There are more than a quarter million species of flowering plants, and they show tremendous diversity. Nonetheless, almost all flowering plants fall into one of three major groups: **monocot, eudicot**, or **magnolid**. The three groups differ in several ways. For example, monocot embryo form just one **cotyledon**, whereas eudicot and magnolid embryos form two cotyledons. The arrangement of their vascular tissues is also different. Examples of the three groups of flowering plants are given in **Table** below.

Group	Sample Families	Sample Families
Monocots	Grasses  [Figure 6]	Orchids  [Figure 7]
Eudicots	Daisies  [Figure 8]	Peas  [Figure 9]
Magnolids	Magnolias  [Figure 10]	Avocados  [Figure 11]

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Summary

- Most modern seed plants are angiosperms that produce seeds in the ovaries of flowers.
- Ovaries may develop into fruits.
- Flowers attract pollinators and fruits are eaten by animals. Both traits aid the dispersal of seeds.

Review

1. Describe the male and female reproductive structures of flowers.
2. State how fruits help flowering plants reproduce.
3. Explain how flowering plants and their animal pollinators co-evolved.
4. Define monocot.

Report Content Errors

9.11 Plant Cell

FlexBooks 2.0 > Biology For High School Diploma > Plant Cell

Last Modified: Mar 24, 2020

[Figure 1]

Why do plant cells look like little rectangles?

A section of a pine embryo. Notice how all the cell seem to stack on each other, with no spaces in between. MIght this allow the cells to form structures that can grow upright?

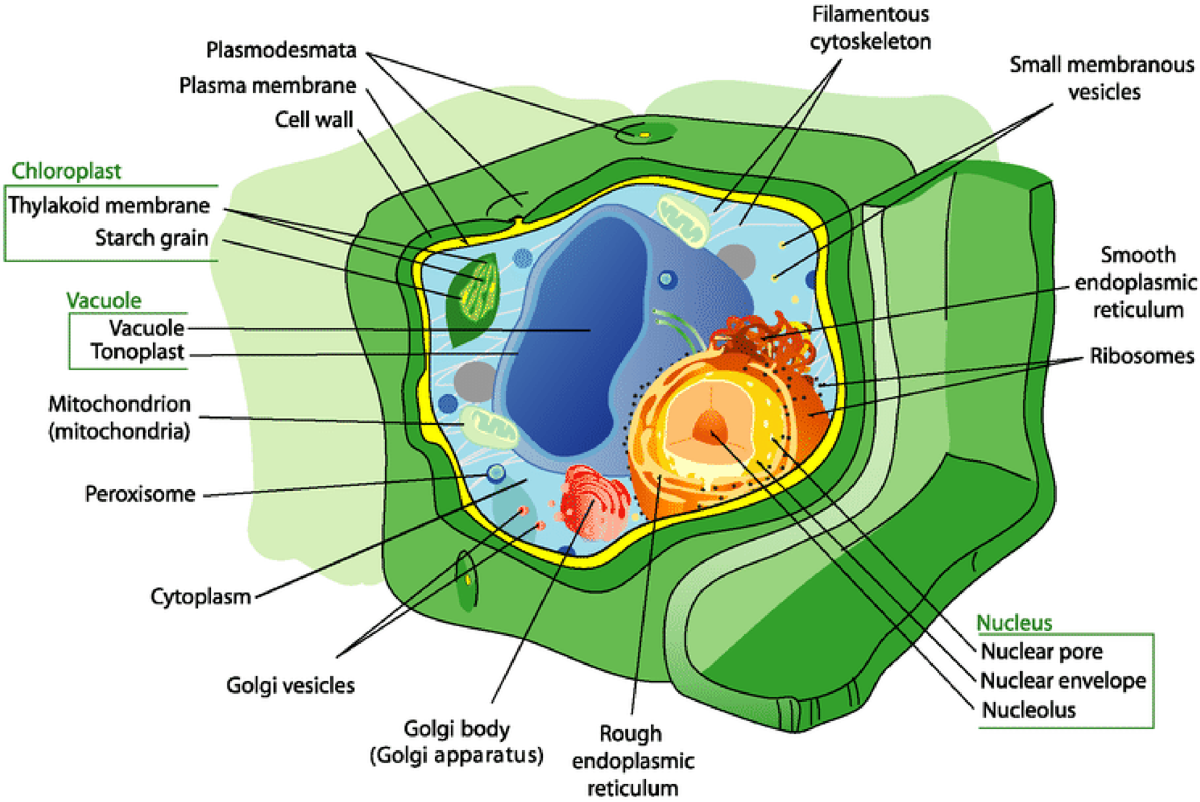
Organs in Plants?

Your body includes organ system, such as the digestive system, made of individual organ, such as the stomach, liver, and pancreas, which work together to carry out a certain function (in this case, breaking down and absorbing food). These organs, in turn, are made of different kinds of tissue, which are groups of cells which work together to perform a specific job. For example, your stomach is made of muscle tissue to facilitate movement and glandular tissue to secrete enzyme for chemical breakdown of food molecules. These tissues, in turn, are made of cells specialized in shape, size, and component organelle, such as mitochondrion for energy and microtubule for movement.

Plants, too, are made of organs, which in turn are made of tissues. Plant tissues, like ours, are constructed of specialized cells, which in turn contain specific organelles. It is these cells, tissues, and organs that carry out the dramatic lives of plants.

Plant Cells

Plant cells resemble other eukaryotic cell in many ways. For example, they are enclosed by a plasma membrane and have a nucleus and other membrane-bound organelles. A typical plant cell is represented by the diagram in **Figure** below.



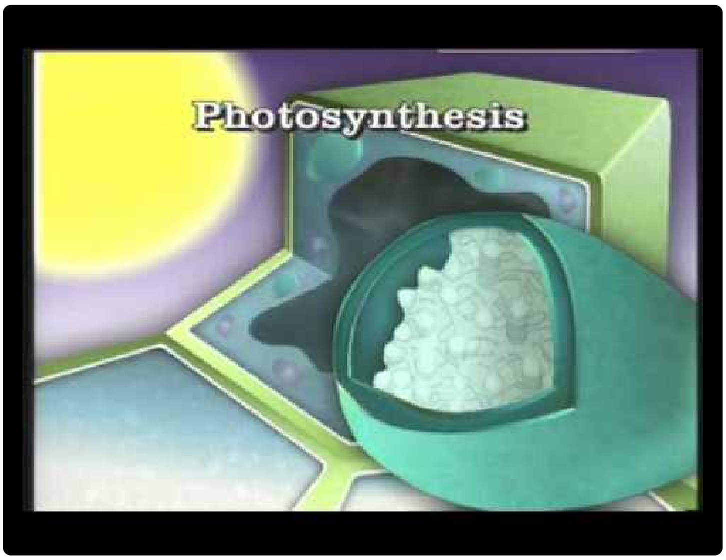
[Figure 2]

Plant cells have all the same structures as animal cells, plus some additional structures. Can you identify the unique plant structures in the diagram?

Plant Cell Structures

Structures found in plant cells but not animal cells include a large **central vacuole**, **cell wall**, and **plastid** such as **chloroplast**.

- The large **central vacuole** is surrounded by its own membrane and contains water and dissolved substances. Its primary role is to maintain pressure against the inside of the cell wall, giving the cell shape and helping to support the plant.
- The **cell wall** is located outside the cell membrane. It consists mainly of **cellulose** and may also contain **lignin**, which makes it more rigid. The cell wall shapes, supports, and protects the cell. It prevents the cell from absorbing too much water and bursting. It also keeps large, damaging molecules out of the cell.
- **Plastids** are membrane-bound organelles with their own DNA. Examples are chloroplasts and **chromoplast**. **Chloroplasts** contain the green pigment **chlorophyll** and carry out **photosynthesis**. Chromoplasts make and store other pigments. They give flower petal their bright colors.



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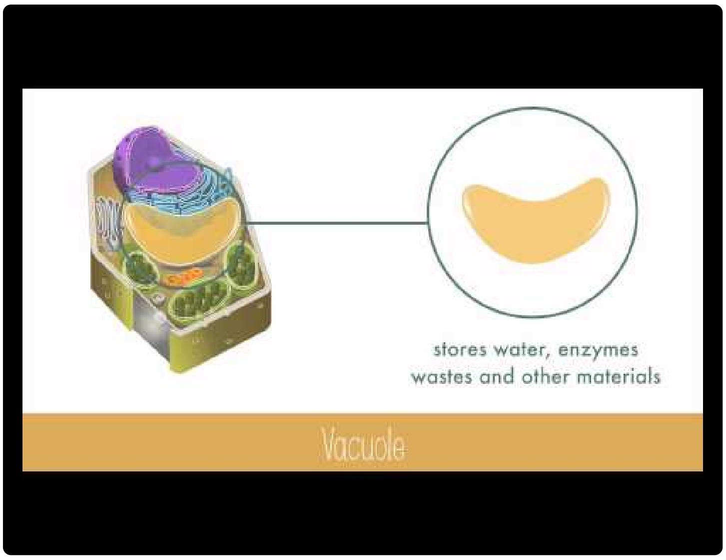
Types of Plant Cells

There are three basic types of cells in most plants. These cells make up ground tissue, which will be discussed in another concept. The three types of cells are described in **Table** below. The different types of plant cells have different structures and functions.

Type of Cell	Structure	Functions	Example
parenchymal	cube-shaped loosely packed thin-walled relatively unspecialized contain chloroplasts	photosynthesis cellular respiration storage	food storage tissues of potatoes  [Figure 3]
collenchymal	elongated irregularly thickened walls	support wind resistance	*strings* running through a stalk of celery  [Figure 4]
sclerenchymal	very thick cell walls containing lignin	support strength	tough fibers in jute (used to make rope)  [Figure 5]



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Summary

- Plants have eukaryotic cells with large central vacuoles, cell walls containing cellulose, and plastids such as chloroplasts and chromoplasts.
- Different types of plant cells include parenchymal, collenchymal, and sclerenchymal cells. The three types differ in structure and function.

Review

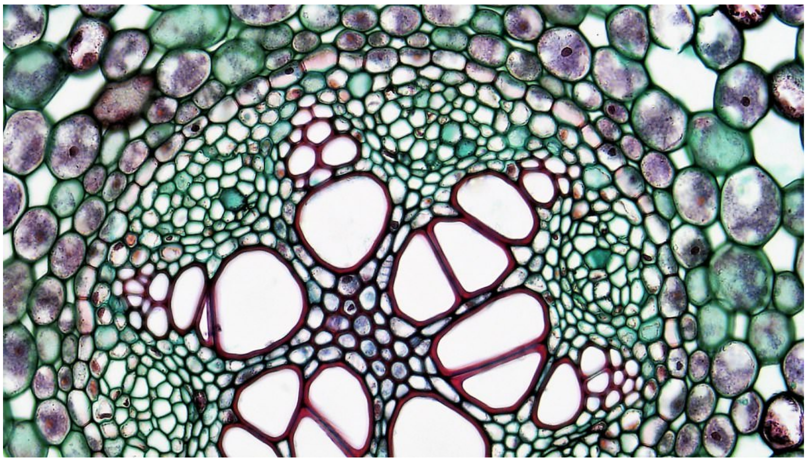
1. Identify three structures found in plant cells but not animal cells. What is the function of each structure?
2. Describe parenchymal plant cells and state their functions.

Report Content Errors

9.12 Plant Tissue

FlexBooks 2.0 > Biology For High School Diploma > Plant Tissue

Last Modified: May 16, 2021



[Figure 1]

What is this abstract pattern?

Is it just a random artistic piece? Is it a depiction of a pattern of bubbles? Would you believe it is part of a plant? It is actually a cross section of an Acorus root. And these are all cell. Cells that have come together to form a tissue, with a specific function. What do you think is the main function of tissue in a plant's root?

Plant Tissues

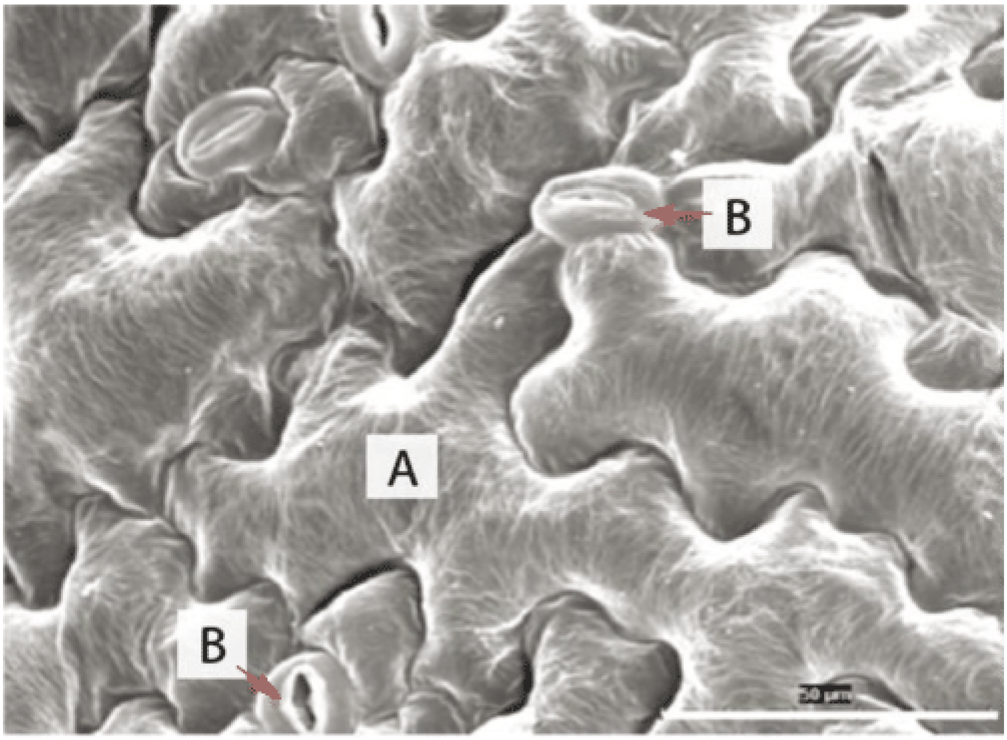
As for all animal, your body is made of four types of tissue: epithelial, muscle, nerve, and connective tissue. Plants, too, are built of tissues, but not surprisingly, their very different lifestyles derive from different kinds of tissues. All three types of plant cells are found in most plant tissues. Three major types of plant tissues are dermal, ground, and **vascular tissue**.

Dermal Tissue

dermal tissue covers the outside of a plant in a single layer of cells called the **epidermis**. You can think of the epidermis as the plant's skin. It mediates most of the interactions between a plant and its environment. Epidermal cells secrete a waxy substance called **cuticle**, which coats, waterproofs, and protects the above-ground parts of plants. Cuticle helps prevent water loss, abrasions, infections, and damage from toxins.

This tissue includes several types of specialized cells. Pavement cells, large, irregularly shaped parenchymal cells which lack chloroplast, make up the majority of the epidermis.

Within the epidermis, thousands of pairs of bean-shaped schlerenchymal **guard cell** swell and shrink by osmosis to open and close **stoma**, tiny pores which control the exchange of oxygen and carbon dioxide gases and the release of water vapor. The lower surfaces of some leaves contain as many as 100,000 stomata per square centimeter.



[Figure 2]

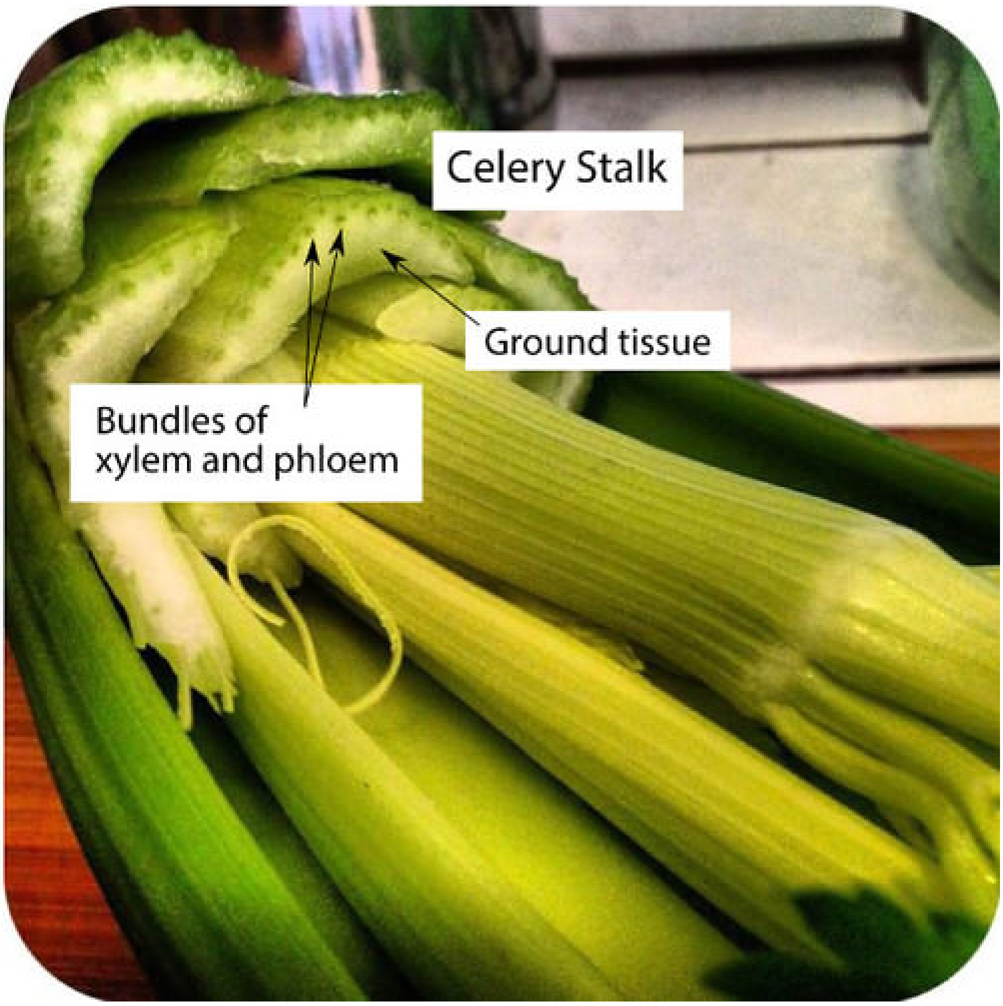
The epidermis of *Arabidopsis* shows both pavement cells (A) and stomata made of sclerenchymal **guard cells** (B), which control water loss and gas exchange.

Ground Tissue

ground tissue makes up much of the interior of a plant and carries out basic metabolic functions. Ground tissue in stem provides support and may store food or water. Ground tissues in roots may also store food.

Vascular Tissue

Vascular tissue runs through the ground tissue inside a plant. Your body was able to grow from a single cell to perhaps 100 trillion cells because, 21 days after fertilization, a tiny heart began to pump blood throughout your tiny self – and it hasn't stopped since. The blood it pumps carries water, oxygen and nutrient to each one of your trillions of cells, and removes CO_2 and other wastes. Of course plants don't have hearts, but they do have vessels that transport water, mineral, and nutrients through the plant. These vessels are the vascular tissue, and consist of **xylem** and **phloem**. Xylem and phloem are packaged together in bundles, as shown in **Figure** below.



[Figure 3]

Bundles of xylem and phloem run through the ground tissue inside this stalk of celery. What function do these tissues serve?

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Summary

- The three types of plant cells are found in each of the major types of plant tissues: dermal, ground, and vascular tissues.
- Dermal tissue covers the outside of a plant in a single layer of cells called the epidermis. It mediates most of the interactions between a plant and its environment.
- Ground tissue makes up most of the interior of a plant. It carries out basic metabolic functions and stores food and water.
- Vascular tissue runs through the ground tissue inside a plant. It consists of bundles of xylem and phloem, which transport fluids throughout the plant.

Review

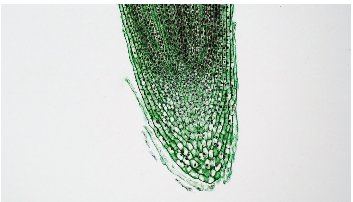
1. Compare dermal, ground, and vascular tissues of plants.
2. What is cuticle? What is its role?
3. What are guard cells and stomata?
4. An important concept in biology is that form follows function. In other words, the structure of an organism, or part of an organism, depends on its function. Apply this concept to plants, and explain why plants have different types of cells and tissues.

Escherichia coli bacteria

9.13 Plant Growth

FlexBooks 2.0 > Biology For High School Diploma > Plant Growth

Last Modified: Jul 04, 2019



[Figure 1]

So how do plants grow?

There must be an area of growth, similar to how the bone in your fingers, arms, and legs grow longer. There is, and it is called the apical meristem, which is shown here.

Growth of Plants

Most plants continue to grow throughout their lives. Like other multicellular organism, plants grow through a combination of cell growth and cell division. Cell growth increases cell size, while cell division (mitosis) increases the number of cells. As plant cells grow, they also become specialized into different cell types through cellular differentiation. Once cells differentiate, they can no longer divide. How do plants grow or replace damaged cells after that?

The key to continued growth and repair of plant cells is **meristem**. Meristem is a type of plant tissue consisting of undifferentiated cells that can continue to divide and differentiate.

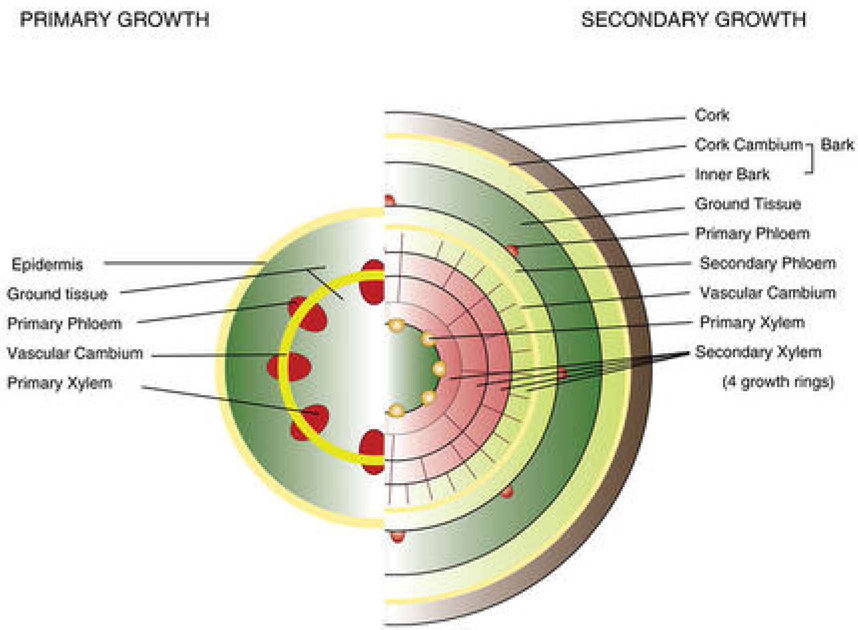
Apical meristems are found at the apex, or tip, of roots and buds, allowing roots and stem to grow in length and leaves and flower to differentiate. Roots and stems grow in length because the meristem adds tissue "behind" it, constantly propelling itself further into the ground (for roots) or air (for stems). Often, the apical meristem of a single branch will become dominant, suppressing the growth of meristems on other branches and leading to the development of a single trunk. In grasses, meristems at the base of the leaf blade allow for regrowth after grazing by herbivore – or mowing by lawnmowers.

[Figure 2]

Microphotograph of the root tip of a broad bean show rapidly dividing apical meristem tissue just behind the root cap. Numerous cells in various stages of mitosis can be observed.

Apical meristems differentiate into the three basic types of meristem tissue which correspond to the three types of tissue: protoderm produces new epidermis, ground meristem produces ground tissue, and procambium produces new xylem and phloem. These three types of meristem are considered **primary meristem** because they allow growth in length or height, which is known as **primary growth**.

secondary meristem allow growth in diameter (secondary growth) in woody plants. Herbaceous plants do not have **secondary growth**. The two types of secondary meristem are both named **cambium**, meaning "exchange" or "change". **vascular cambium** produces secondary xylem (toward the center of the stem or root) and phloem (toward the outside of the stem or root), adding growth to the diameter of the plant. This process produces wood, and builds the sturdy trunks of trees. **cork cambium** lies between the epidermis and the phloem, and replaces the epidermis of roots and stems with bark, one layer of which is cork.



[Figure 3]

Woody plants grow in two ways. **Primary growth** adds length or height, mediated by apical meristem tissue at the tips of roots and shoots – which is difficult to show clearly in cross-sectional diagrams. **Secondary growth** adds to the diameter of a stem or root; vascular cambium adds xylem (inward) and phloem (outward), and cork cambium replaces epidermis with bark.

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Summary

- Most plants continue to grow as long as they live. They grow through a combination of cell growth and cell division (mitosis).
- The key to plant growth is meristem, a type of plant tissue consisting of undifferentiated cells that can continue to divide and differentiate.
- Meristem allows plant stems and roots to grow longer (primary growth) and wider (secondary growth).

Review

1. Define meristem and apical meristem.
2. What are the two types of secondary meristem?
3. Describe cork cambium.
4. What is primary growth and secondary growth?

Report Content Errors

9.14 Roots

FlexBooks 2.0 > Biology For High School Diploma > Roots

Last Modified: Jul 04, 2019

[Figure 1]

Now those are some serious roots. But what exactly are roots?

There are **taproot** and **fibrous root**, **primary root** and **secondary root**. And they always seem to know which way to grow. Roots are very special plant organ. How and why?

Roots

Plants have specialized organs that help them survive and reproduce in a great diversity of habitat. Major organs of most plants include roots, stem, and leaves.

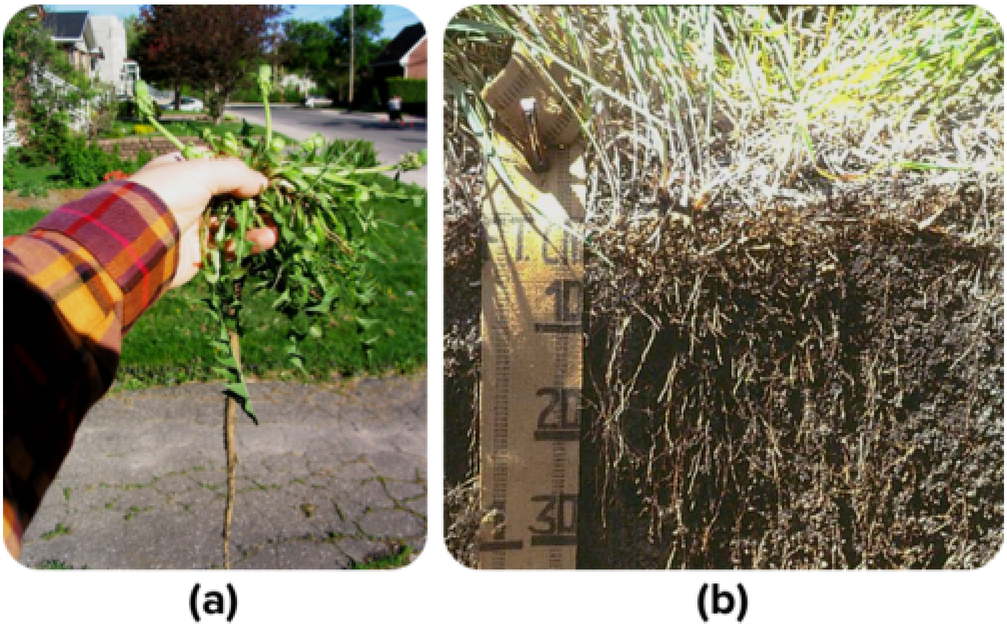
Roots are important organs in all vascular plant. Most vascular plants have two types of roots: **primary roots** that grow downward and **secondary roots** that branch out to the side. Together, all the roots of a plant make up a **root system**.

Root Systems

There are two basic types of root systems in plants: taproot systems and fibrous root systems. Both are illustrated in **Figure** below.

- **Taproot systems** feature a single, thick primary root, called the **taproot**, with smaller secondary roots growing out from the sides. The taproot may penetrate as many as 60 meters (almost 200 feet) below the ground surface. It can plumb very deep water sources and store a lot of food to help the plant survive drought and other environmental extremes. The taproot also anchors the plant very securely in the ground.

- **Fibrous root systems** have many small branching roots, called **fibrous roots**, but no large primary root. The huge number of threadlike roots increases the surface area for absorption of water and mineral, but fibrous roots anchor the plant less securely.

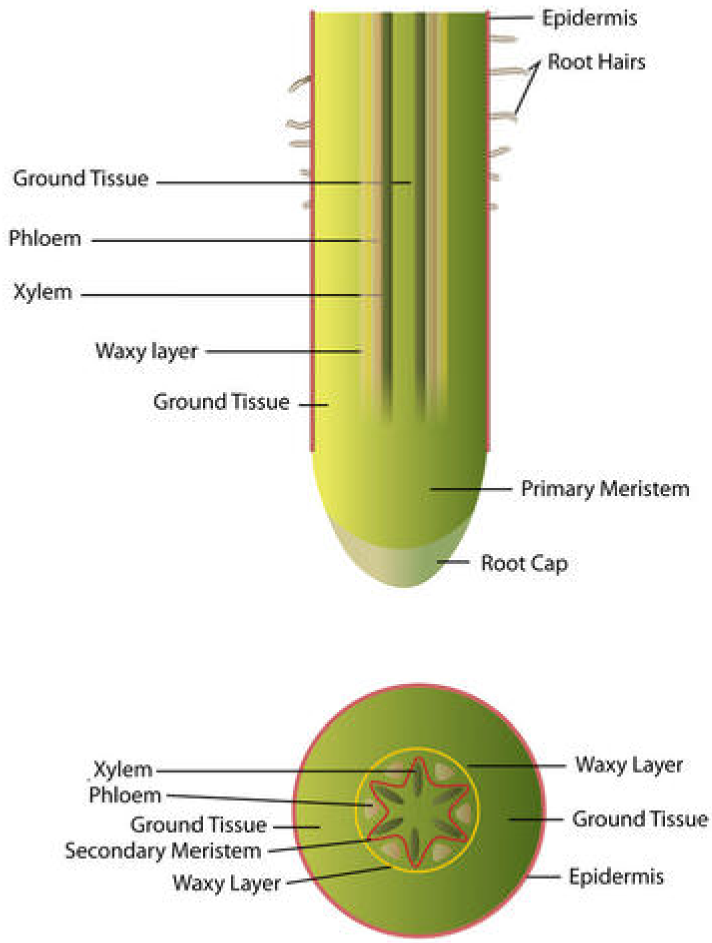


[Figure 2]

Dandelions have taproot systems; grasses have fibrous root systems.

Root Structures and Functions

As shown in **Figure** below, the tip of a root is called the **root cap**. It consists of specialized cell that help regulate primary growth of the root at the tip. Above the root cap is primary meristem, where growth in length occurs.



[Figure 3]

A root is a complex organ consisting of several types of tissue. What is the function of each tissue type?

Above the meristem, the rest of the root is covered with a single layer of epidermal cells. These cells may have **root hair** that increase the surface area for the absorption of water and minerals from the soil. Beneath the epidermis is ground tissue, which may be filled with stored starch. Bundles of vascular tissue form the center of the root. Waxy layers waterproof the vascular tissues so they don't leak, making them more efficient at carrying fluids. **secondary meristem** is located within and around the vascular tissues. This is where growth in thickness occurs.

The structure of roots helps them perform their primary functions. What do roots do? They have three major jobs: absorbing water and minerals, anchoring and supporting the plant, and storing food.

1. Absorbing water and minerals: Thin-walled epidermal cells and root hairs are well suited to absorb water and dissolved minerals from the soil. The roots of many plants also have a mycorrhizal relationship with fungus for greater absorption.

2. Anchoring and supporting the plant: Root systems help anchor plants to the ground, allowing plants to grow tall without toppling over. A tough covering may replace the epidermis in older roots, making them ropelike and even stronger. As shown in **Figure** below, some roots have unusual specializations for anchoring plants.
3. Storing food: In many plants, ground tissues in roots store food produced by the leaves during photosynthesis. The bloodroot shown in **Figure** below stores food in its roots over the winter.

[Figure 4]

Mangrove roots are like stilts, allowing mangrove trees to rise high above the water. The trunk and leaves are above water even at high tide. A bloodroot plant uses food stored over the winter to grow flowers in the early spring.

Root Growth

Roots have primary and secondary meristems for growth in length and width. As roots grow longer, they always grow down into the ground. Even if you turn a plant upside down, its roots will try to grow downward. How do roots “know” which way to grow? How can they tell down from up? Specialized cells in root caps are able to detect gravity. The cells direct meristem in the tips of roots to grow downward toward the center of Earth. This is generally adaptive for land plants. Can you explain why?

As roots grow thicker, they can’t absorb water and minerals as well. However, they may be even better at transporting fluids, anchoring the plant, and storing food (see **Figure** below).

[Figure 5]

Secondary growth of sweet potato roots provides more space to store food. Roots store sugar from photosynthesis as starch. What other starchy roots do people eat?

https://flexbooks.ck12.org/flx/render/embeddedobject/190249

Science Friday: Plants in Space!

For humans to travel to the Moon and Mars, astronauts will need to understand how to grow plants in extreme climates in order to help them stay alive. In this video by science Friday, Dr. Anna-Lisa Paul and Dr. Robert J. Ferl send weed to space to study their behavior on a molecular level.

https://flexbooks.ck12.org/flx/render/embeddedobject/194578

Summary

- Roots absorb water and minerals and transport them to stems. They also anchor and support a plant, and store food.
- A root system consists of primary and secondary roots.
- Each root is made of dermal, ground, and vascular tissues.
- Roots grow in length and width from primary and secondary meristem.

Review

1. What are root hairs? What is their role?
2. Identify three major functions of roots.
3. Contrast a taproot system with a fibrous root system.
4. Explain how roots “know” which way to grow.

Report Content Errors

9.15 Stems

FlexBooks 2.0 > Biology For High School Diploma > Stems

Last Modified: May 21, 2021

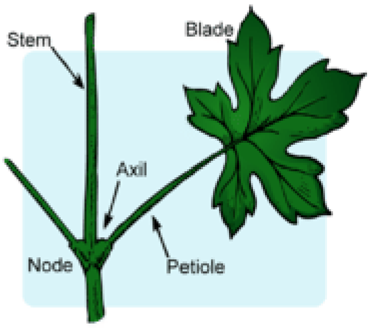
[Figure 1]

How does water get up? How does sugar move down?

What structures hold the plant upright? Are tree trunks also stems? Of course they are. Trees don't start out big and tall - they grow from small plants to large trees. And it is these stems that allow them to grow upright. So, obviously the stem is very important and has numerous functions.

Stems

In vascular plant, **stems** are the organ that hold plants upright so they can get the sunlight and air they need. Stems also bear leaves, flower, cone, and secondary stems. These structures grow at points called **node** (shown in **Figure** below). At each node, there is a bud of meristem tissue that can divide and specialize to form a particular structure.



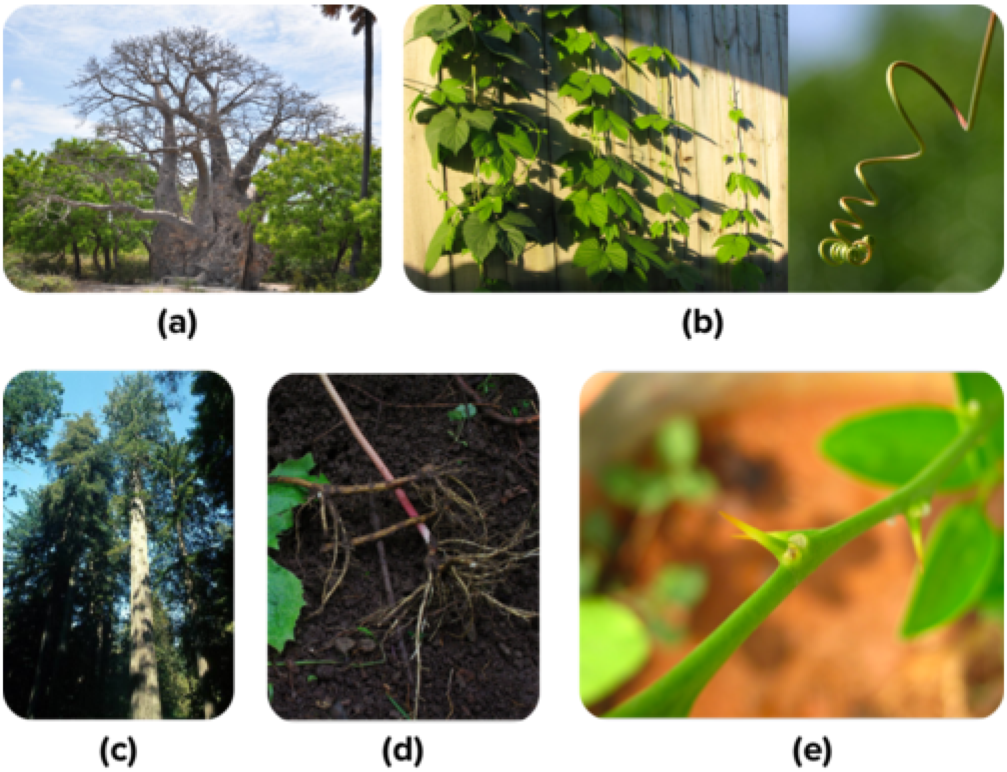
[Figure 2]

The stem of a vascular plant has nodes where leaves and other structures may grow.

Another vital function of stems is transporting water and mineral from roots to leaves and carrying food from leaves to the rest of the plant. Without this connection between roots and leaves, plants could not survive high above ground in the air. In many plants, stems also store food or water during cold or dry seasons.

Stem Diversity

Stems show variation because many stems are specialized. **Figure** below shows examples of stem specialization. With specialized stems, plants can exploit a diversity of niches in virtually all terrestrial ecosystem.



[Figure 3]

Stem specializations such as these let plants grow in many different habitats.

Stem Tissues and Functions

Like roots, the stems of vascular plants are made of dermal, vascular, and ground tissue.

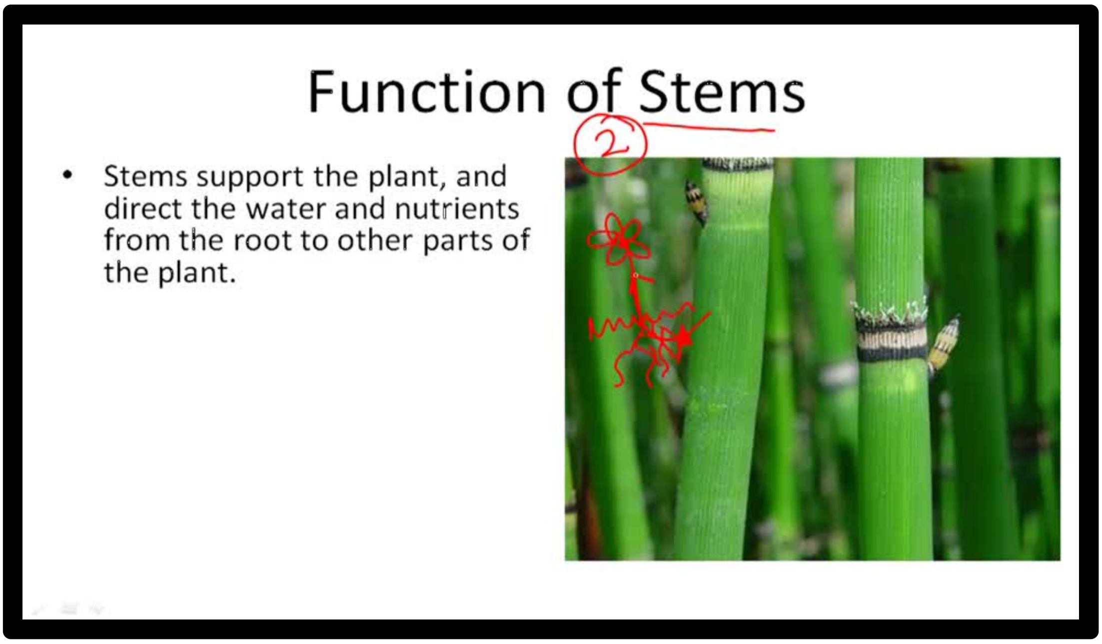
- A single-celled layer of epidermis protects and waterproofs the stem and controls gas exchange.
- In trees, some of the epidermal tissue is replaced by **bark**. **Bark** is a combination of tissues that provides a tough, woody external covering on the stems of trees. The inner part of bark is alive and growing; the outer part is dead and provides strength, support, and protection.
- Ground tissue forms the interior of the stem. The large **central vacuole** of ground tissue cell fill with water to support the plant. The cells may also store food.
- Bundles of vascular tissue run through the ground tissue of a stem and transport fluids. Plants may vary in how these bundles are arranged.

Stem Growth

The stems of all vascular plants get longer through primary growth. This occurs in primary meristem at the tips and nodes of the stems. Most stems also grow in thickness through **secondary growth**. This occurs in **secondary meristem**, which is located in and around the vascular tissues. Secondary growth forms secondary vascular tissues and bark. In many trees, the yearly growth of new vascular tissues results in an annual growth ring like the one in **Figure** below. When a tree is cut down, the rings in the trunk can be counted to estimate the tree's age.

[Figure 4]

The number of rings in this cross-section of tree trunk show how many years the tree lived. What does each ring represent?



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Summary

- Stems hold plants upright, bear leaves and other structures, and transport fluids between roots and leaves.
- Like roots, stems contain dermal, ground, and vascular tissues.
- Trees have woody stems covered with bark.

Review

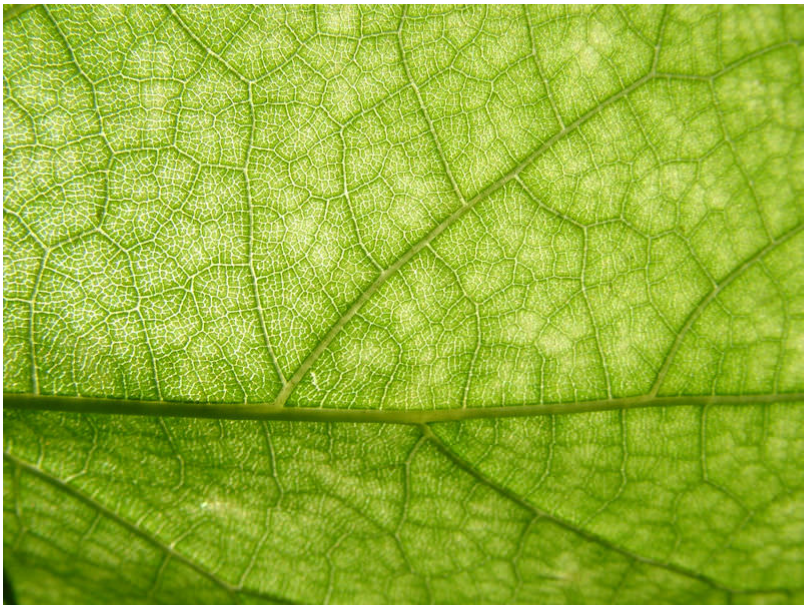
1. Describe two types of specialized stems. What is each type of stem specialized for?
2. What is bark? What purposes does it serve?
3. Apply lesson concepts to predict how the stem of a desert plant might be specialized for its environment.

Report Content Errors

9.16 Leaves

FlexBooks 2.0 > Biology For High School Diploma > Leaves

Last Modified: Jul 04, 2019



[Figure 1]

Could life exist without the leaf?

A leaf looks so simple. But it is actually a very complex structure. And it may be one of the most important organ in all kingdoms. Life as we know it could not exist without leaves. Why? One word: photosynthesis.

Leaves

Plants have specialized organs that help them survive and reproduce in a great diversity of habitat. Major organs of most plants include roots, stem, and leaves. **Leaves** are the keys not only to plant life but to all terrestrial life. The primary role of leaves is to collect sunlight and make food by **photosynthesis**. Despite the fundamental importance of the work they do, there is great diversity in the leaves of plants. However, given the diversity of habitats in which plants live, it's not surprising that there is no single best way to collect solar energy for photosynthesis.

Leaf Variation

Leaves may vary in size, shape, and their arrangement on stems. Nonflowering vascular plant have three basic types of leaves: **microphyll** ("tiny leaves"), **frond**, and **needle**. **Figure** below describes each type.

[Figure 2]

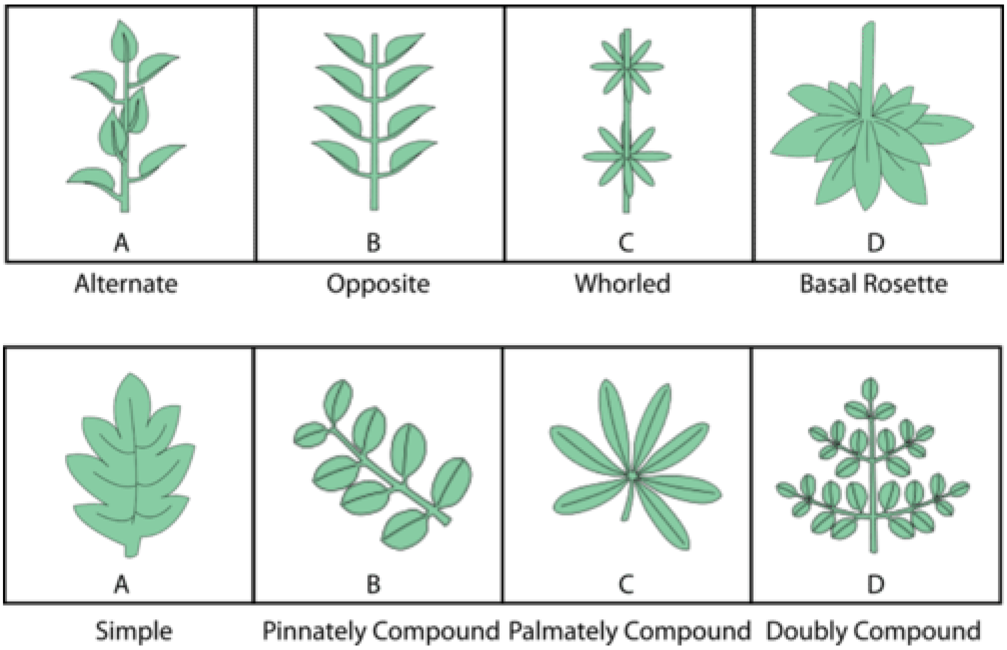
Leaf variation in nonflowering plants reflects their evolutionary origins. Can you explain how?

Flowering vascular plants also have diverse leaves. However, the leaves of all flowering plants have two basic parts in common: the blade and **petiole**. The **blade** of the leaf is the relatively wide, flat part of the leaf that gathers sunlight and undergoes photosynthesis. The **petiole** is the part that attaches the leaf to a stem of the plant. This occurs at a node.

Flowering plant leaves vary in how the leaves are arranged on the stem and how the blade is divided. This is illustrated in **Figure** below. Generally, the form and arrangement of leaves maximizes light exposure while conserving water, reducing wind resistance, or benefiting the plant in some other way in its particular habitat.

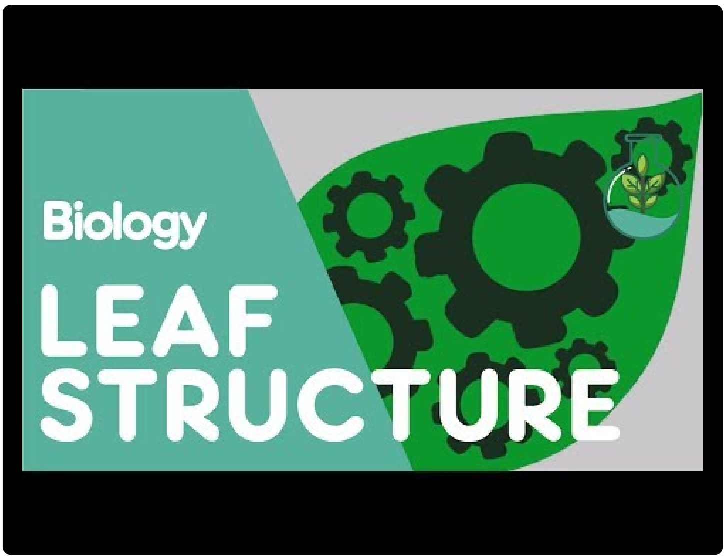
- Leaves arranged in whorls encircle upright stems at intervals. They collect sunlight from all directions.
- Leaves arranged in basal rosettes take advantage of warm temperatures near the ground.
- Leaves arranged in alternate or opposing pairs collect light from above. They are typically found on plants with a single, upright stem.
- The blades of simple leaves are not divided. This provides the maximum surface area for collecting sunlight.

- The blades of compound leaves are divided into many smaller leaflets. This reduces wind resistance and water loss.



[Figure 3]

Leaf variation in flowering plants may include variations in the arrangement of leaves and the divisions of the blade.



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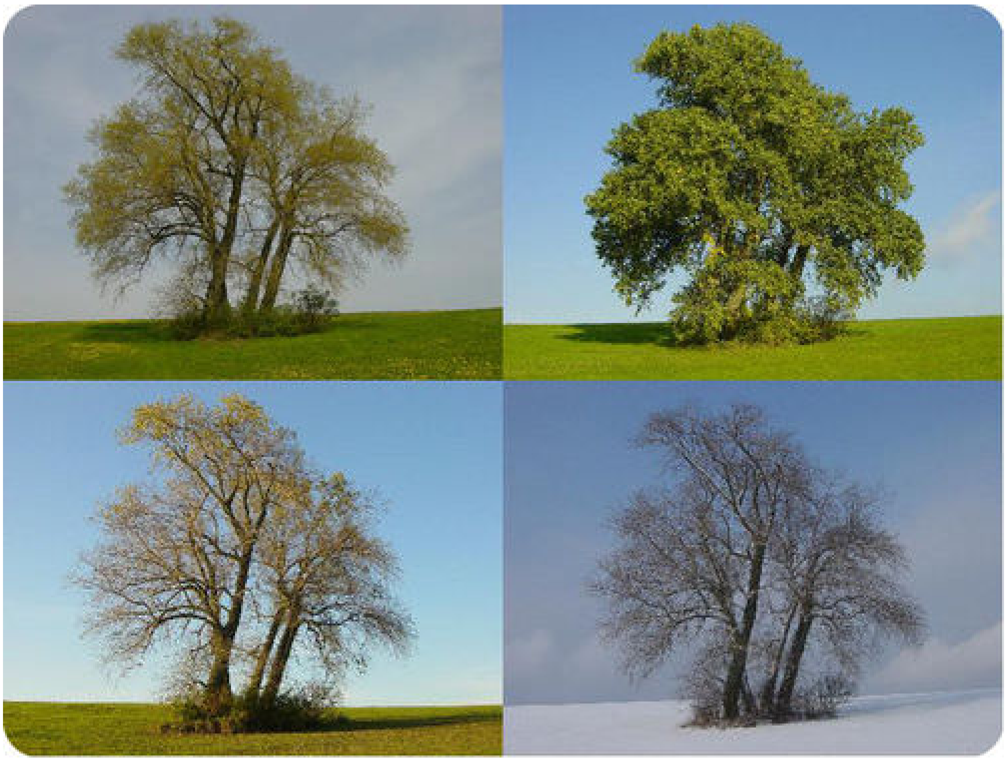
Seasonal Changes in Leaves

Even if you don't live in a place where leaves turn color in the fall, no doubt you've seen photos of their "fall colors" (see **Figure** below). The leaves of many plants turn from green to other, glorious colors during autumn each year. The change is triggered by shorter days and cooler temperatures. Leaves respond to these environmental stimulus by producing less **chlorophyll**. This allows other leaf pigments—such as oranges and yellows—to be seen.



[Figure 4]

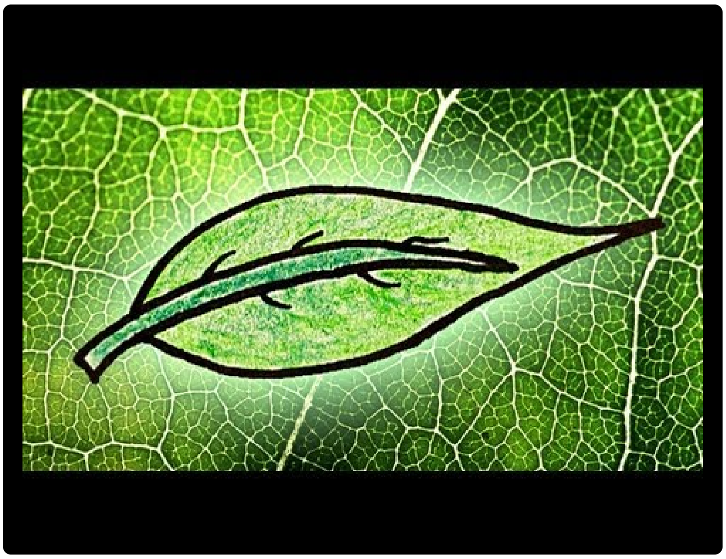
A deciduous tree goes through dramatic seasonal changes each year. Can you identify the seasons in the photo?

After leaves turn color in the fall, they may all fall off the plant for the winter. Plants that shed their leaves seasonally each year are called **deciduous** plants. Shedding leaves is a strategy for reducing water loss during seasons of extreme dryness. On the downside, the plant must grow new leaves in the spring, and that takes a lot of energy and matter. Some plants may "bank" energy over the winter by storing food. That way, they are ready to grow new leaves as soon as spring arrives.

Evergreen plants have a different strategy for adapting to seasonal dryness. They don't waste energy and matter growing new leaves each year. Instead, they keep their leaves and stay green year-round. However, to reduce water loss, they have needle-like leaves with very thick cuticle. On the downside, needle-like leaves reduce the surface area for collecting sunlight. This is one reason that needles may be especially rich in chlorophyll, as you can see from the dark green pine needles in **Figure** below. This is also an important adaptation for low levels of sunlight, allowing evergreens to live far from the equator.

[Figure 5]

Compare the color of the evergreen needles and the deciduous leaf. Why is the darker color of the needles adaptive?



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Summary

- The primary function of leaves is to collect sunlight and make food by photosynthesis.
- In a deciduous plant, leaves seasonally turn color and fall off the plant. They are replaced with new leaves later in the year.
- An evergreen plant keeps its green leaves year-round. It may have needle-like leaves to reduce water loss.

Review

1. Name the two main parts of an angiosperm leaf. What is the function of each part?
2. Identify strategies used by deciduous and evergreen plants to adapt to seasonal dryness.
3. Relate leaf variation to environmental variation.

Report Content Errors

9.17 Plant Reproduction and Life Cycle

FlexBooks 2.0 > Biology For High School Diploma > Plant Reproduction and Life Cycle

Last Modified: Jul 04, 2019

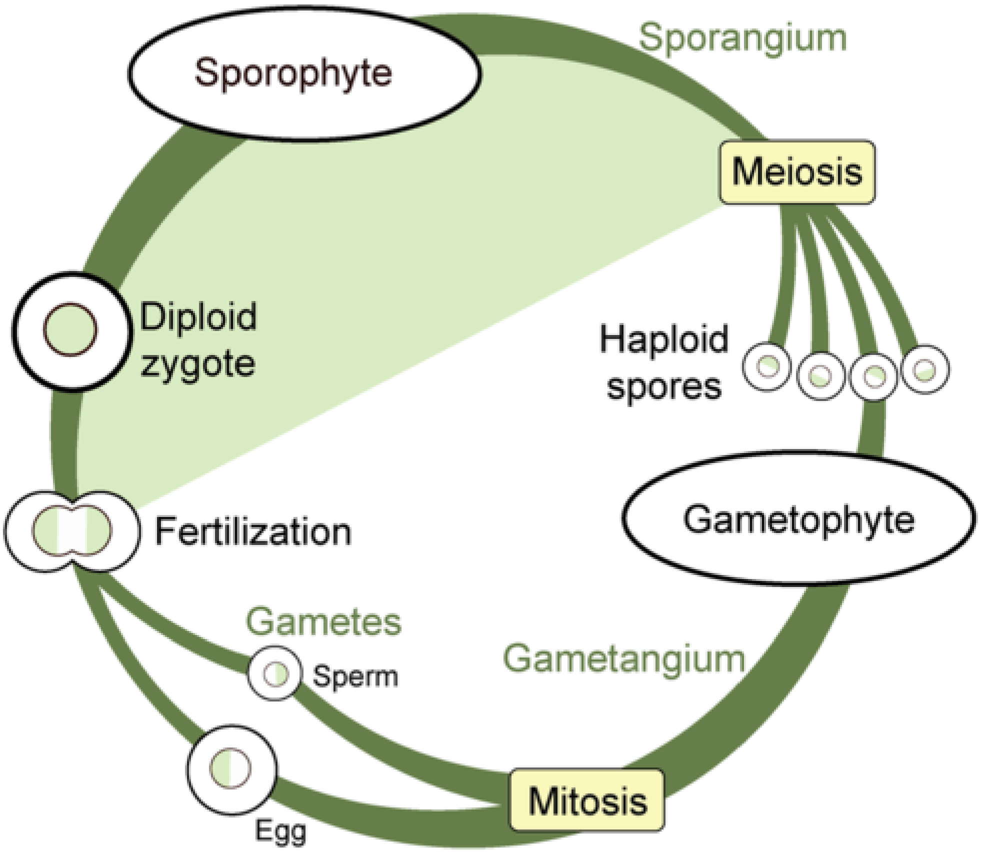
[Figure 1]

Fertilization or pollination. How does this occur in the plant?

pollination. A significant step in the life cycle of flowering plants. But fertilization must occur in the life cycles of all plants, not just those with flower. Does it always use the bird or the bees?

General Plant Life Cycle

The life cycle of all plants is complex because it is characterized by alternation of generations. Plants alternate between diploid **sporophyte** and haploid **gametophyte** generations, and between sexual and asexual reproduction. The ability to reproduce both sexually and asexually gives plants the flexibility to adapt to changing environments. Their complex life cycle allows for great variation. A general plant **life cycle** is represented by the diagram in **Figure** below. From the figure, you can see that the diploid **sporophyte** has a structure called a **sporangium** (plural, sporangia) that undergoes meiosis to form haploid **spores**. A spore develops into a haploid **gametophyte**. The gametophyte has male or female reproductive organ that undergo mitosis to form haploid **gamete** (sperm or eggs). Fertilization of gametes produces a diploid **zygote**. The zygote grows and develops into a mature sporophyte, and the cycle repeats.



[Figure 2]

This diagram represents the life cycle that generally characterizes plants.

One of the two generations of a plant's life cycle is typically dominant to the other generation. Whether it's the sporophyte or gametophyte generation, individuals in the dominant generation live longer and grow larger. They are the green, photosynthetic structures that you would recognize as a fern, tree, or other plant (see **Figure** below). Individuals in the nondominant generation, in contrast, may be very small and rarely seen. They may live in or on the dominant plant.

The dominant generation in nonvascular plant is the gametophyte; in vascular plant, it's the sporophyte. Why is a dominant sporophyte generation an advantage on land?

[Figure 3]

All of these photos show plants of the dominant generation in their life cycle.

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Summary

- All plants have a life cycle with alternation of generations.
- Plants alternate between diploid sporophyte and haploid gametophyte generations, and between sexual reproduction with gametes and asexual reproduction with spores.

Review

1. Outline the general life cycle of plants.
2. What are sporangia? What do they do?
3. Describe the gametophyte.
4. Describe the sporophyte.

Report Content Errors

9.18 Life Cycle of Nonvascular Plants

FlexBooks 2.0 > Biology For High School Diploma > Life Cycle of Nonvascular Plants

Last Modified: Jul 04, 2019

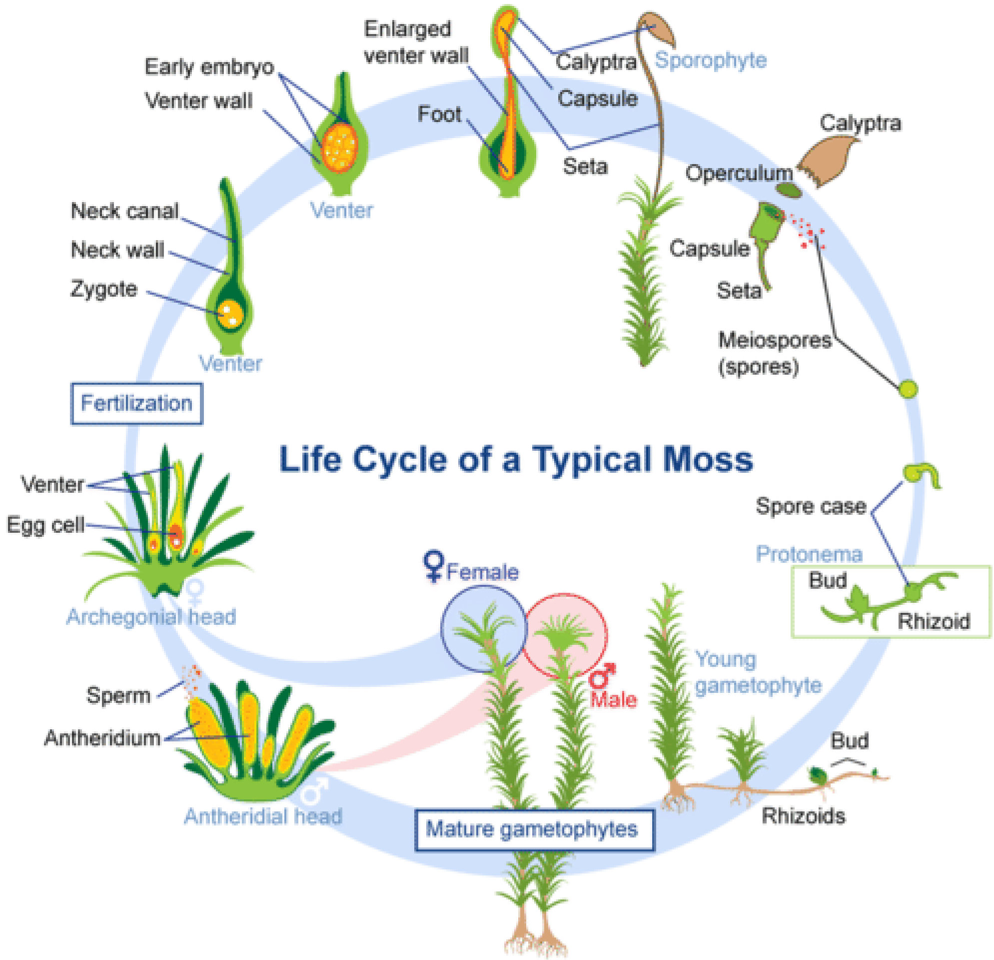
[Figure 1]

Haploid or diploid. Which would you say is dominant?

That may depend on the plant. Start with **moss**. The typical nonvascular plant. But such a simple plant has a very interesting life cycle. Whereas most kinds of plants have two sets of chromosome in their vegetative cell, mosses have only a single set of chromosomes. So, how does meiosis occur?

Life Cycle of Nonvascular Plants

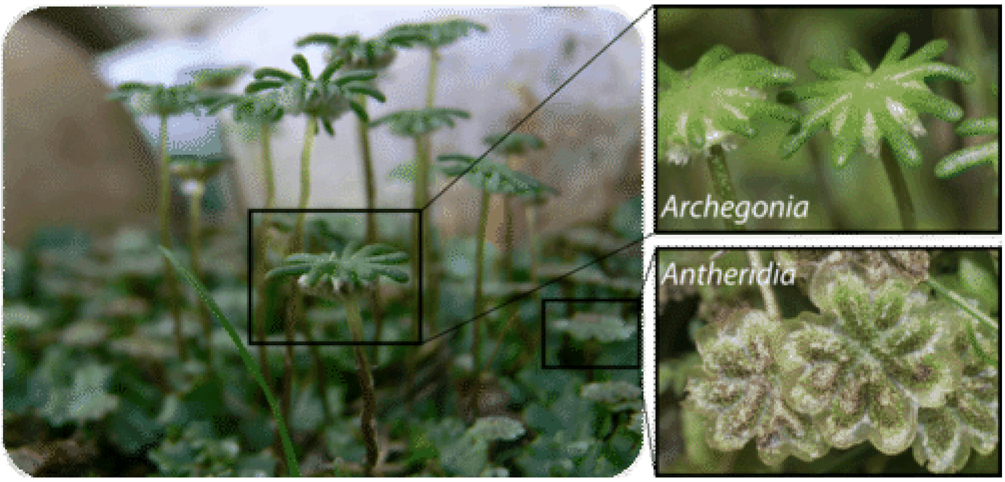
Nonvascular plants include mosses, liverwort, and hornwort. They are the only plants with a life cycle in which the **gametophyte** generation is dominant. **Figure** below shows the life cycle of moss. The familiar, green, photosynthetic moss plants are **gametophytes**. The **sporophyte** generation is very small and dependent on the gametophyte plant.



[Figure 2]

Like other bryophytes, moss plants spend most of their life cycle as gametophytes. Find the sporophyte in the diagram. Do you see how it is growing on the gametophyte plant?

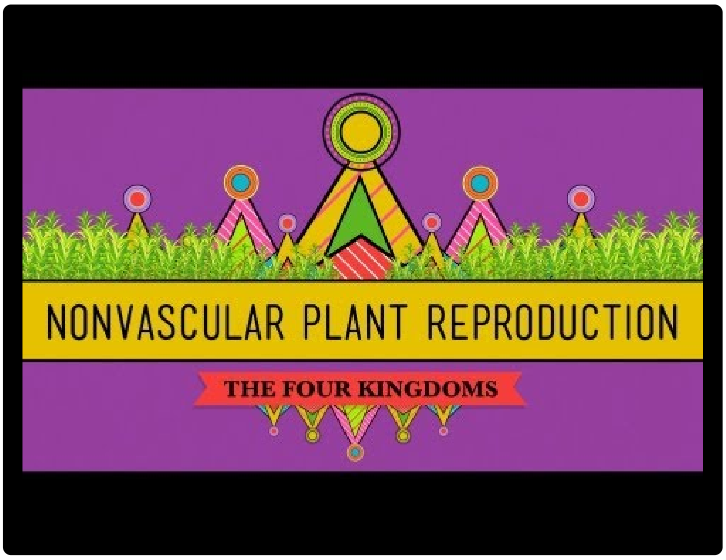
The gametophytes of nonvascular plants have distinct male or female reproductive organ (see **Figure** below). Male reproductive organs, called **antheridia** (singular, antheridium), produce motile sperm with two flagellum. Female reproductive organs, called **archegonia** (singular, archegonium), produce egg.



[Figure 3]

The reproductive organs of bryophytes like this liverwort are male antheridia and female archegonia.

In order for fertilization to occur, sperm must swim in a drop of water from an antheridium to an egg in an archegonium. If fertilization takes place, it results in a **zygote** that develops into a tiny sporophyte on the parent gametophyte plant. The sporophyte produces haploid **spores**, and these develop into the next generation of gametophyte plants. Then the cycle repeats.



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Summary

- In nonvascular plants, the gametophyte generation is dominant. The tiny sporophyte grows on the gametophyte plant.

Review

1. Describe antheridia and archegonia and their functions.
2. Create your own cycle diagram to represent the moss life cycle.

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9.19 Life Cycle of Seedless Vascular Plants

FlexBooks 2.0 > Biology For High School Diploma > Life Cycle of Seedless Vascular Plants

Last Modified: Jul 04, 2019

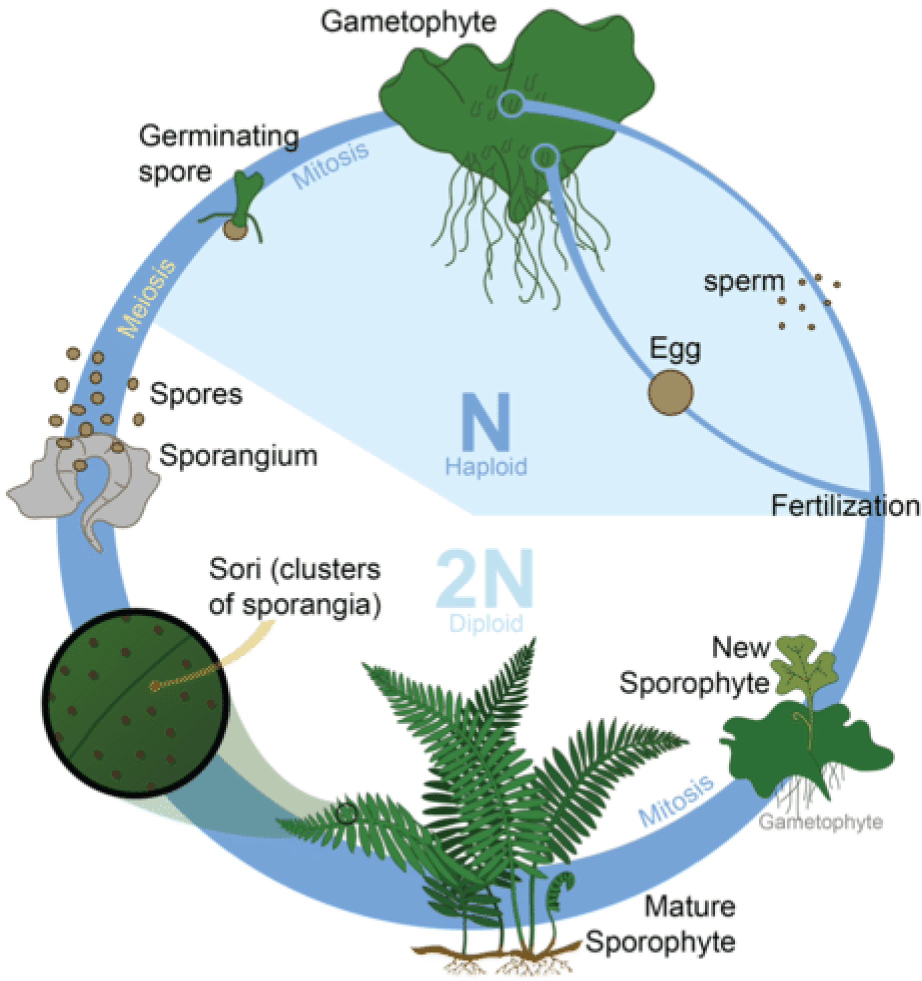
[Figure 1]

What's a fiddlehead?

This fern leaf structure is known as a fiddlehead. Can you understand why? Does it look tasty? Nearly all ferns have fiddleheads, and many recipes exist on how to prepare fiddleheads. But this part of the plant, the leaf or the frond, also plays a very important role in the fern's life cycle.

Life Cycle of Seedless Vascular Plants

Unlike nonvascular plant, all vascular plants—including seedless vascular plants—have a dominant **sporophyte** generation. Seedless vascular plant include clubmoss and ferns. **Figure** below shows a typical fern life cycle.



[Figure 2]

In the life cycle of a fern, the sporophyte generation is dominant.

A mature sporophyte fern has the familiar leafy **fronds**. The undersides of the leaves are dotted with clusters of **sporangium**. Sporangia produce spores that develop into tiny, heart-shaped **gametophyte**. Gametophytes have **antheridia** and **archegonia**. Antheridia produce sperm with many cilia; archegonia produce egg. fertilization occurs when sperm swim to an egg inside an **archegonium**. The resulting zygote develops into an embryo that becomes a new sporophyte plant. Then the cycle repeats.

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Summary

- In vascular plants, the sporophyte generation is dominant.
- In seedless vascular plants such as ferns, the sporophyte releases spores from the undersides of leaves.
- The spores develop into tiny, separate gametophytes, from which the next generation of sporophyte plants grows.

Review

1. What role do leaves play in the reproduction of ferns?
2. Describe antheridia and archegonia and their functions.
3. Create your own cycle diagram to represent the life cycle of a fern.

Report Content Errors

9.20 Life Cycle of Gymnosperms

FlexBooks 2.0 > Biology For High School Diploma > Life Cycle of Gymnosperms

Last Modified: Jul 04, 2019

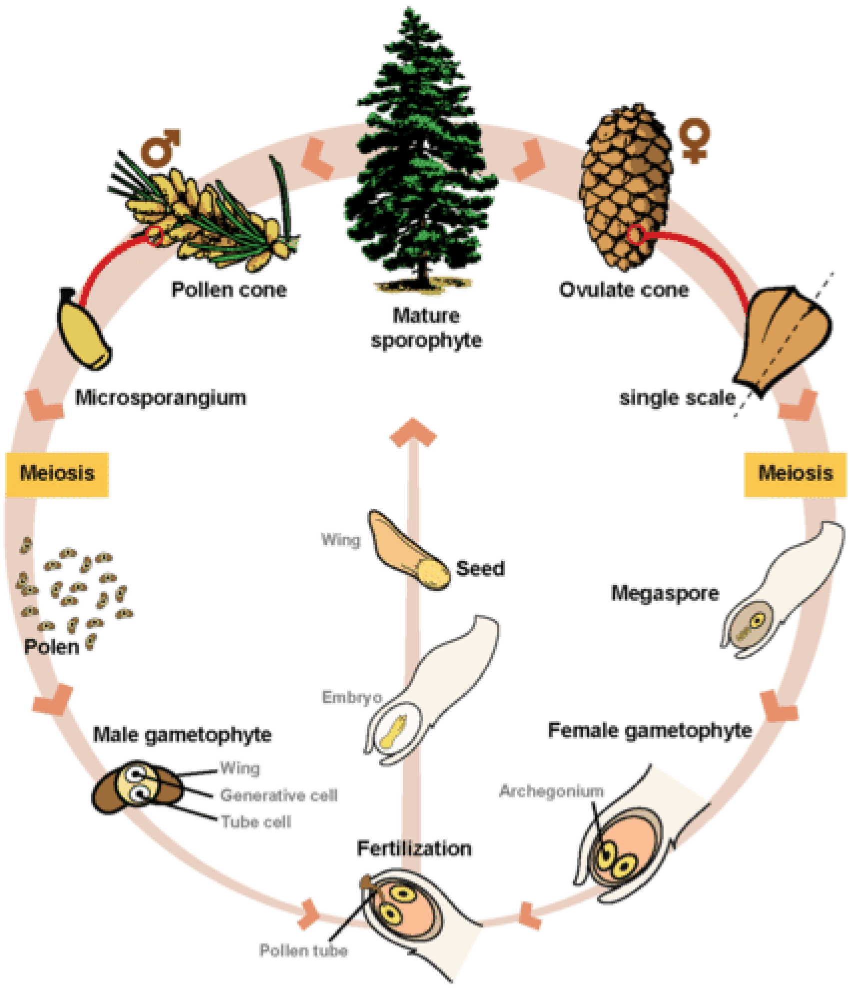
[Figure 1]

Do pine trees produce flowers?

Of course not. But look closely at these pine **cone**. Notice the shape. Can you see the "petal?" They do seem oddly similar to flower. These pine cones have a prominent role in the **gymnosperm** life cycle. So what is the function of a pine cone?

Life Cycle of Gymnosperms

Gymnosperms are vascular plant that produce seed in **cones**. Examples include **conifer** such as pine and spruce trees. The gymnosperm life cycle has a dominant **sporophyte** generation. Both **gametophyte** and the next generation's new sporophytes develop on the sporophyte parent plant. **Figure** below is a diagram of a gymnosperm life cycle.

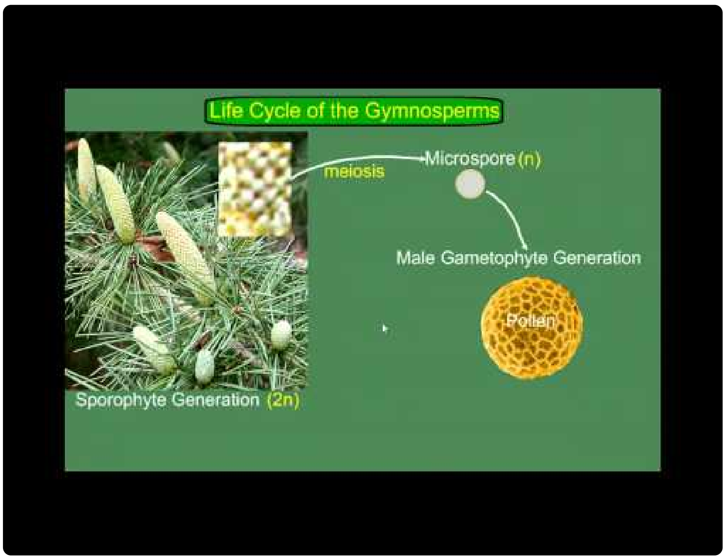


[Figure 2]

The gymnosperm life cycle follows the general plant life cycle, but with some new adaptations. Can you identify them?

Cones form on a mature sporophyte plant. Inside male cones, male spores develop into male gametophytes. Each male gametophyte consists of several cell enclosed within a grain of **pollen**. Inside female cones, female spores develop into female gametophytes. Each female gametophyte produces an egg inside an ovule.

pollination occurs when pollen is transferred from a male to female cone. If sperm then travel from the pollen to an egg so fertilization can occur, a diploid zygote results. The zygote develops into an embryo within a seed, which forms from the ovule inside the female cone. If the seed germinates, it may grow into a mature sporophyte tree, which repeats the cycle.



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Summary

- In gymnosperms, the gametophyte generation takes place in a cone, which forms on the mature sporophyte plant.
- Each male gametophyte is just a few cells inside a grain of pollen. Each female gametophyte produces an egg inside an ovule.
- Pollination must occur for fertilization to take place. Zygotes develop into embryos inside seeds, from which the next sporophyte generation grows.

Review

1. Describe how gymnosperms use cones to reproduce.
2. Create your own cycle diagram to represent the life cycle of a gymnosperm.

Report Content Errors

9.21 Life Cycle of Angiosperms

FlexBooks 2.0 > Biology For High School Diploma > Life Cycle of Angiosperms

Last Modified: Jul 04, 2019

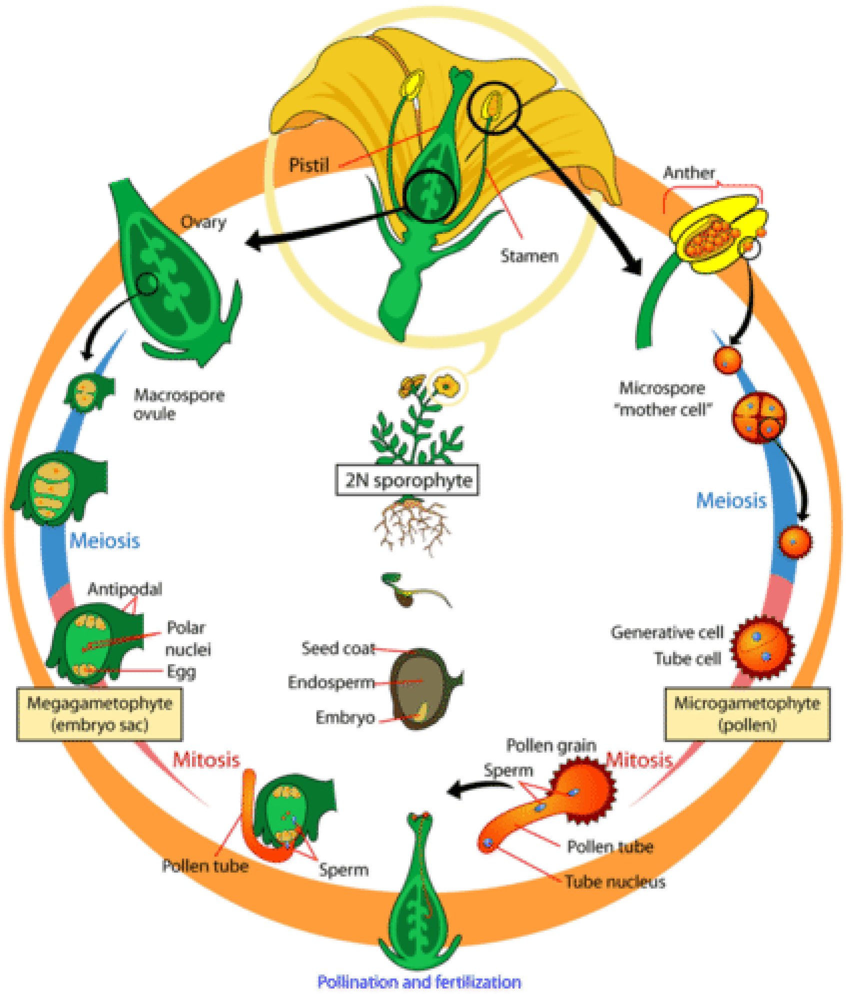
[Figure 1]

What's the most successful type of plant?

Flowering plants. Why? As you know, flower come in many different styles and colors, and many are visually pleasing. This aids in pollination. Also notice the anatomy of this Hibiscus flower. Each part has evolved to play a role in the life cycle.

Life Cycle of Angiosperms

angiosperm, or flowering plants, are the most abundant and diverse plants on Earth. Angiosperms evolved several reproductive adaptation that have contributed to their success. Like all vascular plant, their life cycle is dominated by the **sporophyte** generation. A typical angiosperm life cycle is shown in **Figure** below.

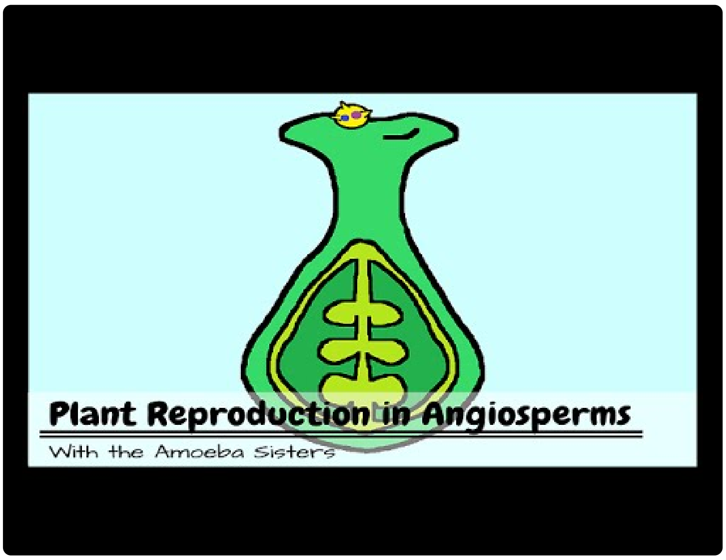


[Figure 2]

Life cycle of an angiosperm

The flower in **Figure** above is obviously an innovation in the angiosperm life cycle. **Flowers** form on the dominant **sporophyte** plant. They consist of highly specialized male and female reproductive organ. Flowers produce **spores** that develop into **gametophyte**. Male gametophytes consist of just a few cell within a **pollen** grain and produce sperm. Female gametophytes produce egg inside the ovary of flowers. Flowers also attract animal **pollinator**.

If pollination and fertilization occur, a diploid zygote forms within an ovule in the ovary. The zygote develops into an embryo inside a seed, which forms from the ovule and also contains food to nourish the embryo. The ovary surrounding the seed may develop into a **fruit**. **Fruits** attract animals that may disperse the seeds they contain. If a seed germinates, it may grow into a mature sporophyte plant and repeat the cycle.



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Summary

- In flowering plants, the gametophyte generation takes place in a flower, which forms on the mature sporophyte plant.
- Each male gametophyte is just a few cells inside a grain of pollen. Each female gametophyte produces an egg inside an ovule.
- Pollination must occur for fertilization to take place. Zygotes develop into embryos inside seeds, from which the next sporophyte generation grows.

Review

1. State the functions of flowers and fruits in angiosperm reproduction.
2. Create your own cycle diagram to represent the life cycle of a daisy.

Resources

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9.22 Plant Adaptations

FlexBooks 2.0 > Biology For High School Diploma > Plant Adaptations

Last Modified: Jul 04, 2019

[Figure 1]

Look closely at the petals of this flower. Do they look different?

This flower is from an aloe plant. Aloes are succulent plants, which have adaptation that allow them to store water in their enlarged fleshy leaves, stem, or roots. This allows them to survive in arid environments.

Plant Adaptations

Plants live just about everywhere on Earth. To live in so many different habitat, they have evolved adaptations that allow them to survive and reproduce under a diversity of conditions.

All plants are adapted to live on land. Or are they? All living plants today have terrestrial ancestors, but some plants now live in the water. They have had to evolve new adaptations for their watery habitat.

Adaptations to Water

Aquatic plants are plants that live in water. Living in water has certain advantages for plants. One advantage is, well, the water. There's plenty of it and it's all around. Therefore, most aquatic plants do not need adaptations for absorbing, transporting, and conserving water.

They can save energy and matter by not growing extensive root systems, vascular tissue, or thick cuticles on leaves. Support is also less of a problem because of the buoyancy of water. As a result, adaptations such as strong woody stems and deep anchoring roots are not necessary for most aquatic plants.

Living in water does present challenges to plants, however. For one thing, pollination by wind or animal isn't feasible under water, so aquatic plants may have adaptations that help them keep their flowers above water. For instance, water lilies have bowl-shaped flowers and broad, flat leaves that float. This allows the lilies to collect the maximum amount of sunlight, which does not penetrate very deeply below the water's surface. Plants that live in moving water, such as streams and rivers, may have different adaptations. For example, cattails have narrow, strap-like leaves that reduce their resistance to the moving water (see **Figure** below).

[Figure 2]

Water lilies and cattails have different adaptations for life in the water. Compare the leaves of the two kinds of plants. How do the leaves help the plants adapt to their watery habitats?

Adaptations to Extreme Dryness

Plants that live in extremely dry environments have the opposite problem: how to get and keep water. Plants that are adapted to very dry environments are called **xerophyte**. Their adaptations may help them increase water intake, decrease water loss, or store water when it is available.

The saguaro cactus pictured in **Figure** below has adapted in all three ways. When it was still a very small plant, just a few inches high, its shallow roots already reached out as much as 2 meters (7 feet) from the base of the stem. By now, its root system is much more widespread.

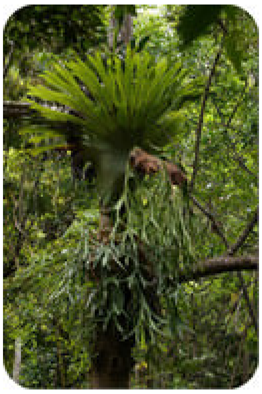
It allows the cactus to gather as much moisture as possible from rare rainfalls. The saguaro doesn't have any leaves to lose water by transpiration. It also has a large, barrel-shaped stem that can store a lot of water. Thorns protect the stem from thirsty animals that might try to get at the water inside.

[Figure 3]

The saguaro cactus has many adaptations for extreme dryness. How does it store water?

Adaptations to Air

Plants called **epiphyte** grow on other plants. They obtain moisture from the air and make food by photosynthesis. Most epiphytes are fern or orchids that live in tropical or temperate rainforests (see **Figure** below). host trees provide support, allowing epiphyte plants to obtain air and sunlight high above the forest floor. Being elevated above the ground lets epiphytes get out of the shadows on the forest floor so they can get enough sunlight for photosynthesis. Being elevated may also reduce the risk of being eaten by herbivore and increase the chance of pollination by wind.



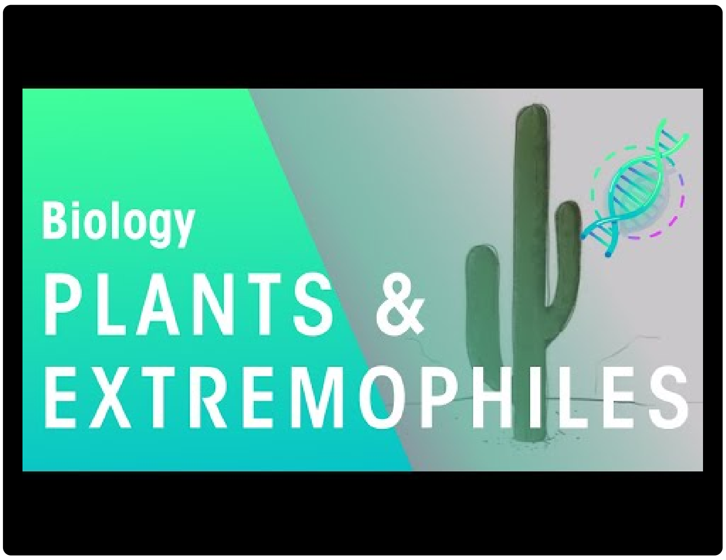
[Figure 4]

These Elkhorn and Staghorn ferns are growing on a rainforest tree as epiphytes.

Epiphytes don't grow in soil, so they may not have roots. However, they still need water for photosynthesis. Rainforests are humid, so the plants may be able to absorb the water they need from the air. However, many epiphytes have evolved modified leaves or other structures for collecting rainwater, fog, or dew. The leaves of the bromeliad shown in **Figure** below are rolled into funnel shapes to collect rainwater. The base of the leaves forms a tank that can hold more than 8 liters (2 gallons) of water. Some insects and amphibian may spend their whole life cycle in the pool of water in the tank, adding mineral to the water with their wastes. The tissue at the base of the leaf are absorbent, so they can take in both water and minerals from the tank.

[Figure 5]

The leaves of this bromeliad are specialized to collect, store, and absorb rainwater.



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Summary

- Plants live just about everywhere on Earth, so they have evolved adaptations that allow them to survive and reproduce under a diversity of conditions.
- Various plants have evolved adaptations to live in the water, in very dry environments, or in the air as epiphytes.

Review

1. List special challenges that aquatic plants face.
2. What are xerophytes? Give an example.
3. Identify three general ways that plants can adapt to extreme dryness.
4. Describe how epiphytes can absorb moisture without growing roots in soil.
5. Why are epiphytes found mainly in rainforest ecosystems?
6. Apply the concept of symbiosis to epiphytes and their host plants. Do you think they have a symbiotic relationship? If so, which type of symbiotic relationship do you think they have? Explain your answer.

Report Content Errors

9.23 Plant Responses

FlexBooks 2.0 > Biology For High School Diploma > Plant Responses

Last Modified: Jan 27, 2020

[Figure 1]

So what happens to a vineyard in the middle of winter?

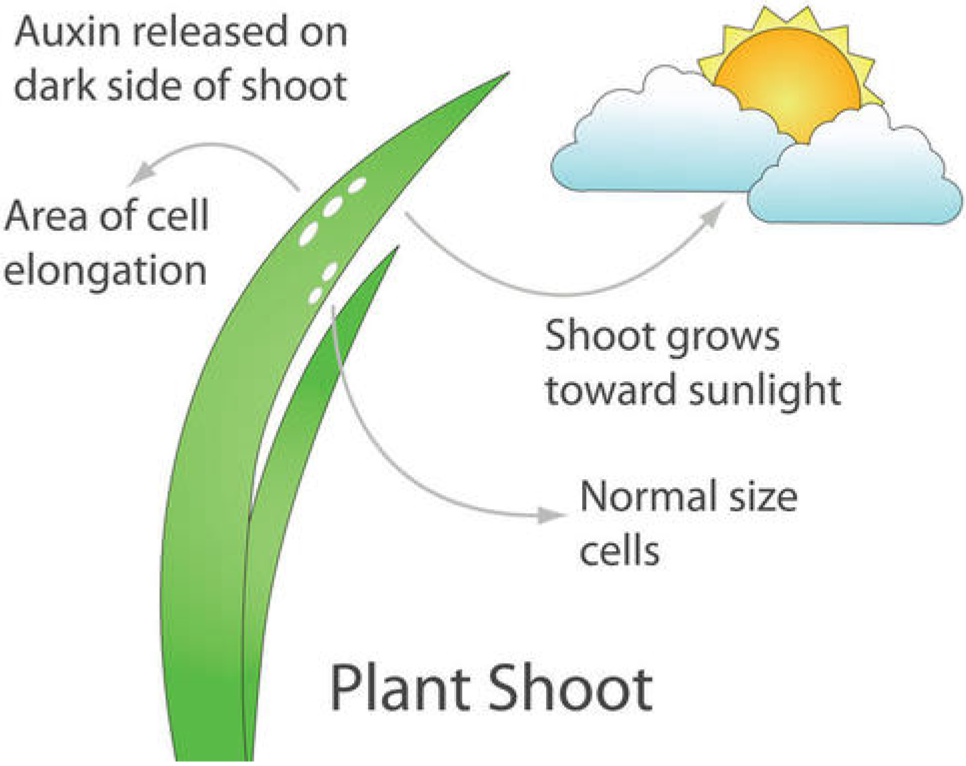
The vines cannot die each year. Instead, the plants go into a state of **dormancy**, almost as if they are taking a long nap.

Plant Responses

Like all organism, plants detect and respond to stimulus in their environment. Unlike animal, plants can't run, fly, or swim toward food or away from danger. They are usually rooted to the soil. Instead, a plant's primary means of response is to change how it is growing. Plants also don't have a nervous system to control their responses. Instead, their responses are generally controlled by **hormone**, which are chemical messenger molecules.

Plant Tropisms

Plant roots always grow downward because specialized cell in root cap detect and respond to gravity. This is an example of a **tropism**. A **tropism** is a turning toward or away from a stimulus in the environment. Growing toward gravity is called **geotropism**. Plants also exhibit **phototropism**, or growing toward a light source. This response is controlled by a plant growth hormone called **auxin**. As shown in **Figure** below, auxin stimulates cells on the dark side of a plant to grow longer. This causes the plant to bend toward the light.



[Figure 2]

Phototropism is controlled by the growth hormone auxin.

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Daily and Seasonal Responses

Plants also detect and respond to the daily cycle of light and darkness. For example, some plants open their leaves during the day to collect sunlight and then close their leaves at night to prevent water loss. Environmental stimuli that indicate changing seasons trigger other responses. Many plants respond to the days growing shorter in the fall by going **dormant**. They suspend growth and development in order to survive the extreme cold and dryness of winter. **Dormancy** ensures that seed will germinate and plants will grow only when conditions are favorable.

Responses to Disease

Plants don't have immune systems, but they do respond to disease. Typically, their first line of defense is the death of cells surrounding infected tissue. This prevents the infection from spreading. Many plants also produce hormones and toxins to fight pathogen. For example, willow trees produce salicylic acid to kill bacterium. The same compound is used in many acne products for the same reason. Exciting new research suggests that plants may even produce chemicals that warn other plants of threats to their health, allowing the plants to prepare for their own defense. As these and other responses show, plants may be rooted in place, but they are far from helpless.

Science Friday: Plants in Space!

For humans to travel to the Moon and Mars, astronauts will need to understand how to grow plants in extreme climates in order to help them stay alive. In this video by science Friday, Dr. Anna-Lisa Paul and Dr. Robert J. Ferl send weed to space to study their behavior on a molecular level.

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Summary

- Like all organisms, plants detect and respond to stimuli in their environment. Their main response is to change how they grow.
- Plant responses are controlled by hormones. Some plant responses are tropisms.
- Plants also respond to daily and seasonal cycles and to disease.

Review

1. What is the primary way that plants respond to environmental stimuli? What controls their responses?
2. Define tropism. Name one example in plants.
3. State ways that plants respond to disease.
4. Why is it adaptive for plants to detect and respond to daily and seasonal changes?

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9.24 REFERENCES

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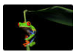	**Credit:** Geoff Galice **Source:** https://commons.wikimedia.org/wiki/File:Red-eyed_Tree_Frog_(Agalychnis_callidryas)_3.jpg **License:** CC BY 2.0
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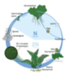	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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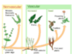
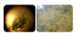
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Left: User:Pallastrelli/Wikimedia Commons; Right: User:Panek/Wikimedia Commons **Source:** Left: http://commons.wikimedia.org/wiki/File:Chara_lupa.JPG; Right: http://commons.wikimedia.org/wiki/File:Stonewort_meadow.jpg **License:** Left: Public Domain; Right: CC BY 3.0
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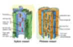
<tr><td></td><td>Credit: Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation
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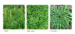
<tr><td></td><td>Credit: Club: Jason Hollinger; Bog: Gary Peeples/USFWS; Fir: Homer Edward Price
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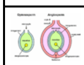
<tr><td></td><td>Credit: Tameeria
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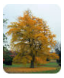
<tr><td></td><td>Credit: Jim Linwood
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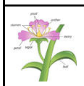
<tr><td></td><td>Credit: Christopher AuYeung and Hana Zavadska
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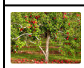
<tr><td></td><td>Credit: Liz West
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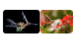
<tr><td></td><td>Credit: Bat: Courtesy of the US Fish and Wildlife Service; Moth: Thomas Bresson
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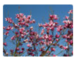	**Credit:** Charles D P Miller **Source:** https://www.flickr.com/photos/cdpm/5541183986/ **License:** CC BY 2.0
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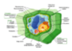	**Credit:** Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) **Source:** http://commons.wikimedia.org/wiki/File:Plant_cell_structure_svg.svg **License:** Public Domain
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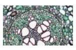
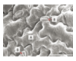
	**Credit:** bccoer **Source:** https://www.flickr.com/photos/146824358@N03/35399385663 **License:** CC0
	**Credit:** J Umbrasaite, A Schweighofer, et al. **Source:** http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0015357 **License:** CC BY 2.5
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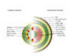	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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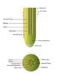	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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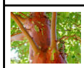
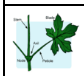
	**Credit:** Flickr: ktsadowski **Source:** https://www.flickr.com/photos/34226483@N00/2740888084/ **License:** CC BY 2.0
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0

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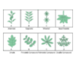	**Credit:** Alternate, Opposite, Whorled, Pinnately Compound, Palmately Compund, Doubly Compound: Agnieszka Kwiecień (User:Nova/Wikimedia Commons); Basal Rosette, Simple: Rupali Raju/CK-12 Foundation **Source:** Alternate, Opposite, Whorled: http://commons.wikimedia.org/wiki/File:Ulistnienie.svg; Pinnately Compound, Palmately Compund, Doubly Compound: http://commons.wikimedia.org/wiki/File:Li%C5%9Bcie_z%C5%82o%C5%BCone.svg **License:** CC BY 3.0
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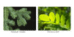	**Credit:** Evergreen: Courtesy of Robert H. Mohlenbrock, USDA NRCS; Deciduous: Hans Braxmeier **Source:** Evergreen: http://commons.wikimedia.org/wiki/File:Abies_balsamea_branch.jpg; Deciduous: http://pixabay.com/en/journal-green-leaf-veins-filigree-141494/ **License:** Public Domain
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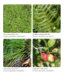	**Credit:** Moss: S. Rae; Fern: John Tann; Pine: Ken Bosma; Apple: Juha Ryhänen **Source:** Moss: http://www.flickr.com/photos/35142635@N05/5474415455/; Fern: http://www.flickr.com/photos/31031835@N08/3125057762/; Pine: http://www.flickr.com/photos/kretyen/2761375368/; Apple: http://pixabay.com/en/the-apple-tree-apple-257958/ **License:** Moss, Fern, Pine: CC BY 2.0; Apple: Public Domain
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CHAPTER 10

Animals

Chapter Outline

10.1 Animals

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[Figure 1]

Is an insect an animal?

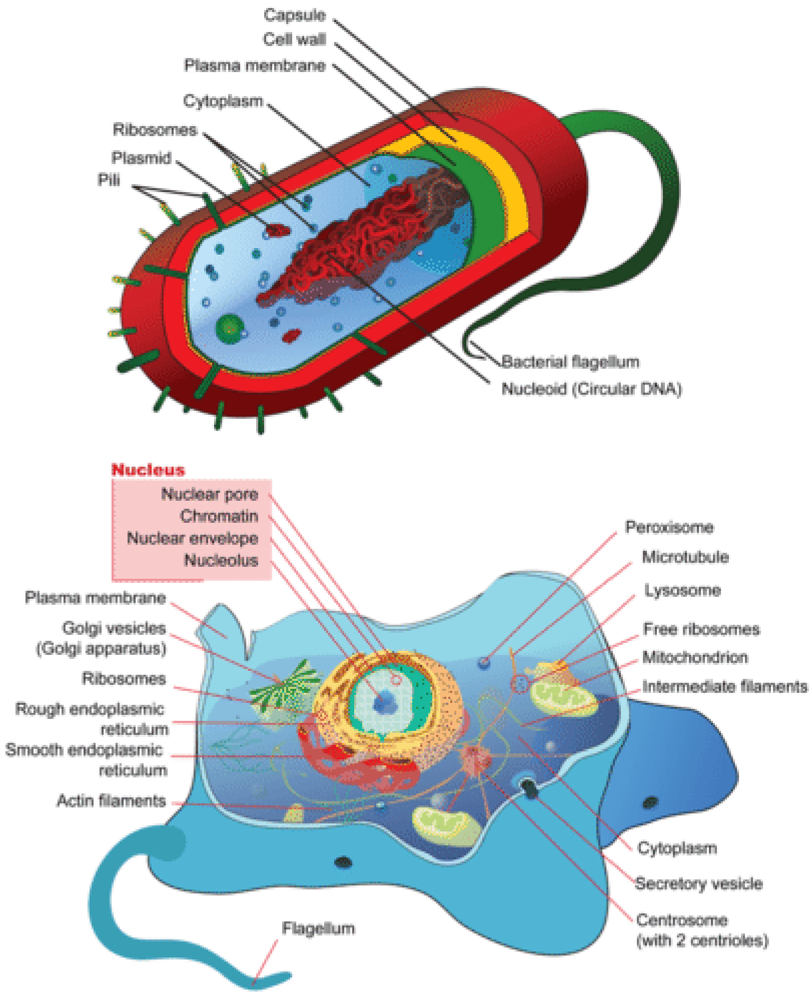
Of course it is. Is a snail an insect? No, snails are mollusks. Notice the large "foot" that allows **movement**, and the antennas are obvious. Actually, a snail's eyes are on the two long projections on its head, and the projections are called eyestalks. These are characteristics of this animal.

Characteristics of Animals

Animals are a kingdom of multicellular eukaryote. They cannot make their own food. Instead, they get nutrient by eating other living things. Therefore, animals are **heterotroph**.

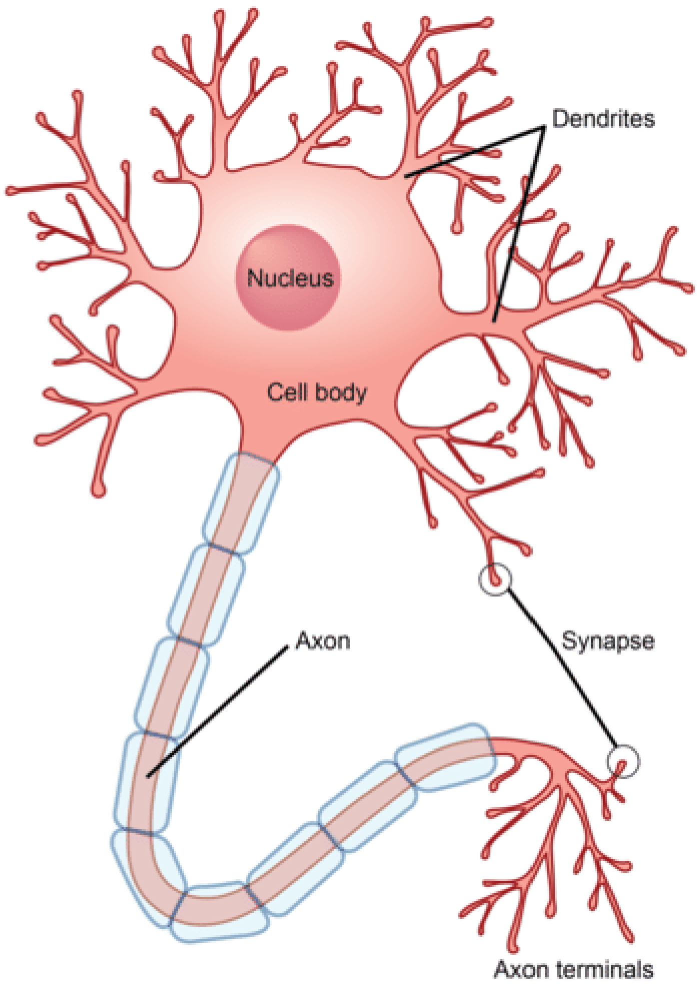
Animal Cells

Like the cell of all eukaryotes, animal cells have a nucleus and other membrane-bound organelle (see **Figure** below). Unlike the cells of plants and fungus, animal cells lack a cell wall. This gives animal cells flexibility. It lets them take on different shapes so they can become specialized to do particular jobs. The human nerve cell shown in **Figure** below is a good example. Its shape suits its function of transmitting nerve impulse over long distances. A nerve cell would be unable to take this shape if it were surrounded by a rigid cell wall.



[Figure 2]

Animal Cell. The shape of an animal cell is not constrained by a rigid cell wall. A bacterial cell is shown above for comparison.



[Figure 3]

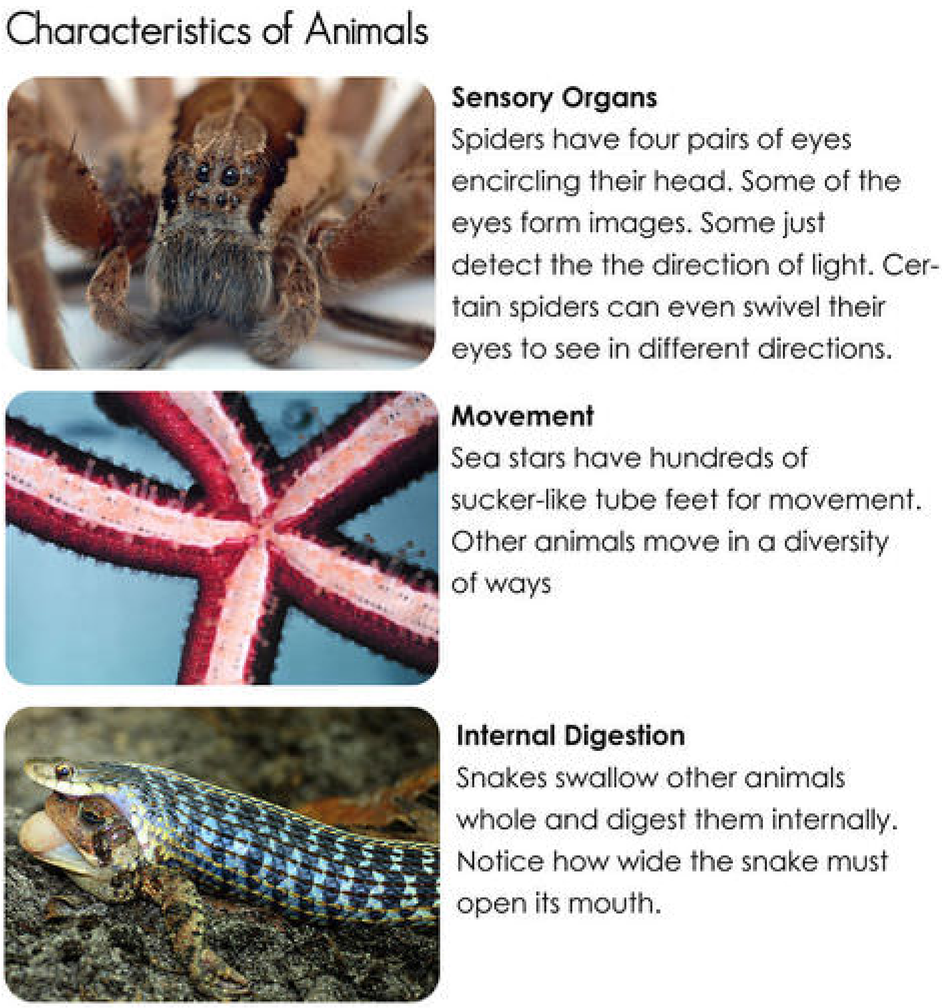
Human Nerve Cell. A human nerve cell is specialized to transmit nerve impulses. How do you think the cell's shape helps it perform this function?

Animal Structure and Function

Animals not only have specialized cells. Most animals also have tissue and organ. In many animals, organs form organ system, such as a nervous system. Higher levels of organization allow animals to perform many complex functions. What can animals do that most other living things cannot? Most animals share these characteristics: **sensory organs**, **movement**, and **internal digestion**. All of them are illustrated in **Figure** below.

- Animals can detect environmental stimulus, such as light, sound, and touch. Stimuli are detected by sensory nerve cells. The information is transmitted and processed by the nervous system. The nervous system, in turn, may direct the body to respond.
- All animals can move, at least during some stage of their life cycle. Muscles and nerves work together to allow movement. Being able to move lets animals actively search for food and mates. It also helps them escape from predator.

- Virtually all animals have internal digestion of food. Animals consume other organism and may use special tissues and organs to digest them. (Many other organisms absorb nutrients directly from the environment.)

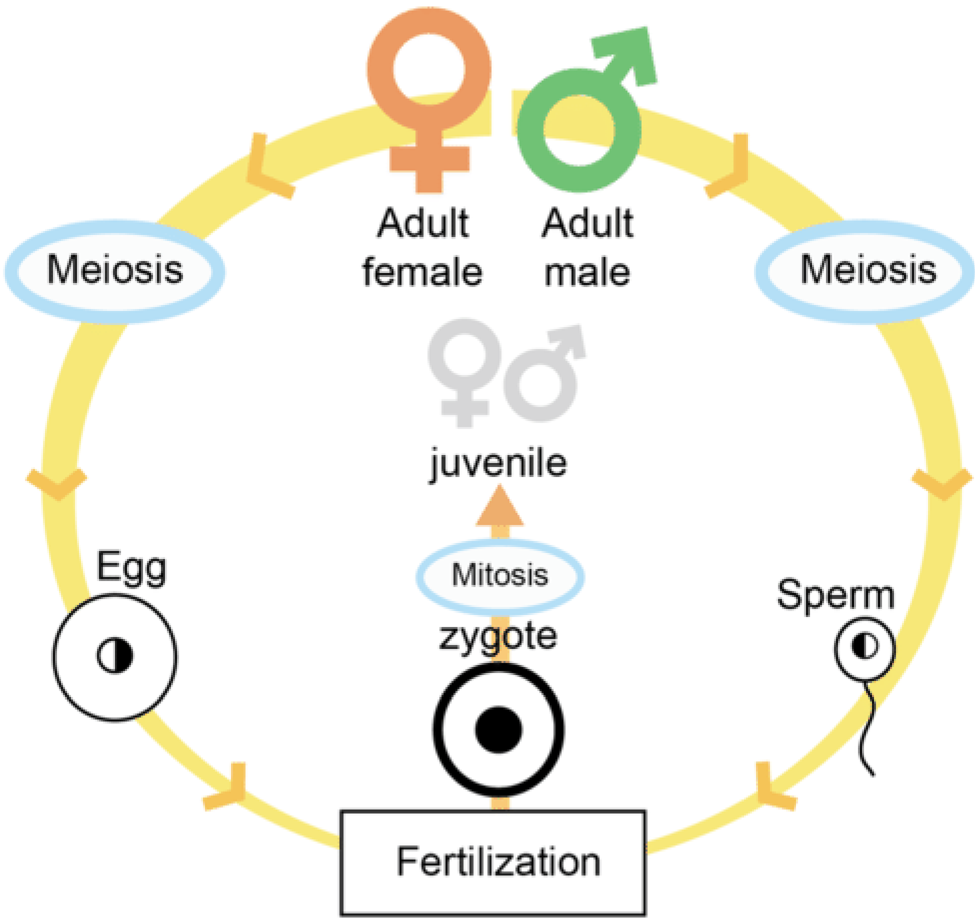


[Figure 4]

Most animals share these characteristics: sensory organs, movement, and internal digestion.

Animal Life Cycle and Reproduction

Many animals have a relatively simple life cycle. A general animal life cycle is shown in **Figure** below. Most animals spend the majority of their life as diploid organisms. Just about all animals reproduce sexually. Diploid adults undergo meiosis to produce sperm or egg. fertilization occurs when a sperm and an egg fuse. The zygote that forms develops into an embryo. The embryo eventually develops into an adult.



[Figure 5]

Animal Life Cycle. An animal life cycle that includes only sexual reproduction is shown here. Some animals also reproduce asexually. How does the animal life cycle compare with the life cycle of a plant?

https://flexbooks.ck12.org/flx/render/embeddedobject/190255

Summary

- Animals are multicellular eukaryotes that lack cell walls.
- All animals are heterotrophs.
- Animals have sensory organs, the ability to move, and internal digestion. They also have sexual reproduction.

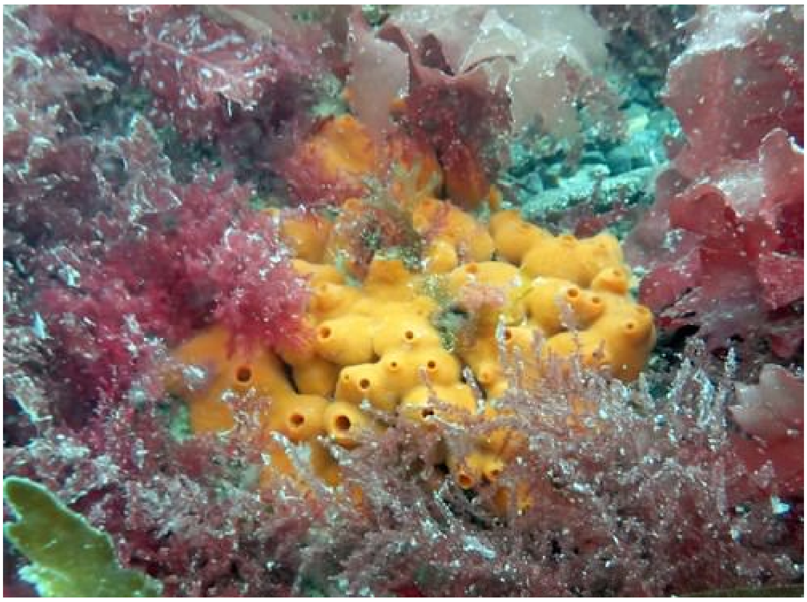
Review

1. Identify traits that characterize all animals.
2. State one way that animal cells differ from the cells of plants and fungi. What is the significance of this difference?
3. Describe animal digestion.
4. Describe a general animal life cycle.

10.2 Animal Classification

FlexBooks 2.0 > Biology For High School Diploma > Animal Classification

Last Modified: May 21, 2021



[Figure 1]

Plant or animal?

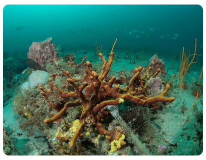
animal. What type? Now that is a good question. This azure vase sponge is an animal, but how is it classified? It is estimated that there are easily over a million species of animals on Earth. How are all these species divided into their various classifications?

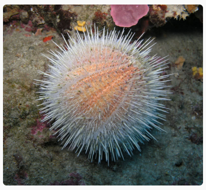
Classification of Animals

All animals share basic traits. But animals also show a lot of diversity. They range from simple sponges to complex humans.

Major Animal Phyla

Members of the animal kingdom are divided into more than 30 phyla. **Table** below lists the nine phyla with the greatest number of species. Each of the animal phyla listed in the table has at least 10,000 species.

	Phylum	Animals It Includes
 [Figure 2]	Porifera	sponges
 [Figure 3]	Cnidaria	jellyfish, corals
 [Figure 4]	Platyhelminthes	flatworm, tapeworms, flukes
 [Figure 5]	Nematoda	roundworms
 [Figure 6]	Mollusca	snails, clams, squids
 [Figure 7]	Annelida	earthworm, leech, marine worms
 [Figure 8]	Arthropoda	insects, spiders, crustaceans, centipedes

 [Figure 9]	Echinodermata	sea stars, sea urchins, sand dollars, sea cucumbers
 [Figure 10]	Chordata	tunicate, lancelets, fish, amphibian, reptile, bird, mammal

Invertebrate vs. Vertebrate

The first eight phyla listed in **Table** above include only **invertebrate** animals. **Invertebrates** are animals that lack a **vertebral column**, or **backbone**. The last phylum in the table, the Chordata, also includes many invertebrate species. Tunicates and lancelets are both invertebrates. Altogether, invertebrates make up at least 95 percent of all animal species. The remaining animals are **vertebrate**. **Vertebrates** are animals that have a backbone. All vertebrates belong to the phylum **Chordata**. They include fish, amphibians, reptiles, birds, and mammals.

https://flexbooks.ck12.org/flx/render/embeddedobject/190256

Summary

- Vertebrates have a backbone, but invertebrates do not.

- Except for the chordates, all animal phyla consist only of invertebrates.
- Chordates include both vertebrates and invertebrates.

Review

1. State how the phylum Chordata differs from other animal phyla.
2. Compare and contrast invertebrates and vertebrates.

Report Content Errors

10.3 Animal Behavior Evolution

FlexBooks 2.0 > Biology For High School Diploma > Animal Behavior Evolution

Last Modified: May 16, 2021

[Figure 1]

What is this elephant doing?

Obviously he is spraying water from his trunk. Why? Is this elephant's behavior a form of playing or is there another possible reason?

Animal Behavior

Did you ever see a dog sit on command? Have you ever watched a cat trying to catch a mouse? These are just two examples of the many behaviors of animal. **animal behavior** includes all the ways that animals interact with each other and the environment. Examples of common animal behaviors are pictured in **Figure** below.

[Figure 2]

Examples of Animal Behavior. Can you think of other examples of animal behavior besides the three shown here?

The branch of biology that studies animal behavior is called **ethology**. Ethologists usually study how animals behave in their natural environment, rather than in a lab. They generally try to answer four basic questions about the behaviors they observe:

1. What causes the behavior? What is the **stimulus**, or trigger, for the behavior? What structures and functions of the animal are involved in the behavior?
2. How does the behavior develop? Is it present early in life? Or does it appear only as the animal matures? Are certain experiences needed for the behavior to develop?
3. Why did the behavior evolve? How does the behavior affect the fitness of the animal performing it? How does it affect the survival of the species?
4. How did the behavior evolve? How does it compare with similar behaviors in related species? In what ancestor did the behavior first appear?

Evolution of Animal Behavior

To the extent that behaviors are controlled by gene, they may evolve through natural selection. If behaviors increase **fitness**, they are likely to become more common over time. If they decrease fitness, they are likely to become less common.

Nature vs. Nurture

Some behaviors seem to be controlled solely by genes. Others appear to be due to experiences in a given environment. Whether behaviors are controlled mainly by genes or by the environment is often a matter of debate. This is called the **nature-nurture debate**. Nature refers to the genes an animal inherits. Nurture refers to the environment that the animal experiences.

In reality, most animal behaviors are not controlled by nature or nurture alone. Instead, they are influenced by both nature and nurture. In dogs, for example, the tendency to behave toward other dogs in a certain way is probably controlled by genes. However, the normal behaviors can't develop in an environment that lacks other dogs. A puppy raised in isolation from other dogs may never develop the normal behaviors. It may always fear other dogs or act aggressively toward them.

How Behaviors Evolve

It's easy to see how many common types of behavior evolve. That's because they obviously increase the fitness of the animal performing them. For example, when wolves hunt together in a pack, they are more likely to catch prey (see **Figure** below). Therefore, hunting with others increases a wolf's fitness. The wolf is more likely to survive and pass its genes to the next generation by behaving this way.

[Figure 3]

Wolves hunt together in packs. This is adaptive because it increases their chances of killing prey and obtaining food.

The evolution of certain other types of behavior is not as easy to explain. An example is a squirrel chattering loudly to warn other squirrels that a predator is near. This is likely to help the other squirrels avoid the predator. Therefore, it could increase their fitness. But what about the squirrel raises the alarm? This squirrel is more likely to be noticed by the predator. Therefore, the behavior may actually lower this squirrel's fitness. How could such a behavior evolve through natural selection?

One possible answer is that helping others often means helping close relatives. Close relatives share many of the same genes that they inherited from their common ancestor. As a result, helping a close relative may actually increase the chances that copies of one's own genes will be passed to the next generation. In this way, a behavior that puts oneself at risk could actually increase through natural selection. This form of natural selection is called **kin selection**.

science Friday: When Eels Attack!

Electric eels have been known to jump out of the water and shock animals like horses. What would cause this extraordinary behavior? In this video by Science Friday, Kenneth Catania of Vanderbilt University discusses this behavior and the experiment that demonstrate this.

https://flexbooks.ck12.org/flx/render/embeddedobject/192004

Science Friday: Run, Octopus, Run!

Octopus move around using a variety of motions. One unique motion they can perform is to "run" backwards on two arms. In this video by Science Friday, Chrissy Huffard at Stanford explains the possible use of this behavior

https://flexbooks.ck12.org/flx/render/embeddedobject/192005

Summary

- Most animal behaviors are controlled by both genes and experiences in a given environment.
- To the extent that behaviors are controlled by genes, they may evolve.
- Behaviors that improve fitness increase through natural selection.

Review

1. Define animal behavior.
2. What is the nature-nurture debate?
3. What is kin selection?
4. How do behaviors become common?

Report Content Errors

10.4 Innate Behavior

FlexBooks 2.0 > Biology For High School Diploma > Innate Behavior

Last Modified: Jul 04, 2019

[Figure 1]

Is this Blue-footed Booby actually dancing?

The courtship of the Blue-footed Booby consists of the male flaunting his blue feet and dancing to impress the female. During the dance, the male will spread his wing and stamp his feet on the ground. Are these bird born with this skill, or do they learn it?

Innate Behavior

Behaviors that are closely controlled by gene with little or no environmental influence are called **innate behaviors**. These are behaviors that occur naturally in all members of a species whenever they are exposed to a certain **stimulus**. Innate behaviors do not have to be learned or practiced. They are also called instinctive behaviors. An **instinct** is the ability of an animal to perform a behavior the first time it is exposed to the proper stimulus. For example, a dog will drool the first time—and every time—it is exposed to food.

Significance of Innate Behavior

Innate behaviors are rigid and predictable. All members of the species perform the behaviors in the same way. Innate behaviors usually involve basic life functions, such as finding food or caring for offspring. Several examples are shown in **Figure** below. If an animal were to perform such important behaviors incorrectly, it would be less likely to survive or reproduce.

Spider spinning a web Bird building a nest

Caterpillar making a cocoon Dolphin leaping from the water

[Figure 2]

Examples of Innate Behavior. These innate behaviors are necessary for survival or reproduction. Can you explain why each behavior is important?

Intelligence and Innate Behavior

Innate behaviors occur in all animals. However, they are less common in species with higher levels of intelligence. Humans are the most intelligent species, and they have very few innate behaviors. The only innate behaviors in humans are **reflex**. A **reflex** is a response that always occurs when a certain stimulus is present. For example, a human infant will grasp an object, such as a finger, that is placed in its palm. The infant has no control over this reaction because it is innate. Other than reflexes such as this, human behaviors are learned–or at least influenced by experience—rather than being innate.

Innate Behavior in Human Beings

All animals have innate behaviors, even human beings. Can you think of human behaviors that do not have to be learned? Chances are, you will have a hard time thinking of any. The only truly innate behaviors in humans are called **reflex behaviors**. They occur mainly in babies. Like innate behaviors in other animals, reflex behaviors in human babies may help them survive.

An example of a reflex behavior in babies is the sucking reflex. Newborns instinctively suck on a nipple that is placed in their mouth. It is easy to see how this behavior evolved. It increases the chances of a baby feeding and surviving. Another example of a reflex behavior in babies is the grasp reflex (**Figure** below). Babies instinctively grasp an object placed in the palm of their hand. Their grip may be surprisingly strong. How do you think this behavior might increase a baby's chances of surviving?

[Figure 3]

One of the few innate behaviors in human beings is the grasp reflex. It occurs only in babies.

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Summary

- Innate behaviors are instinctive. They are controlled by genes and always occur in the same way.

- Innate behaviors do not have to be learned or practiced.
- Innate behaviors generally involve basic life functions, so it's important that they be performed correctly.

Review

1. What are innate behaviors? Give an example.
2. What would happen to an individual who poorly performs innate behaviors?
3. What is an instinct?

Report Content Errors

10.5 Learned Behavior

Last Modified: May 16, 2021

[Figure 1]

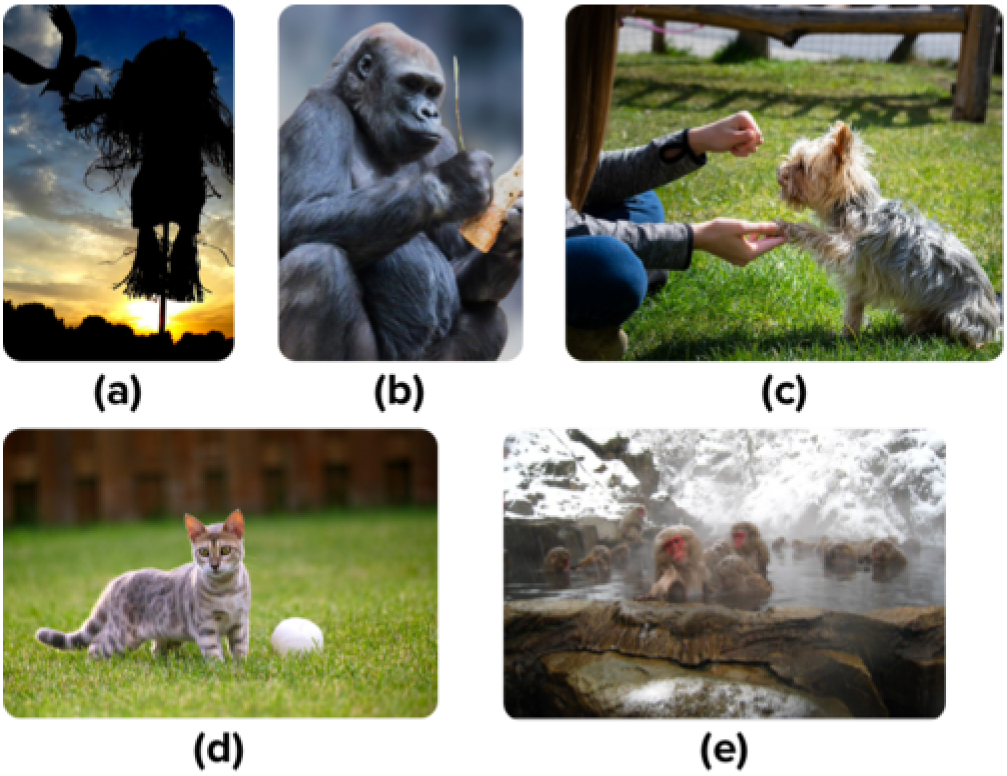
Fighting or playing?

You might think that these young tigers are fighting, but they're really just playing. Like most other young mammal, tigers like to play. Why do mammals play? Is playing just for fun, or does it serve some other purpose as well? Playing is actually an important way of **learning**. By playing, these tigers are learning moves that will help them become successful predator as adults. Playing is just one of many ways that mammals and other animal learn how to behave.

Learned Behavior

Learning is a change in behavior that occurs as a result of experience. Compared with innate behavior, learned behaviors are more flexible. They can be modified to suit changing conditions. This may make them more adaptive than innate behaviors. For example, drivers may have to modify how they drive (a learned behavior) when roads are wet or icy. Otherwise, they may lose control of their vehicle.

Animals may learn behaviors in a variety of ways. Some ways are quite simple. Others are more complex. Several types of learning are described in **Figure** below.



[Figure 2]

Types of Learning. Five different ways that animals may learn behaviors are shown here. What have you learned in each of these ways? (a) habituation (b) insight learning (c) conditioning (d) playing (e) observation

Insight Learning

insight learning, which is based on past experience and reasoning, is a hallmark of the human animal. Humans have used insight learning to solve problems ranging from starting a fire to traveling to the moon. It usually involves coming up with new ways to solve problems. Insight learning generally happens quickly. An animal has a sudden flash of insight. Insight learning requires relatively great intelligence. Human beings use insight learning more than any other species. They have used their intelligence to solve problems ranging from inventing the wheel to flying rockets into space.

Think about problems you have solved. Maybe you figured out how to solve a new type of math problem or how to get to the next level of a video game. If you relied on your past experiences and reasoning to do it, then you were using insight learning.

One type of insight learning is making tools to solve problems. Scientists used to think that humans were the only animals intelligent enough to make tools. In fact, tool-making was believed to set humans apart from all other animals.

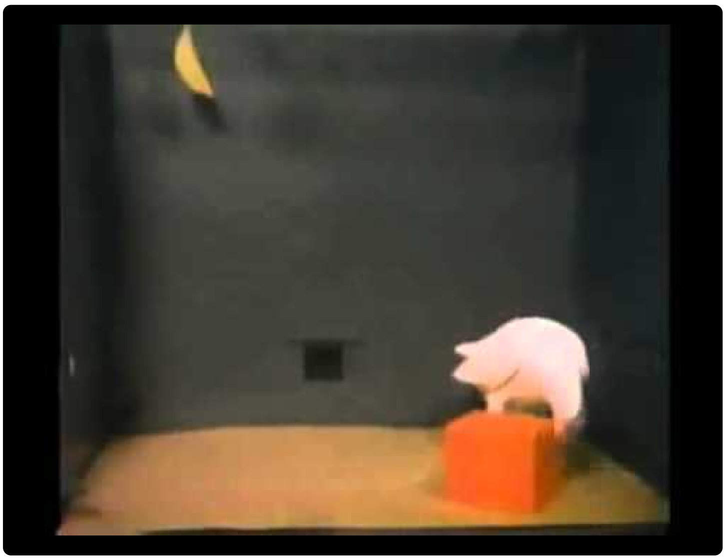
In 1960, primate expert Jane Goodall discovered that chimpanzees also make tools. She saw a chimpanzee strip leaves from a twig. Then he poked the twig into a hole in a termite mound. After termites climbed onto the twig, he pulled the twig out of the hole and ate the insects clinging to it. The chimpanzee had made a tool to "fish" for termites. He had used insight to solve a problem. Since then, chimpanzees have been seen making several different types of tools. For example, they sharpen sticks and use them as spears for hunting. They use stones as hammers to crack open nuts.

Scientists have also observed other species of animals making tools to solve problems. A crow was seen bending a piece of wire into a hook. Then the crow used the hook to pull food out of a tube.

An example of a gorilla using a walking stick is shown below (**Figure** below). Behaviors such as these show that other species of animals can use their experience and reasoning to solve problems. They can learn through insight.

[Figure 3]

This gorilla is using a branch as a tool. She is leaning on it to keep her balance while she reaches down into swampy water to catch a fish.



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Summary

- Learning is a change in behavior that occurs as a result of experience.
- Learned behaviors are adaptive because they are flexible. They can change if the environment changes.
- Behaviors can be learned in several different ways, including through play.

Review

1. What is learning?
2. Name three types of learning in animals.
3. Compare and contrast instinct and learning.

Report Content Errors

10.6 Social Behavior

FlexBooks 2.0 > Biology For High School Diploma > Social Behavior

Last Modified: Jul 04, 2019

[Figure 1]

Playing or fighting?

This display of **aggression** may be over a mate or land. But they definitely are not playing. This fight will continue until one is badly injured and flees, or the fight may continue to the death.

Social Behaviors

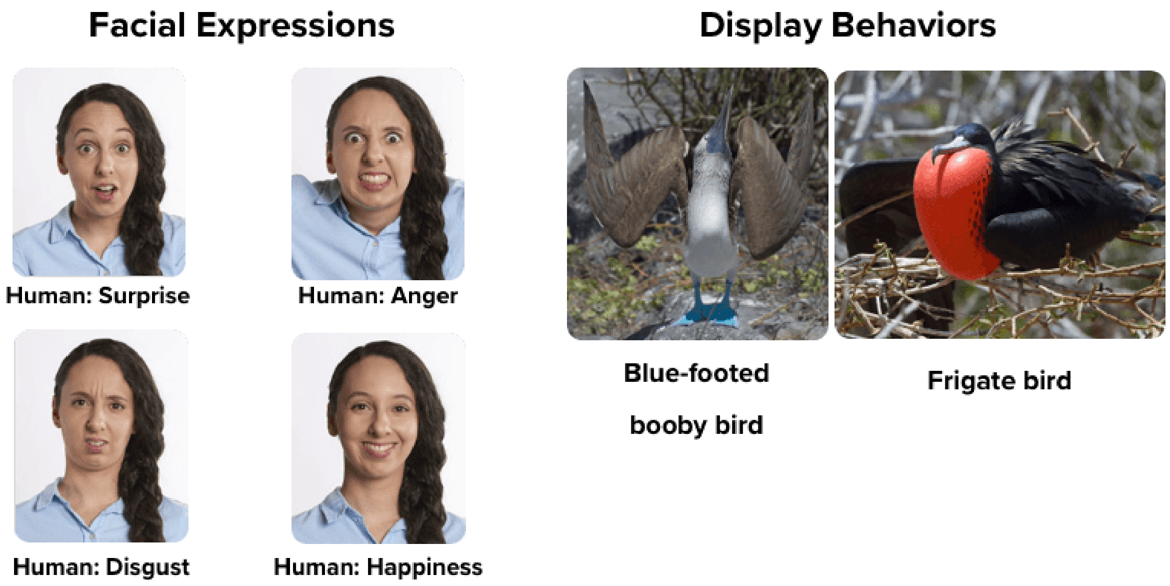
Different types of behavior evolved in animal because the behaviors helped them survive or reproduce. In many species, animals live together in a close-knit group with other members of their species. Such a group is referred to as a **society**. Animals that live in a society are known as **social animal**. They live and work together for the good of the group. This is called **cooperation**. Generally, each member of the group has a specific role that it plays in the society. Cooperation allows the group to do many things that a lone animal could never do. Look at the ants in **Figure** below. By working together, they are able to carry a large insect back to the nest to feed other members of their society.

[Figure 2]

Cooperation in a Social Insect. These ants are cooperating in a task that a single ant would be too small to do alone.

Communication

For individuals to cooperate, they need to **communicate**. Animals can communicate with sounds, chemicals, or visual cues. For example, to communicate with sounds, bird sing and frog croak. Both may be communicating that they are good mates. Ants communicate with chemicals called **pheromone**. For example, they use the chemicals to mark trails to food sources so other ants can find them. Male dogs use pheromones in urine to mark their territory. They are "telling" other dogs to stay out of their yard. You can see several examples of visual communication in **Figure** below.



[Figure 3]

Visual Communication in Animals. Many animals use visual cues to communicate.

Aggression

Aggression is behavior that is intended to cause harm or pain. It may involve physical violence against other individuals. For example, two male gorillas may fight and use their canine teeth to inflict deep wounds. Expressing aggression this way may lead to serious injury and even death.

In many species display behavior, rather than actual physical attacks, are used to show aggression. This helps prevent injury and death. Male gorillas, for example, are more likely to put on a display of aggression than to attack another male. In fact, gorillas have a whole series of display behaviors that they use to show aggression. They beat on their chest, dash back and forth, and pound the ground with their hands.

Competition

Aggressive behavior often occurs when individuals compete for the same resources. Animals may compete for territory, water, food, or mates. There are two basic types of competition: intraspecific and interspecific.

- **intraspecific competition** occurs between members of the same species. For example, two male deer may compete for mates by clashing their antlers together.
- **interspecific competition** occurs between members of different species. For example, one species of ant may attack and take over the colony of another ant species.

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Summary

- Types of animal behavior include social behaviors such as cooperation and communication.
- Competition may lead to aggressive behaviors or displays of aggression.

Review

1. Explain why communication is necessary for social living.
2. Describe communication in ants.
3. What is aggression?
4. What type of competition occurs between two dogs?
5. Create a bulletin board or brief video to demonstrate the role of facial expressions in human communication.

Report Content Errors

10.7 Cyclic Behavior

FlexBooks 2.0 > Biology For High School Diploma > Cyclic Behavior

Last Modified: Jul 04, 2019

[Figure 1]

The seventh greatest wonder in the world. Really?

The Masai Mara Wildebeest **migration**. The annual wildebeest migration in Kenya and Tanzania is arguably the most spectacular natural event in Africa. More than 3 million large mammal have made the vast Masai Mara and Serengeti plains their home, and each summer they migrate, looking for greener pastures. And yes, some call it "the seventh greatest wonder in the world."

Cyclic Behaviors

Many animal behavior occur in a regular cycle. Two types of cyclic behaviors are **circadian rhythm** and migration.

Circadian rhythms are regular changes in biology or behavior that occur in a 24-hour cycle. In humans, for example, blood pressure and body temperature change in a regular way throughout each 24-hour day. animal may eat and drink at certain times of day as well. Humans have daily cycles of behavior, too. Most people start to get sleepy after dark and have a hard time sleeping when it is light outside. In many species, including humans, circadian rhythms are controlled by a tiny structure called the **biological clock**. This structure is located in a gland at the base of the brain. The biological clock sends signals to the body. The signals cause regular changes in behavior and body processes. The amount of light entering the eyes helps control the biological clock. The clock causes changes that repeat every 24 hours.

Migration refers to seasonal movement of animals from one area to another. Migrants typically travel long distances, and travel the same paths each seasonal cycle. Usually, the migrants move to another area in order to find food or mates. Many bird, fish, and insects migrate. Mammals such as whales and caribou migrate as well. **Figure** below shows the migration route of a bird called a godwit. Another example of a behavior with a yearly cycle is **hibernation**. **Hibernation** is a state in which an animal's body processes are slower than usual, and its body temperature falls. An animal uses less energy than usual during hibernation. This helps the animal survive during a time of year when food is scarce. Hibernation may last for weeks or months. Animals that hibernate include species of bats, squirrels, and snakes. Most people think that bears hibernate. In fact, bears do not go into true hibernation. In the winter, they go into a deep sleep. However, their body processes do not slow down very much. Their body temperature also remains about the same as usual. Bears can be awakened easily from their winter sleep.

[Figure 2]

Godwit Migration Route. Godwits make this incredibly long journey twice a year. In the fall, they migrate from the Arctic to Antarctica. They make the return flight in the spring.

KQED: Flyways: The Migratory Routes of Birds

For thousands of years and countless generations, migratory birds have flown the same long-distance paths between their breeding and feeding grounds. Understanding the routes these birds take, called **flyway**, helps conservation efforts and gives scientists better knowledge of global changes, both natural and man-made.

https://flexbooks.ck12.org/flx/render/embeddedobject/469

Summary

- Types of animal behavior include cyclic behaviors such as circadian rhythms and migration.

Review

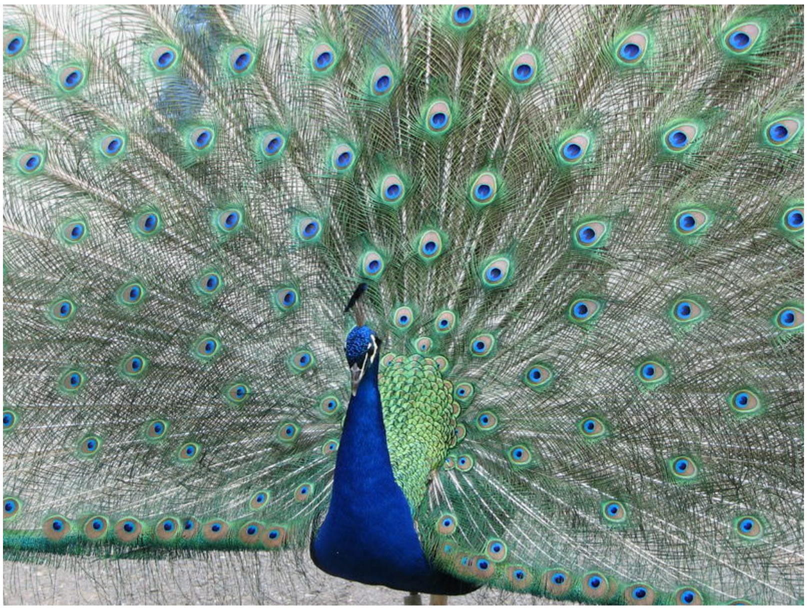
1. What are circadian rhythms? Give an example.
2. Why is migration considered a cyclic behavior?

Report Content Errors

10.8 Reproductive Behavior

FlexBooks 2.0 > Biology For High School Diploma > Reproductive Behavior

Last Modified: Mar 28, 2022



[Figure 1]

So when does the peacock extend his tail?

Peafowl are best known for the male's extravagant tail. Obviously though, a peacock cannot have his tail extended continuously. It would make it very difficult to move around. And it may be very tiring. So when does the peacock extend his tail? The peacock displays his tail as part of **courtship**.

Mating and Courtship

mating refers to the union of a male and female of the same species for reproduction. The relationship between mates varies by species. Adults may have many mates, or they may mate with just one individual. Mates may stay together only while mating, for an entire breeding season, or even for life.

Females are likely to be more selective than males in choosing mates. In many species, males put on **courtship** displays to encourage females to choose them as mates. For example, to attract a mate, a male bowerbird builds an elaborate nest decorated with hundreds of small blue objects (see **Figure** below).

[Figure 2]

Bowerbird Decorating His Nest. A male bowerbird spends many hours collecting bits of blue glass and other small blue objects to decorate his nest. A female bowerbird inspects the nests of many males before choosing as a mate the male with the best nest.

https://flexbooks.ck12.org/flx/render/embeddedobject/318030

Parental Care

In most species of fish, amphibian, and reptile, parents provide no care to their offspring. In bird and mammal, on the other hand, parental care is common. Most often, the mother provides the care. However, in some species, both parents or just the father may be involved.

Parental care is generally longest and most involved in mammals. Besides feeding and protecting their offspring, parents may teach their offspring skills they will need to survive on their own. For example, meerkat adults teach their pups how to eat scorpions. They show the pups how to safely handle the poisonous insects and how to remove the stingers.

[Figure 3]

This mother killdeer is pretending she has a broken wing. She is trying to attract a predator's attention in order to protect her chicks. This behavior puts her at risk of harm. How can it increase her fitness?

Defending Territory

Some species of animal are **territorial**. This means that they defend their area. The area they defend usually contains their nest and enough food for themselves and their offspring. A species is more likely to be territorial if there is not very much food in their area. Animals generally do not defend their territory by fighting. Instead, they are more likely to use **display behavior**. The behavior tells other animals to stay away. It gets the message across without the need for fighting. Display behavior is generally safer and uses less energy than fighting. Male gorillas use display behavior to defend their territory. They pound on their chests and thump the ground with their hands to warn other male gorillas to keep away from their area. The robin displays his red breast to warn other robins to stay away (**Figure** below).

[Figure 4]

The red breast of this male robin is easy to see. The robin displays his bright red chest to defend his territory. It warns other robins to keep out of his area.

Some animals deposit chemicals to mark the boundary of their territory. This is why dogs urinate on fire hydrants and other objects. Cats may also mark their territory by depositing chemicals. They have scent glands in their face. They deposit chemicals by rubbing their face against objects.

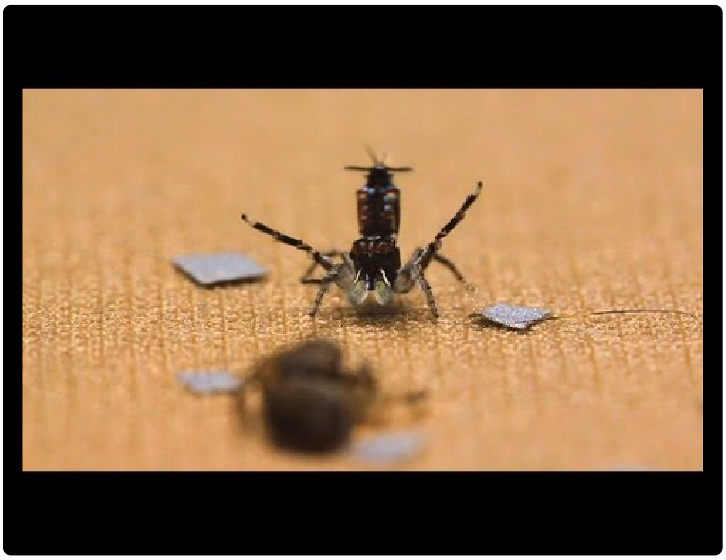
science Friday: "Hot" For Turkey

A male wild turkey's display conjures images of Americana and festive feasts, but isn't intended for human eyes. In this video by Science Friday, Dr. Richard Buchholz describes how female turkeys use it to discern a male's genetic prowess.

https://flexbooks.ck12.org/flx/render/embeddedobject/193628

Science Friday: Shake Your Silk-Maker: The Dance of the Peacock Spider

With their ornately-colored bodies, rhythmic pulsations, and booty-shaking dance moves, male peacock spiders attract the attention of spectating females as well as researchers. In this video by Science Friday, researcher Madeline Girard interprets what these displays actually say to a female spider.



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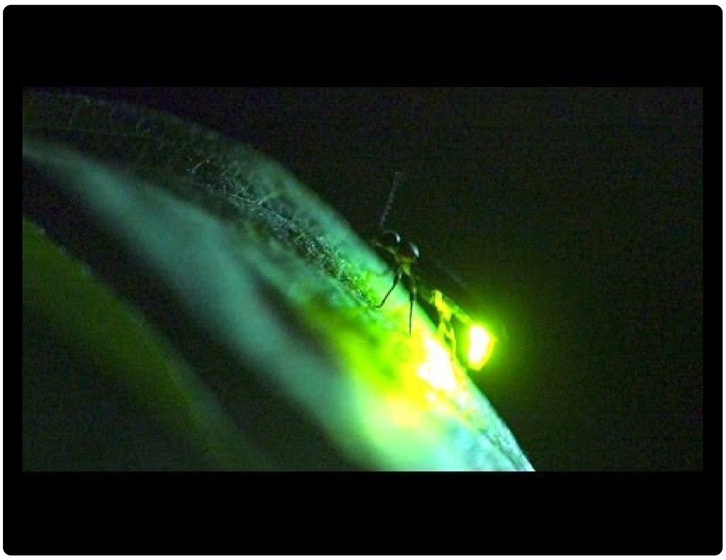
Science Friday:In A Flash: Firefly Communication

Fireflies communicate with a "language of light" that scientists still don't completely understand. In this video by Science Friday, researchers James Lloyd and Marc Branham discuss unique flash patterns and times for some of the 2,000 types of fireflies that light up the summer nights.



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Summary

- Behaviors relating to reproduction include mating, courtship, and parenting behaviors.

Review

1. Describe an example of courtship behavior in animals.
2. In what vertebrates is parental care common?
3. Give two examples of parental care.

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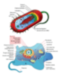	**Credit:** Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) **Source:** Top: http://commons.wikimedia.org/wiki/File:Average_prokaryote_cell-_en.svg; Bottom: http://commons.wikimedia.org/wiki/File:Animal_cell_structure_en.svg **License:** Public Domain
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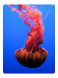	**Credit:** Flickr: jimg944 **Source:** https://www.flickr.com/photos/jimg944/3539484130/ **License:** CC BY 2.0
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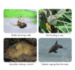	**Credit:** Spider: Dan Foy (Flickr:orangeacid); Bird: Miguel Andrade; Caterpillar: James Niland; Dolphin: Pen Waggener **Source:** Spider: http://www.flickr.com/photos/orangeacid/236234522/; Bird: http://commons.wikimedia.org/wiki/File:Nest_bird.jpg; Caterpillar: http://www.flickr.com/photos/bareego/6574102553/; Dolphin: http://www.flickr.com/photos/epw/235086733/ **License:** Spider: CC BY 2.0; Bird: Public Domain; Caterpillar: CC BY 2.0; Dolpin: CC BY 2.0
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CHAPTER 11

Invertebrates

Chapter Outline

11.1 Invertebrate Diversity

FlexBooks 2.0 > Biology For High School Diploma > Invertebrate Diversity

Last Modified: Sep 09, 2019

[Figure 1]

What type of animal is a Sea Cucumber?

That is a Sea Cucumber, and it is an animal. The Sea Cucumber is a soft-bodied **invertebrate** that is related to the starfish and sea urchins. There are over 1,100 species that are found worldwide in intertidal zones as well as deep waters.

Characteristics of Invertebrates

The majority of animals today are invertebrates. They have a wide range of physical traits and ways of life. Modern invertebrates include animals as different as the sponge and tarantula. Why are both of these animals classified as invertebrates? What traits do they have common?

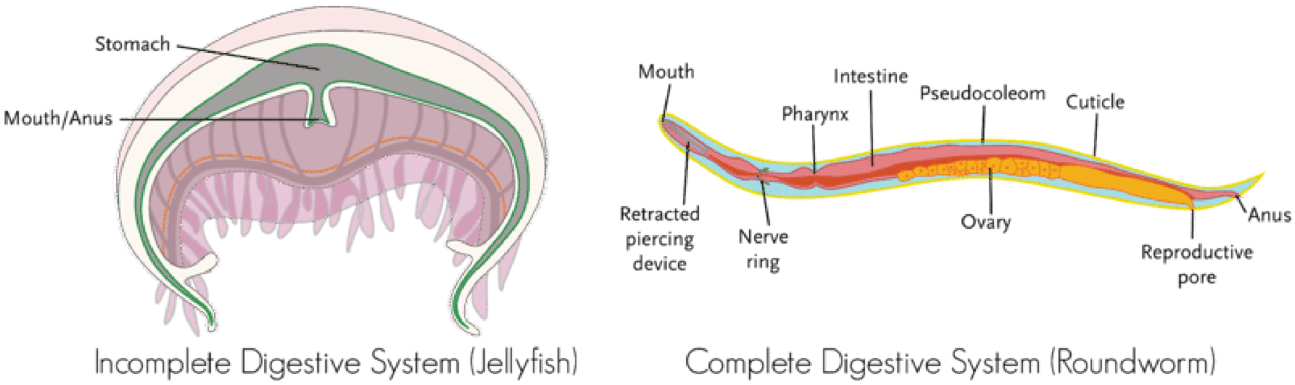
[Figure 2]

Examples of Invertebrates. Both a sponge (left) and tarantula (right) are invertebrates. Can you identify any traits they share?

One trait **invertebrates** like the sponge and tarantula share is lack of a backbone. In fact, they don't have any bone at all. These are defining traits of all invertebrates. Some invertebrates have a skeleton, but it isn't made of bone. Many other traits of invertebrates show considerable diversity.

Digestion

Invertebrates have one of two types of digestive system: an incomplete or **complete digestive system**. Both are shown in **Figure** below. An **incomplete digestive system** consists of a digestive cavity with one opening. The single opening serves as both mouth and anus. A **complete digestive system** consists of a digestive tract with two openings. One opening is the mouth. The other is the anus.



[Figure 3]

Two Types of Digestive Systems in Invertebrates. On the left is an incomplete digestive system, found in a jellyfish; on the right is the complete digestive system of a roundworm. Invertebrates may have either of these two types of digestive system. Find the parts of each digestive system in each drawing. How do the two systems differ?

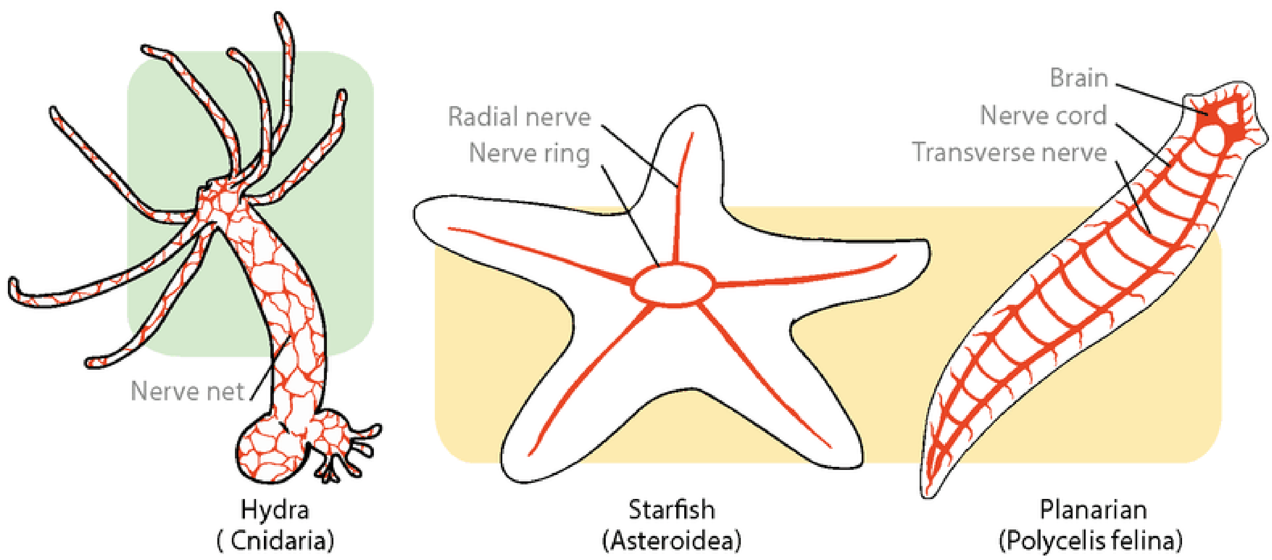
Movement

All invertebrates can move on their own during at least some stage of their life cycle. However, they may differ in how they move. Several ways are described below.

- Some invertebrates are simply carried along by water currents. They cannot control their movement in a particular direction. An example is a jellyfish.
- Other invertebrates can contract muscles to move independently of water currents or on solid surfaces. They can also control the direction in which they move. An example is a roundworm. It can move forward and to the left or right.
- Still other invertebrates have specialized **appendage** for movement. For example, they may have jointed legs for walking or climbing or wing for flying. An example is an insect such as a fly.

Nervous System

Most invertebrates have a **nervous system**. The nervous system allows them to sense and respond to their environment. The simplest invertebrate nervous system is just a network of nerve that can sense touch, called a **nerve net** (see **Figure** below). Most invertebrates have a more complex nervous system. It may include a **brain** and several different sense organ.



[Figure 4]

The nervous system of invertebrates.

Reproduction

Most invertebrates reproduce sexually. diploid adults produce haploid gamete (sperm and eggs). In some species, the same individuals produce both sperm and egg. In other species, sperm and eggs are produced by separate male and female individuals. fertilization occurs when a sperm and an egg fuse to form a diploid zygote. The zygote develops into an embryo and eventually into a new adult organism. On the way, it may pass through one or more larval stages. A **larva** (plural, larvae) is a juvenile, or immature, stage of an animal. It is generally quite different in form and function from the adult form of the species. For example, the larva may be able to swim freely, whereas the adult must remain permanently attached to a solid surface.

Some invertebrates can also reproduce asexually. This may occur by fission or **budding**. **Fission** takes place when an animal simply divides into two parts. Each part then regrows the missing part. The result is two whole organisms. **Budding** may take place when a parent forms a small bump, or bud. The bud remains attached to the parent while it develops into a new individual.

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Summary

- The majority of living animals are invertebrates. Invertebrates lack a backbone.
- Invertebrates may have an incomplete or a complete digestive system.
- Invertebrates vary in how they move and in the complexity of their nervous system.
- Most invertebrates reproduce sexually. After hatching, many invertebrates pass through one or more larval stages that are different from the adult stage.

Review

1. Describe the range of variation in the nervous systems of invertebrates.
2. Compare and contrast incomplete and complete digestive systems.
3. Describe fission and budding.
4. Create a diagram to show the life cycle of an invertebrate with a larval stage. Include simple sketches of the adult and larval stages of the animal.

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11.2 Invertebrate Evolution

FlexBooks 2.0 > Biology For High School Diploma > Invertebrate Evolution

Last Modified: Jul 04, 2019

[Figure 1]

How many different types of beetles are there?

There are about 350,000 species of beetles spread all over the world. But let's focus on this one. Look at the detail on this Rhinoceros beetle. The horns are used in fighting other males during mating season, and for digging. The body of an adult rhino beetle is covered by a thick exoskeleton. A pair of thick wing lay atop another set of wings underneath, allowing the rhinoceros beetle to fly. Compare those evolutionary adaptation to a simple sponge, and the evolutionary significance of invertebrate becomes obvious.

Invertebrate Evolution

Invertebrates evolved several important traits before vertebrate even appeared. These traits are now found in just about all animal.

Multicellularity

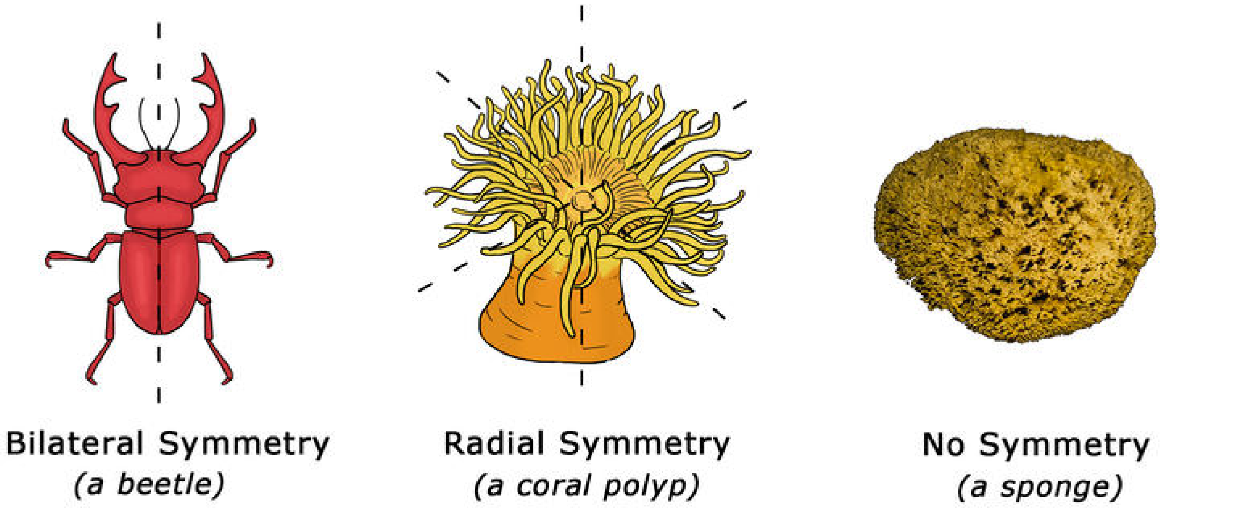
The first animal trait to evolve was **multicellularity**. This was highly adaptive. Multiple cell could do different jobs. They could evolve special adaptations that allowed them to do their job really well. However, the first invertebrates still lacked tissue. Sponges represent the first organism at the multicellular stage of invertebrate evolution.

Tissues

Living cnidarians, such as jellyfish, represent the next stage of invertebrate evolution. This was the evolution of tissues. It was the first step in the evolution of organ and organ system. At first, invertebrates developed tissues from just two embryonic cell layers. There was an outer cell layer called **ectoderm** and an inner cell layer called **endoderm.** The two cell layers allowed different types of tissues to form.

Radial Symmetry

Another trait that evolved early on was **symmetry**. To understand symmetry, you need to see an animal that lacks symmetry. A sponge, like the one in **Figure** below, lacks symmetry. This means it cannot be divided into two identical halves. A symmetrical organism, in contrast, can be divided into two identical halves. Both the coral polyp and the beetle in **Figure** below have symmetry.



[Figure 2]

Symmetry in Invertebrates. Sponges lack symmetry. Radial symmetry evolved first. This was followed by bilateral symmetry. How do the two types of symmetry differ?

The coral polyp in **Figure** above has **radial symmetry.** This was the first type of symmetry to evolve. The coral has a distinct top and bottom but not distinct ends. It can be divided into identical halves like a pie, but not into right and left halves. Animals with radial symmetry have no sense of directions such as forward and backward or left and right. This makes controlled movement in these directions impossible.

Cephalization

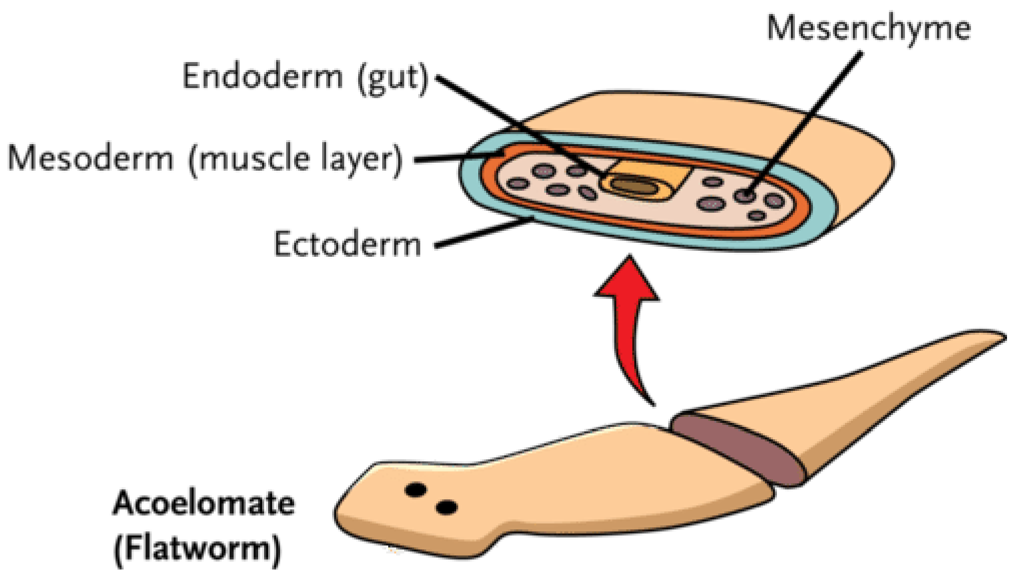
flatworm represent the next stage of invertebrate evolution. They evolved **cephalization.** This is the concentration of nerve tissue at one end of the body, forming a head region. This is highly adaptive. It allows central control of the entire organism. Cephalization was first step in the evolution of a brain.

Bilateral Symmetry

An outcome of cephalization was **bilateral symmetry.** This is demonstrated by the beetle in **Figure** above. With concentrated nerve tissue at the head but not at the tail end, the two ends of the body are distinct from each other. The animal can be divided down the middle to form identical right and left halves. It allows the animal to tell front from back and left from right. This is needed for controlled movements in these directions.

Mesoderm

Ancestors of flatworms also evolved **mesoderm.** This is a third layer of cells between the ectoderm and the endoderm (see **Figure** below). Evolution of this new cell layer allowed animals to develop new types of tissues, such as muscle.



[Figure 3]

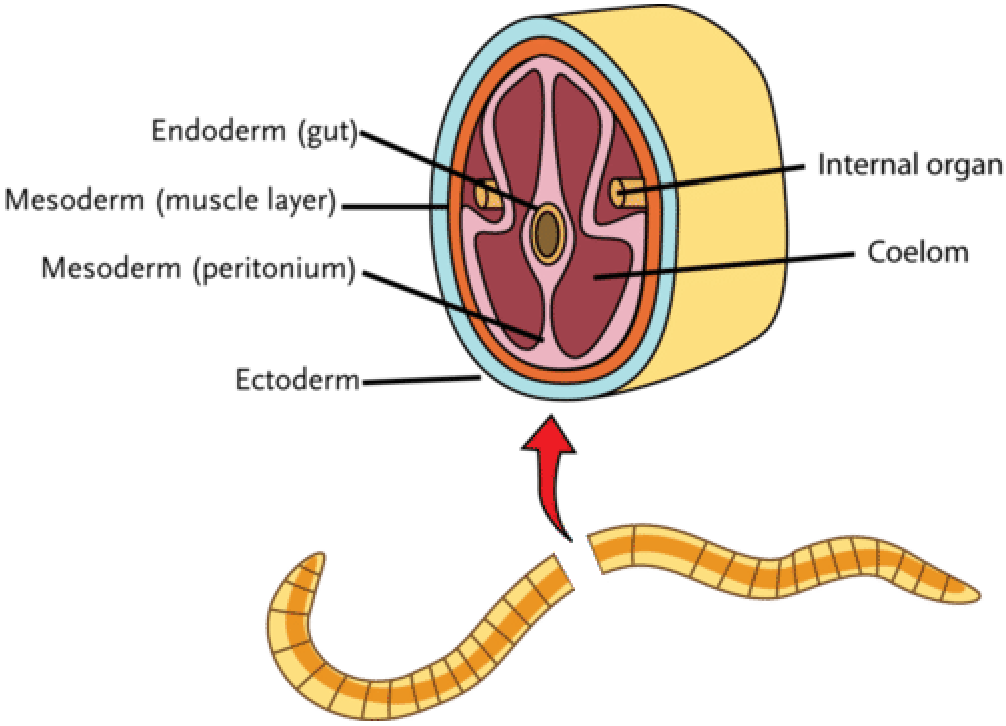
Three Cell Layers in a Flatworm. A flatworm has three cell layers.

Complete Digestive System

Early invertebrates had an incomplete digestive system. There was just one opening for the mouth and anus. Ancestors of modern roundworms were the first animals to evolve a **complete digestive system**. With a separate mouth and anus, food could move through the body in just one direction. This made digestion more efficient. An animal could keep eating while digesting food and getting rid of waste. Different parts of the digestive tract could also become specialized for different digestive functions. This led to the evolution of digestive organs.

Pseudocoelom and Coelom

Ancestors of roundworms also evolved a **pseudocoelom.** This is a partial body cavity that is filled with fluid. It allows room for internal organs to develop. The fluid also cushions the internal organs. The pressure of the fluid within the cavity provides stiffness. It gives the body internal support, forming a **hydrostatic skeleton.** It explains why roundworms are round and flatworms are flat. Later, a true **coelom** evolved. This is a fluid-filled body cavity, completely enclosed by mesoderm. It lies between the digestive cavity and body wall (see **Figure** below). Invertebrates with a true coelom include mollusks and annelids.



[Figure 4]

Cross Section of an Invertebrate with a Coelom. The coelom forms within the mesoderm.

Segmented Body

segmentation evolved next. This is a division of the body into multiple segments. Both the earthworm and ant pictured in **Figure** below have segmented bodies. This trait increases flexibility. It permits a wider range of motion. All annelids and arthropod are segmented. Arthropods also evolved jointed appendage. For example, they evolved jointed legs for walking and “feelers” (antennae) for sensing.

[Figure 5]

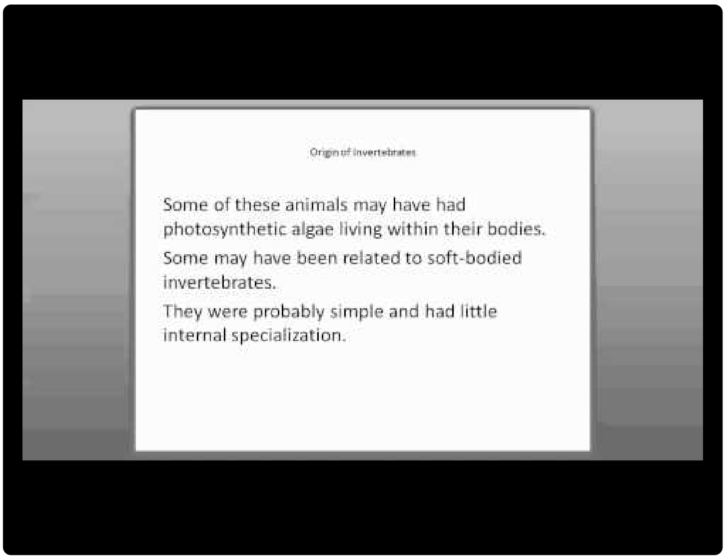
Segmented Invertebrates. Earthworm (Annelid) and Black Ant (Arthropod). An earthworm consists of many small segments. An ant has three larger segments. Notice the ants jointed legs and "feelers."

Notochord

Some invertebrates evolved a **notochord**. This is the stiff support rod in a **chordate**. The first chordates were probably similar to modern invertebrate chordates. The sea squirt in **Figure** below is an example. Later, some invertebrate chordates evolved into vertebrates.

[Figure 6]

Notochord. A sea squirt is an invertebrate with a notochord.



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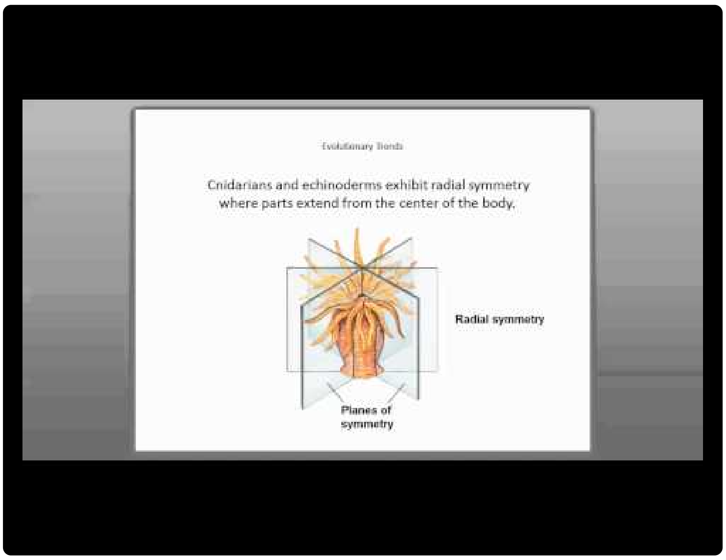

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Summary

- Many important traits evolved in invertebrates. They include: multicellularity, tissues and organs, radial and bilateral symmetry, cephalization, mesoderm, complete digestive system, coelom, segmented body, and notochord.

Review

1. Distinguish among asymmetry, radial symmetry, and bilateral symmetry.
2. Define cephalization. What is its relationship to bilateral symmetry?
3. What is mesoderm? Name an invertebrate with mesoderm.
4. Define coelom. What invertebrates have a true coelom?
5. What is segmentation? Why is it advantageous?
6. Compare and contrast incomplete and complete digestive systems. Why is a complete digestive system more efficient?

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11.3 Invertebrate Classification

FlexBooks 2.0 > Biology For High School Diploma > Invertebrate Classification

Last Modified: Feb 08, 2022

[Figure 1]

Invertebrate, arthropod or insect?

This Monarch caterpillar is an invertebrate. It is also an insect and an arthropod. Of all the animal species, it is estimated that well over 90% are invertebrates. Of all invertebrates, the insects are by far the most numerous. There are so many species of insects that scientists have yet to discover them all, let alone name or count them. Estimates of the total number of insect species fall in the range of 1 to 30 million. So, it helps if there are methods to classify not just the insects, but all invertebrates.

Classification of Invertebrates

Eight major phyla contain the majority of invertebrate species.

Major Invertebrate Phyla

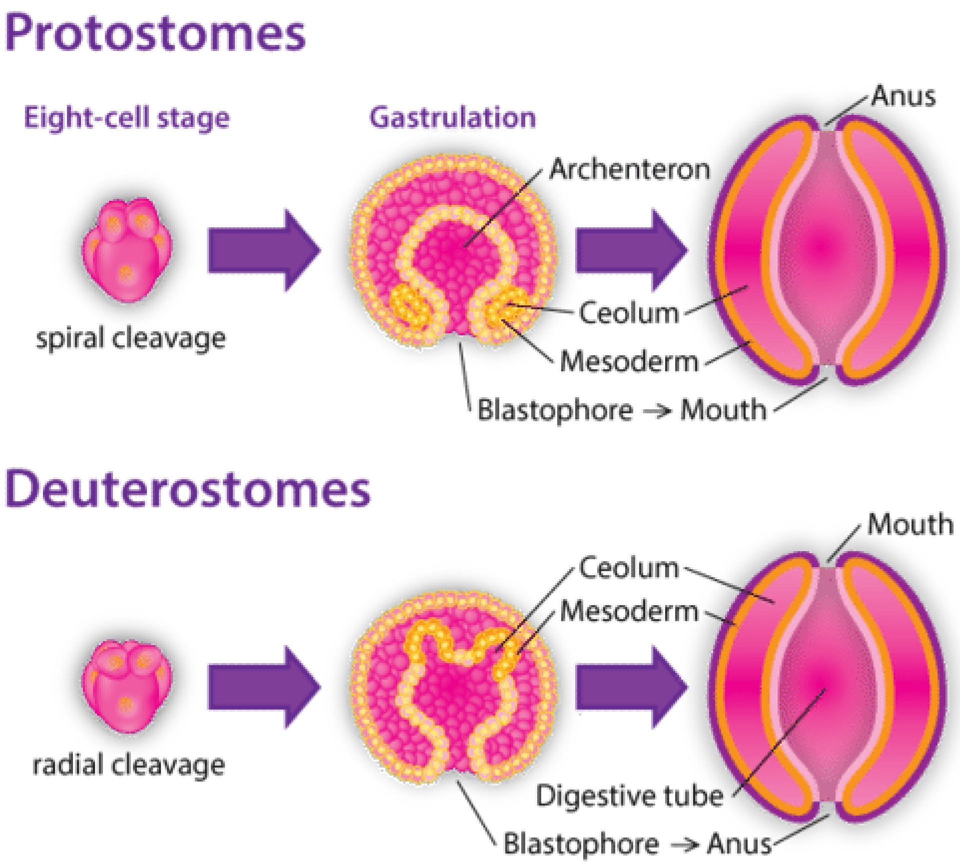
Table below gives an overview of the eight invertebrate phyla with the greatest number of species.

Phylum (includes)	Notable Characteristics	Example
Porifera (sponges)	multicellularity, specialized cell but no tissue, asymmetry, incomplete digestive system	sponges
Cnidaria (jellyfish, corals)	radial symmetry, true tissues, incomplete digestive system	jellyfish
Platyhelminthes (flatworm, tapeworms, flukes)	cephalization, bilateral symmetry, mesoderm, incomplete digestion with some exceptions	flatworm
Nematoda (roundworms)	pseudocoelom, complete digestive system	roundworm
Mollusca (snails, clams, squids)	true coelom, organ system, some with primitive brain	snail
Annelida (earthworm, leech, marine worms)	segmented body, primitive brain	earthworm
Arthropoda (insects, spiders, crustaceans, centipedes)	segmented body, jointed appendage, exoskeleton, brain	insect (dragonfly)
Echinodermata (sea stars, sea urchins, sand dollars, sea cucumbers)	complete digestive system, coelom, spiny internal skeleton	sea urchin

Protostomes and Deuterostomes

Most invertebrates (and higher animals) can be placed in one of two groups based on how they develop as embryo. The two groups are called **protostome** and **deuterostome**. As shown in **Figure** below, organism in the two groups have different ways of forming the coelom and mouth, among other differences.

Mollusks, annelids, and arthropods are protostomes. echinoderm and chordate are deuterostomes. This distinction is important. Why does it matter? It shows that echinoderms are more closely related to chordates than are the other invertebrate phyla. This is not apparent based on other, more obvious traits.

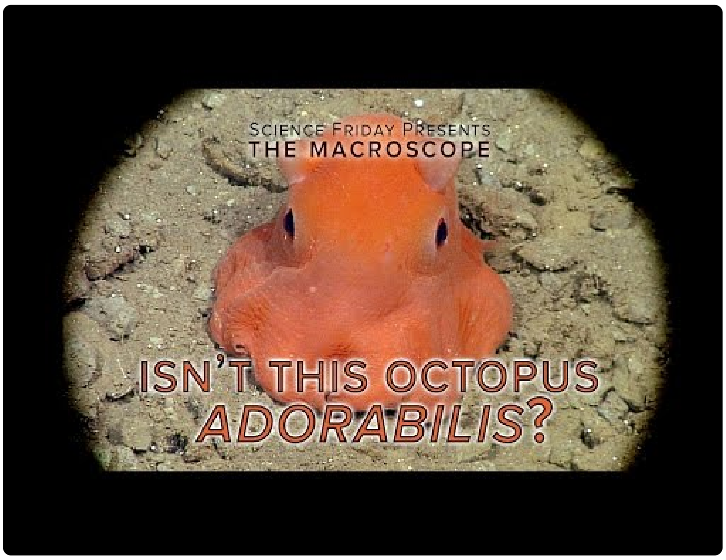


[Figure 2]

Protostomes vs. Deuterostomes. In protostomes such as mollusks, the coelom forms within the mesoderm. In deuterostomes such as echinoderms, the coelom forms from a pouch of endoderm. How does the formation of the mouth differ in these two groups of animals?

science Friday: Isn't this Octopus Adorabilis?

What do you call a tiny octopus with big eyes, gelatinous skin and is cute as a button? Nobody knows quite yet! In this video by Science Friday, Stephanie Bush aims to classify and name this presently undescribed deep-sea cephalopod.



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Summary

- Eight invertebrate phyla contain most invertebrate species.
- Invertebrates (and higher animals) can also be placed in one of two groups based on how they develop as embryos.

Review

1. What are protostomes?
2. Describe evidence showing that echinoderms are more closely related to chordates than are other invertebrate phyla.
3. Assume you have discovered a new invertebrate. It has a segmented body, a brain, and jointed appendages. In which phylum would you place it? Why?

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11.4 Sponges

FlexBooks 2.0 > Biology For High School Diploma > Sponges

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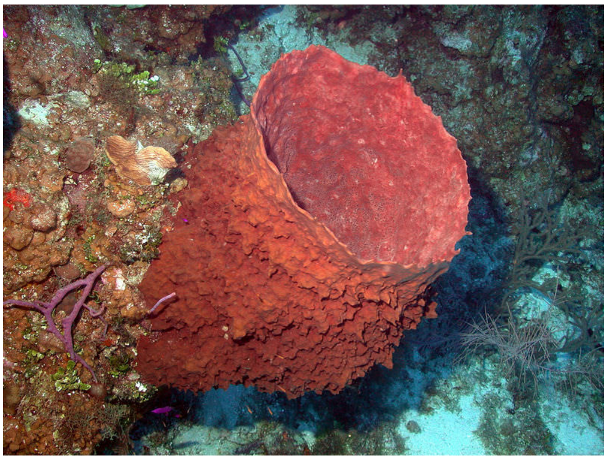


[Figure 1]

So what exactly is a sponge?

Here we have a giant barrel sponge. How can something that looks like that be considered an *animal?* Where's the head? Where are the legs? Where's the mouth?

Sponges

invertebrate are animals without a backbone. They are the most numerous animals on Earth. Most invertebrates are insects. However, simpler invertebrates evolved before insects. Some, like the sponges you will read about in this concept, have existed virtually unchanged for hundreds of millions of years. Their continued existence is evidence that they are well adapted for their habitat. They also evolved some of the most important traits that are found in almost all animals today. Without the traits that evolved in sponges and other simple invertebrates, you would not exist. Sponges are aquatic invertebrates that make up the phylum **Porifera.** The word "porifera" means pore-bearing. The phylum is aptly named. As you can see from **Figure** below, a sponge has a porous body. There are at least 5,000 living species of sponges. Almost all of them inhabit the ocean, living mainly on coral reefs or the ocean floor.

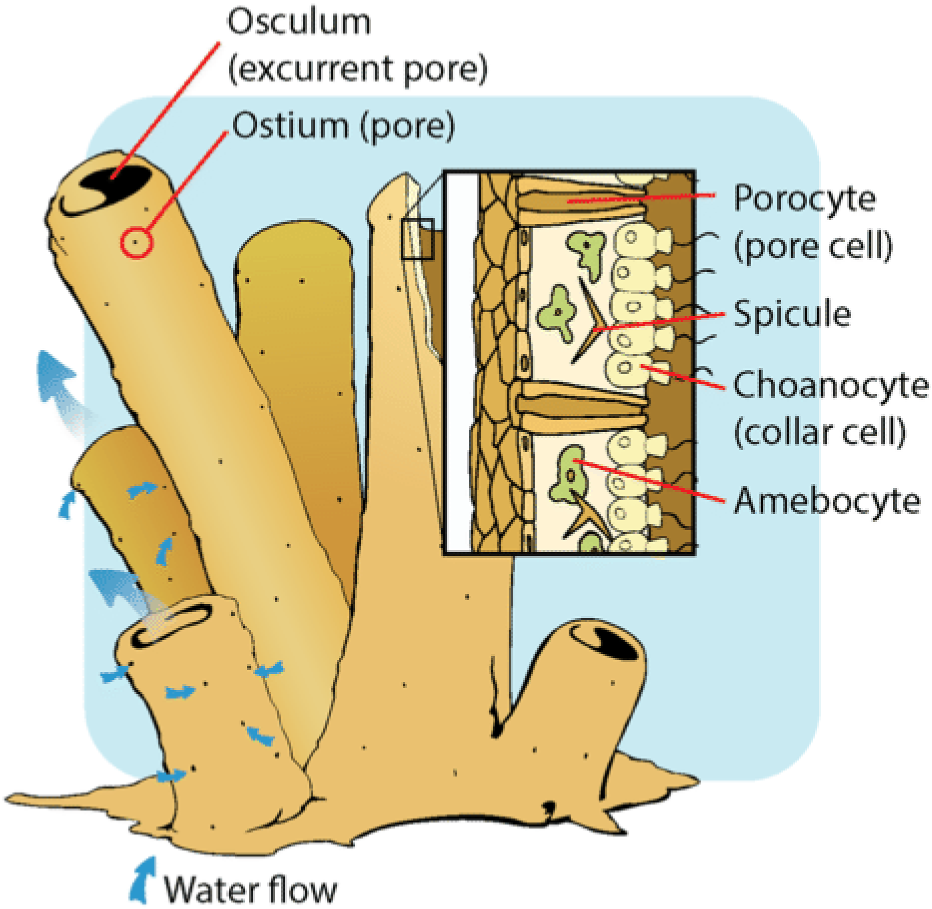
[Figure 2]

Sponge on a Coral Reef. This orange sponge is covered with pores. Can you predict the function of the pores?

Structure and Function of Sponges

Sponges come in a variety of shapes and sizes. For example, they may be shaped like tubes, fans, cone, or just blobs. They range in diameter from about a centimeter (0.4 inches) to over a meter (3.3 feet). Many species live in colonies that may be quite large. Adult sponges are **sessile.** This means they are unable to move from place to place. Root-like projections anchor them to solid surfaces such as rocks and reefs.

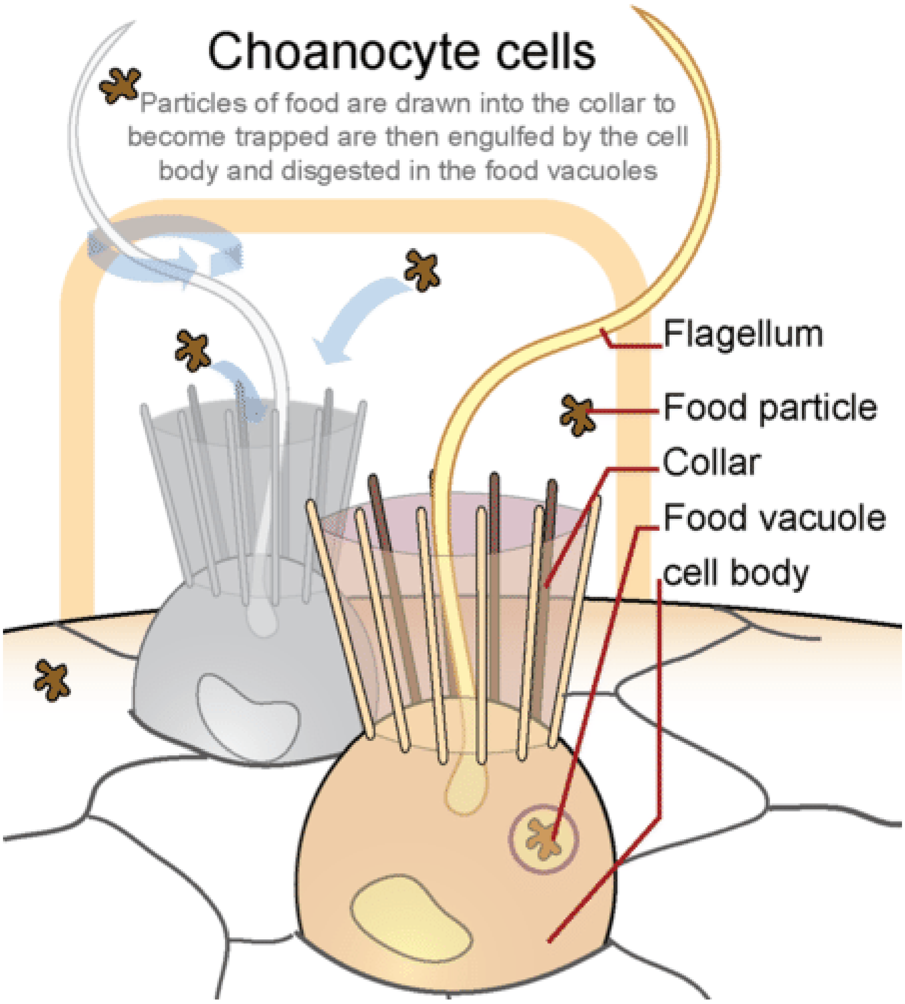
Sponges have an internal skeleton that gives them support and protection. An internal skeleton is called an **endoskeleton.** A sponge endoskeleton consists of short, sharp rods called **spicule** (see **Figure** below). Spicules are made of silica, calcium carbonate, or **spongin**, a tough protein. They grow from specialized cell in the body of the sponge.



[Figure 3]

Sponge Anatomy. A sponge lacks tissues and organs, but it has several types of specialized cells.

Sponges are **filter feeder.** They pump water into their body through their pores. The water flows through a large central cavity called the **spongocoel** (see **Figure** above). As the water flows by, specialized **collar cell** (which are also known as choanocytes) filter out food particles such as bacterium. Collar cells have tiny hairs that trap the particles. They also have a flagellum that whips the water and keeps it moving. Once the food is trapped, the collar cells digest it (see **Figure** below). Cells called amebocytes also help digest the food. They distribute the nutrient to the rest of the body as well. Finally, the water flows back out of the body through an opening called the **osculum**. As water flows through the sponge, oxygen diffuses from the water to the sponge's cells. The cells also expel wastes into the water for removal through the osculum.

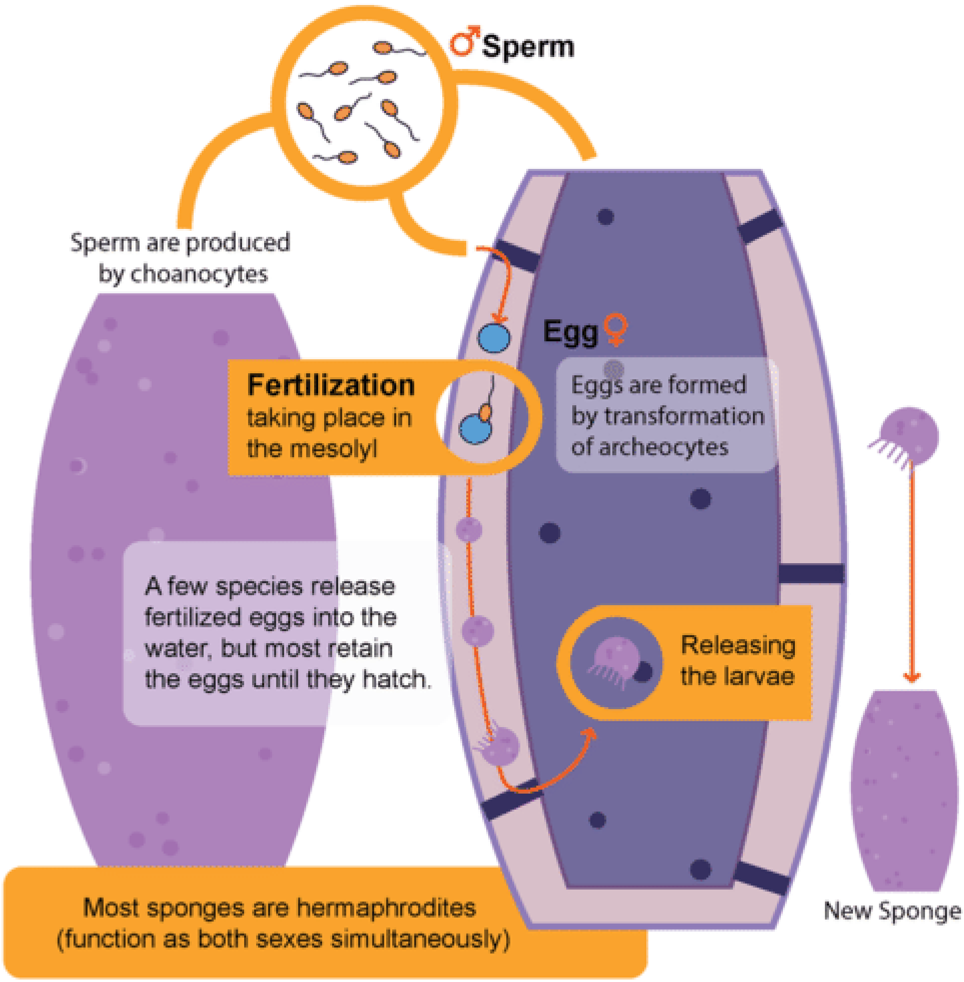


[Figure 4]

Collar Cell. The collar cells of sponges trap and digest food.

Sponge Reproduction

Sponges reproduce both asexually and sexually. asexual reproduction occurs by budding. **Figure** below shows the sponge life cycle when sexual reproduction is involved. Adult sponges produce egg and sperm. In many species, the same individuals produce both. However, they don't produce eggs and sperm at the same time. As a result, self-fertilization is unlikely to occur. What is an advantage of avoiding self-fertilization?



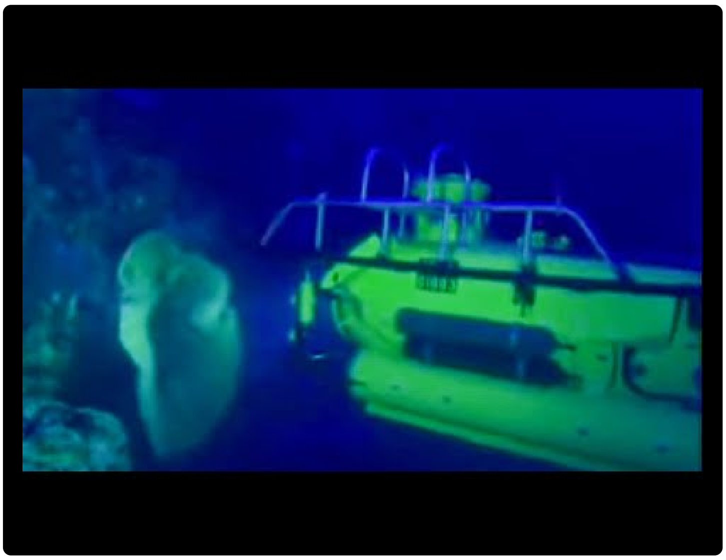
[Figure 5]

The sponge life cycle includes sexual reproduction. Sponges may also reproduce asexually.

Sperm are released into the surrounding water through the osculum. If they enter a female sponge through a pore, they may be trapped by collar cells. Trapped sperm are delivered to eggs inside the female body, where fertilization takes place. The resulting zygote develops into a larva. Unlike the adult, the larva is motile. It is covered with cilia that propel it through the water. As the larva grows, it becomes more similar to an adult sponge and loses its ability to swim.

Ecology of Sponges

Sponges that live on coral reefs have symbiotic relationships with other reef species. They provide shelter for alga, shrimp, and crabs. In return, they get nutrients from the metabolism of the organism they shelter. Sponges are a source of food for many species of fish. Because sponges are sessile, they cannot flee from predator. Their sharp spicules provide some defense. They also produce toxins that may poison predators that try to eat them.



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Summary

- Sponges are aquatic invertebrates. They make up the phylum Porifera.
- Sponges have specialized cells and an endoskeleton.
- Sponges lack tissues and body symmetry.
- Adult sponges are sessile filter feeders.
- Sponge larvae have cilia for swimming.

Review

1. Define sessile. Name an invertebrate with a sessile adult stage.
2. Describe the skeleton of a sponge.
3. Sponges have specialized cells called collar cells. Describe how collar cells are specialized for the functions they serve.
4. Create a diagram of an adult sponge body plan that shows how sponges obtain food.

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11.5 Cnidarians

FlexBooks 2.0 > Biology For High School Diploma > Cnidarians

Last Modified: Jul 04, 2019

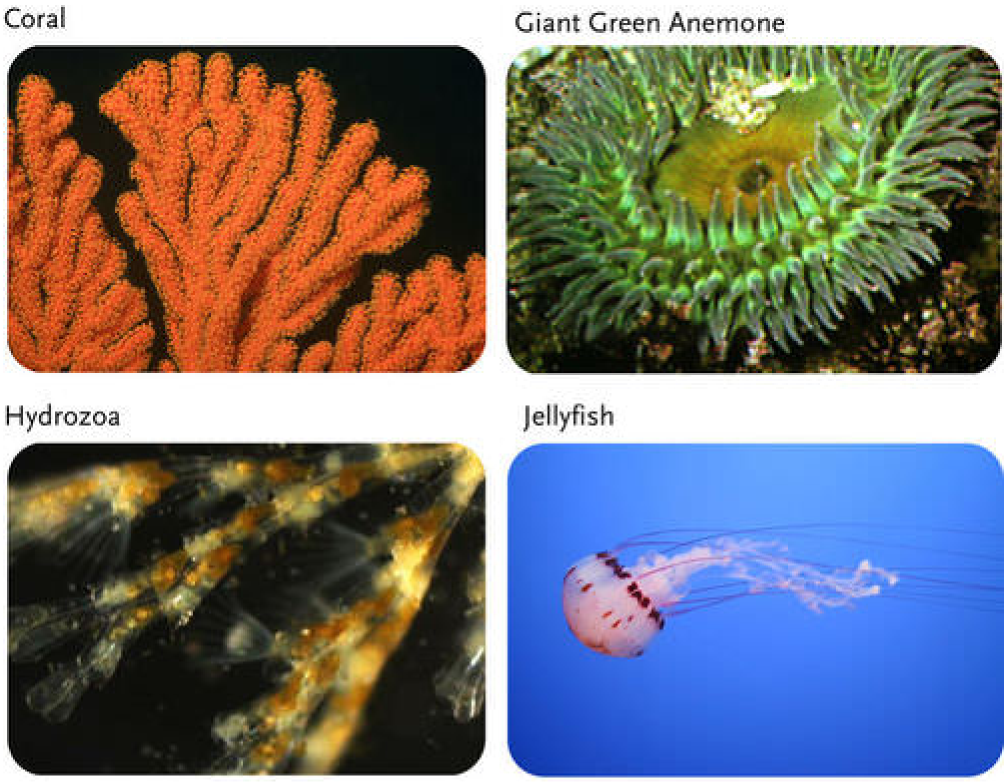
[Figure 1]

The sea anemone. Plant or animal?

It may look like a plant, but it's not. Sea anemones are a group of water-dwelling, predatory animal in the phylum **Cnidaria**. A sea anemone is a **polyp** attached at the bottom to the surface beneath it. They can have anywhere from a few tens of tentacles to a few hundred tentacles. And they eat small fish and shrimp.

Cnidarians

Cnidarians are invertebrate such as jellyfish and corals. They belong to the phylum Cnidaria. All cnidarians are aquatic. Most of them live in the ocean. Cnidarians are a little more complex than sponges. They have radial symmetry and tissue. There are more than 10,000 cnidarian species. They are very diverse, as shown in **Figure** below.

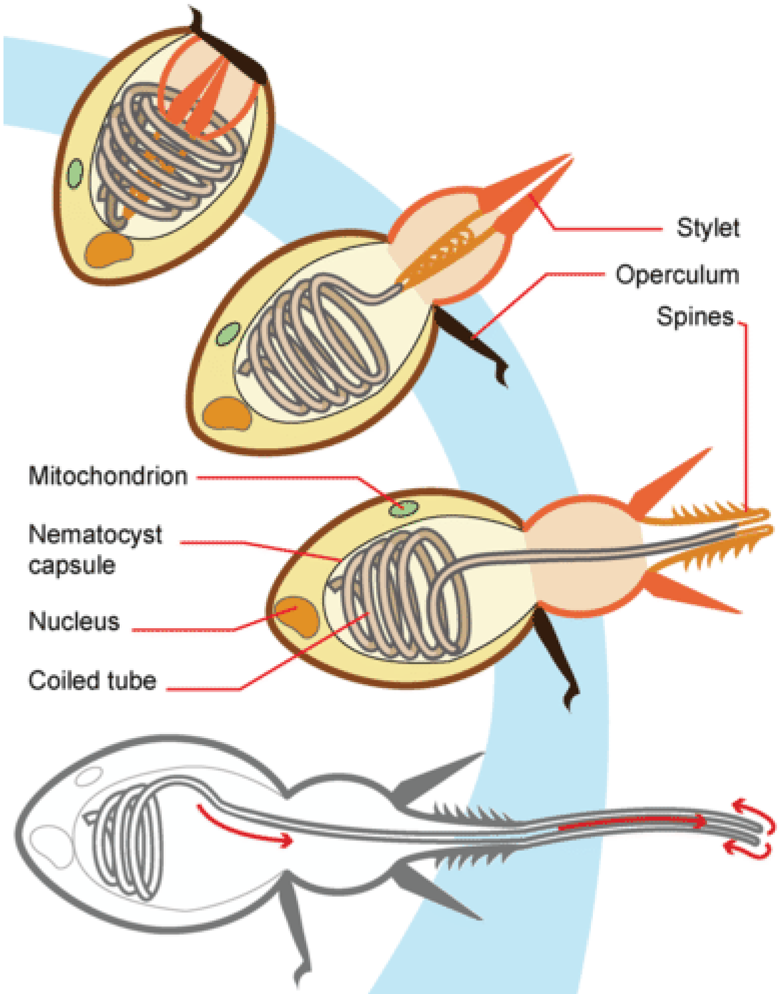


[Figure 2]

Cnidarian Diversity. Cnidarians show a lot of variability.

Structure and Function of Cnidarians

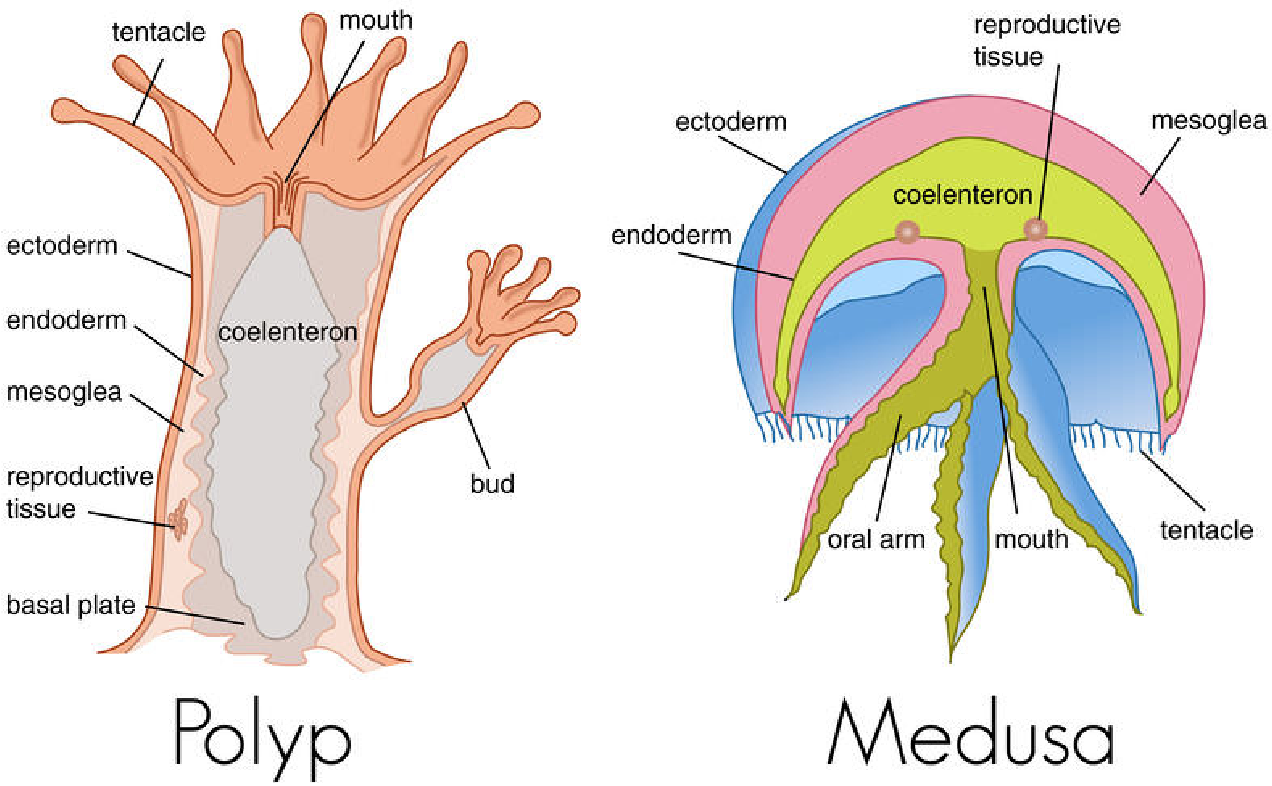
All cnidarians have something in common. It's a **nematocyst**, like the one shown in **Figure** below. A **nematocyst** is a long, thin, coiled stinger. It has a barb that may inject poison. These tiny poison "darts" are propelled out of special cell. They are used to attack prey or defend against predator.



[Figure 3]

Cnidarian Nematocyst. A cnidarian nematocyst is like a poison dart. It is ejected from a specialized cell.

There are two basic body plans in cnidarians. They are called the polyp and **medusa**. Both are shown in **Figure** below. The **polyp** has a tubular body and is usually sessile. The **medusa** (plural, **medusae**) has a bell-shaped body and is typically motile. Some cnidarian species alternate between polyp and medusa forms. Other species exist in just one form or the other.



[Figure 4]

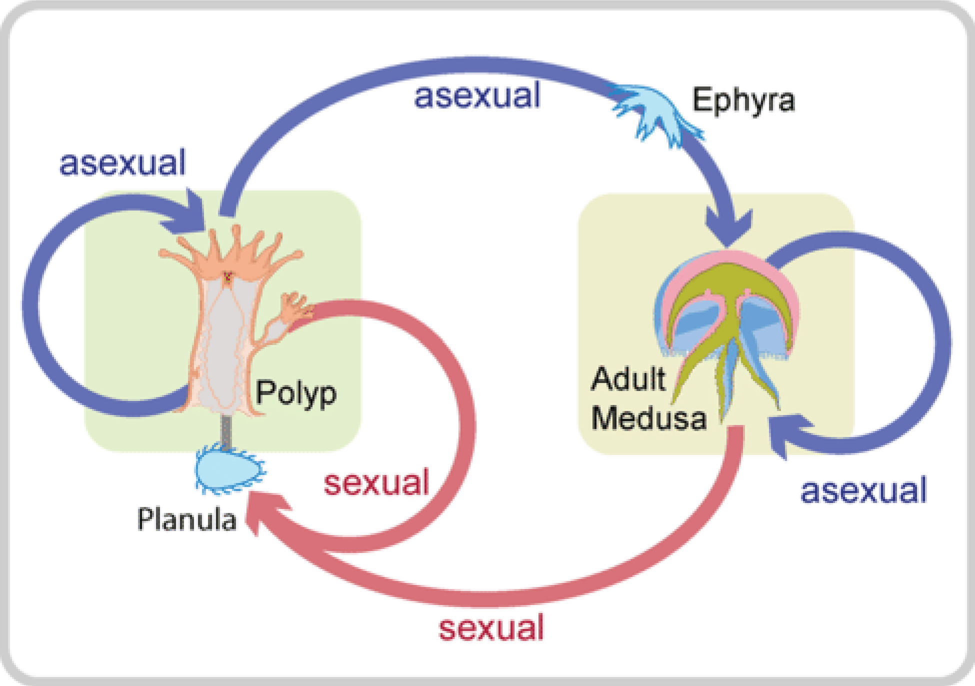
Cnidarian Body Plans. Cnidarians may exist in the polyp (left) or medusa (right) form.

The body of a cnidarian consists of two cell layers, ectoderm and endoderm. The cells surround a digestive cavity called the **coelenteron** (see **Figure** below). Cnidarians have a simple digestive system. The single opening is surrounded by tentacles, which are used to capture prey. The tentacles are covered with nematocyst cells. digestion takes place in the coelenteron. nutrient are absorbed and gases exchanged through the cells lining this cavity. Fluid in the coelenteron creates a hydrostatic skeleton.

Cnidarians have a simple nervous system consisting of a **nerve net** that can detect touch. They may also have other sensory structures. For example, jellyfish have light-sensing structures and gravity-sensing structures. These senses give them a sense of up versus down. It also helps them balance.

Cnidarian Reproduction

Figure below shows a general cnidarian life cycle. Polyps usually reproduce asexually. One type of asexual reproduction in polyps leads to the formation of new medusae. Medusae usually reproduce sexually. sexual reproduction forms a zygote. The zygote develops into a larva called a **planula**. The planula, in turn, develops into a polyp. There are many variations on the general life cycle. Obviously, species that exist only as polyps or medusae have a life cycle without the other form.



[Figure 5]

General Cnidarian Life Cycle. Cnidarians may reproduce both asexually and sexually.

Ecology of Cnidarians

Cnidarians can be found in almost all ocean habitat. They may live in water that is shallow or deep, warm or cold. A few species live in freshwater. Some cnidarians live alone, while others live in colonies.

Corals form large colonies in shallow tropical water. They are confined to shallow water because they have a mutualistic relationship with alga that live inside them. The algae need sunlight for photosynthesis, so they must be relatively close to the surface of the water. Corals exist only as polyps. They catch plankton with their tentacles. Many secrete a calcium carbonate exoskeleton. Over time, this builds up to become a coral reef (see **Figure** below). Coral reefs provide food and shelter to many ocean organism. They also help protect shorelines from erosion by absorbing some of the energy of waves. Coral reefs are at risk of destruction today.

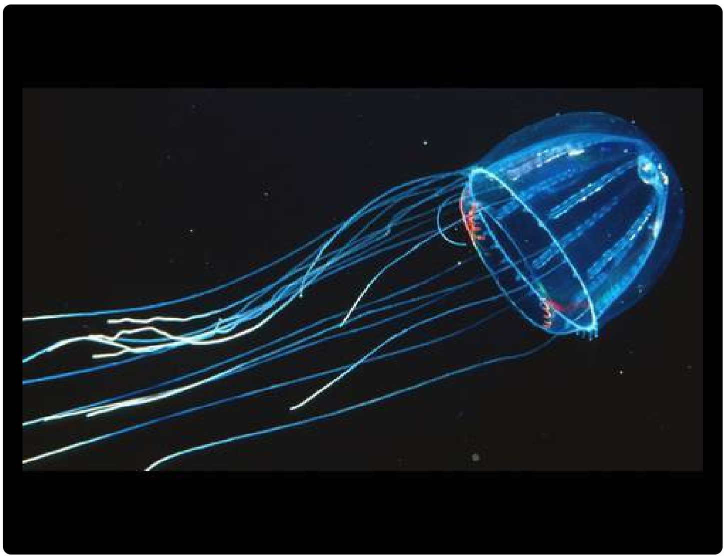
[Figure 6]

Great Barrier Reef. The Great Barrier Reef is a coral reef off the coast of Australia.

Unlike corals, jellyfish spend most of their lives as medusae. They live virtually everywhere in the ocean. They are typically carnivore. They prey on zooplankton, other invertebrates, and the egg and larvae of fish.

KQED: Amazing Jellies

Jellyfish. They are otherworldly creatures that glow in the dark, without brains or bone, some more than 100 feet long. And there are many different types. Jellyfish are free-swimming members of the phylum Cnidaria. Jellyfish are found in every ocean, from the surface to the deep sea.



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Summary

- Cnidarians include jellyfish and corals.
- Cnidarians are aquatic invertebrates. They have tissues and radial symmetry. They also have tentacles with stingers.
- There are two cnidarian body plans: the polyp and the medusa. They differ in several ways.
- Many corals secrete an exoskeleton that builds up to become a coral reef.

Review

1. What is a nematocyst? What is its function?
2. How do coral reefs form?

3. Compare and contrast cnidarian polyps and medusae.

Report Content Errors

11.6 Flatworms

FlexBooks 2.0 > Biology For High School Diploma > Flatworms

Last Modified: Jul 04, 2019

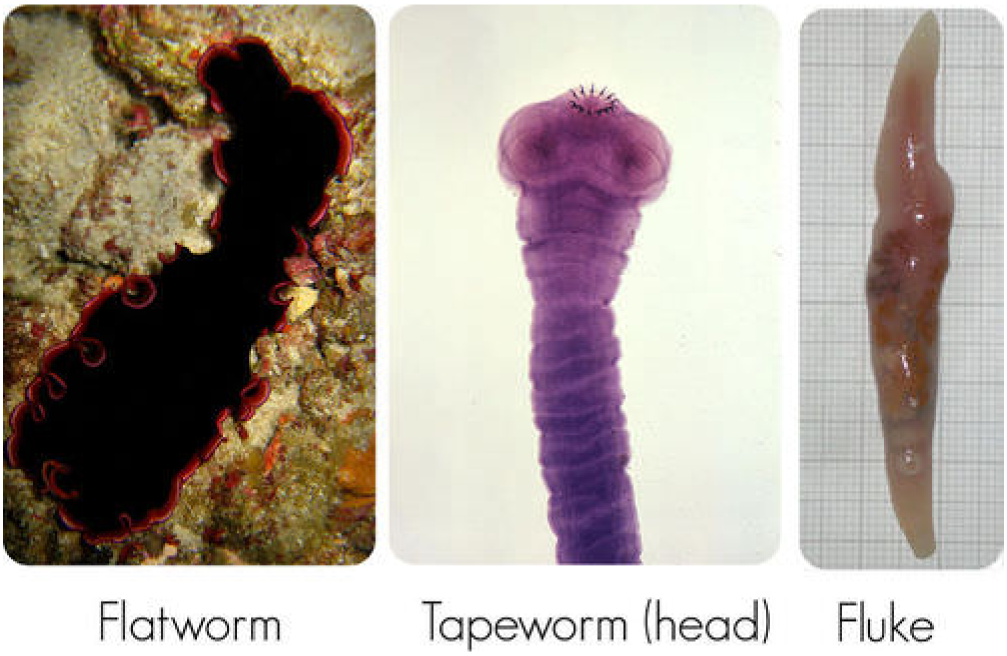
[Figure 1]

Would you believe that this gold-dotted creature is a flatworm?

No? Well it is. There are more than 25,000 different types of flatworms, so they can be very different in how they appear. And many don't even look like your typical worm.

Flatworms

Flatworms belong to the phylum **Platyhelminthes.** Examples of flatworms are shown in **Figure** below. There are more than 25,000 species in the flatworm phylum.



[Figure 2]

Platyhelminthes. Platyhelminthes include flatworms, tapeworms, and flukes.

Structure and Function of Flatworms

Flatworms range in length from about 1 millimeter (0.04 inches) to more than 20 meters (66 feet). They have a flat body because they do not have a coelom or even a pseudocoelom. They also lack a respiratory system. Instead, their cell exchange gases by diffusion directly with the environment. They have an incomplete digestive system.

Flatworms reflect several major evolutionary advances in invertebrate. They have three embryonic cell layers, including mesoderm. The mesoderm layer allows them to develop organ system. For example, they have muscular and excretory systems. The muscular system allows them to move from place to place over solid surfaces. The excretory system lets them maintain a proper balance of water and salts. Flatworms also show cephalization and bilateral symmetry.

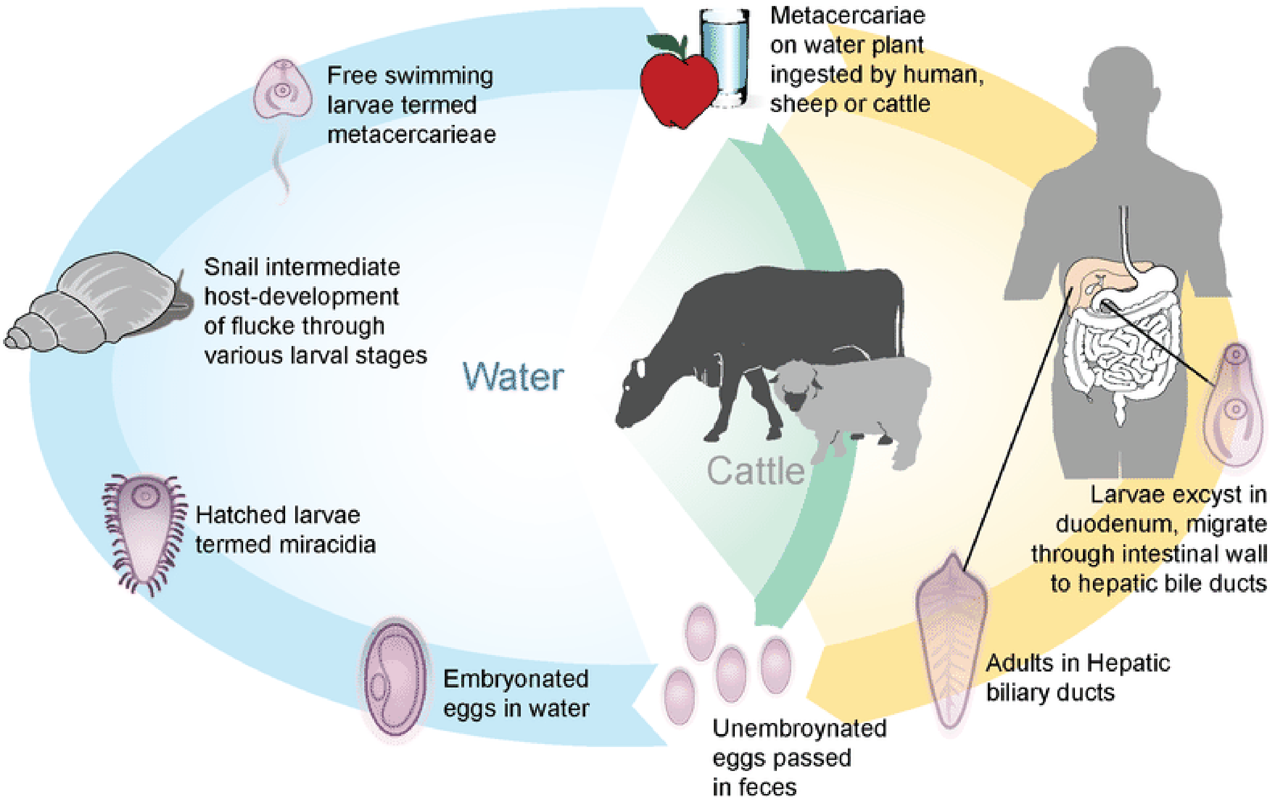
Flatworm Reproduction

Flatworms reproduce sexually. In most species, the same individuals produce both egg and sperm. After fertilization occurs, the fertilized eggs pass out of the adult's body and hatch into larva. There may be several different larval stages. The final larval stage develops into the adult form, and the life cycle repeats.

Ecology of Flatworms

Both flukes and tapeworms are parasite with vertebrate hosts, including human hosts. Flukes live in the host's circulatory system or liver. Tapeworms live in the host's digestive system. Usually, more than one type of host is required to complete the parasite's life cycle.

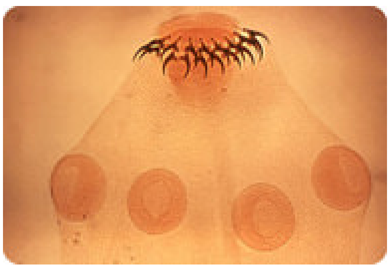
Look at the life cycle of the liver fluke in **Figure** below. As an adult, the fluke has a vertebrate host. As a larva, it has an invertebrate host. If you follow the life cycle, you can see how each host becomes infected so the fluke can continue its life cycle.



[Figure 3]

Life Cycle of the Sheep Liver Fluke. The sheep liver fluke has a complicated life cycle with two hosts. How could such a complicated way of life evolve?

Tapeworms and flukes have suckers and other structures for feeding on a host. Tapeworms also have a **scolex**, a ring of hooks on their head to attach themselves to the host (see **Figure** below). Unlike other invertebrates, tapeworms lack a mouth and digestive system. Instead, they absorb nutrient directly from the host's digestive system with their suckers.



[Figure 4]

Tapeworm Suckers and Hooks. The head of a tapeworm has several suckers. At the very top of the head is a "crown" of hooks called a scolex.

Not all flatworms are parasites. Some are free-living carnivore. They eat other small invertebrates and decaying animal. Most of the free-living species live in aquatic habitat, but some live in moist soil.

Summary

- Platyhelminthes are flatworms such as tapeworms and flukes.
- Flatworms have a mesoderm cell layer and simple organ systems. They also show cephalization and bilateral symmetry.
- Many flatworms are parasites with vertebrate hosts. Some are free-living carnivores that live mainly in aquatic habitats.

Review

1. Flatworms were the first to evolve the mesoderm. What advantage does the mesoderm provide?
2. Describe specialized feeding structures of parasitic platyhelminthes.
3. Some parasitic flatworms have a very complicated life cycle with more than one host. Infer why this might be adaptive.

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11.7 Roundworms

FlexBooks 2.0 > Biology For High School Diploma > Roundworms

Last Modified: Jul 04, 2019

[Figure 1]

When most people picture a worm, do they picture a roundworm?

Actually, they do not. Whereas flatworm are flat, roundworms obviously appear round. With over 80,000 species, there are plenty of different types of roundworms. But these are still not the types of worms most people picture when they think of worms.

Roundworms

Roundworms make up the phylum **Nematoda**. This is a very diverse animal phyla. It has more than 80,000 known species.

Structure and Function of Roundworms

Roundworms range in length from less than 1 millimeter to over 7 meters (23 feet) in length. As their name suggests, they have a round body. This is because they have a **pseudocoelom**. This is one way they differ from flatworms. Another way is their complete digestive system. It allows them to take in food, digest food, and eliminate wastes all at the same time.

Roundworms have a tough covering of cuticle on the surface of their body. It prevents their body from expanding. This allows the buildup of fluid pressure in the pseudocoelom. As a result, roundworms have a hydrostatic skeleton. This provides a counterforce for the contraction of muscles lining the pseudocoelom. This allows the worms to move efficiently along solid surfaces.

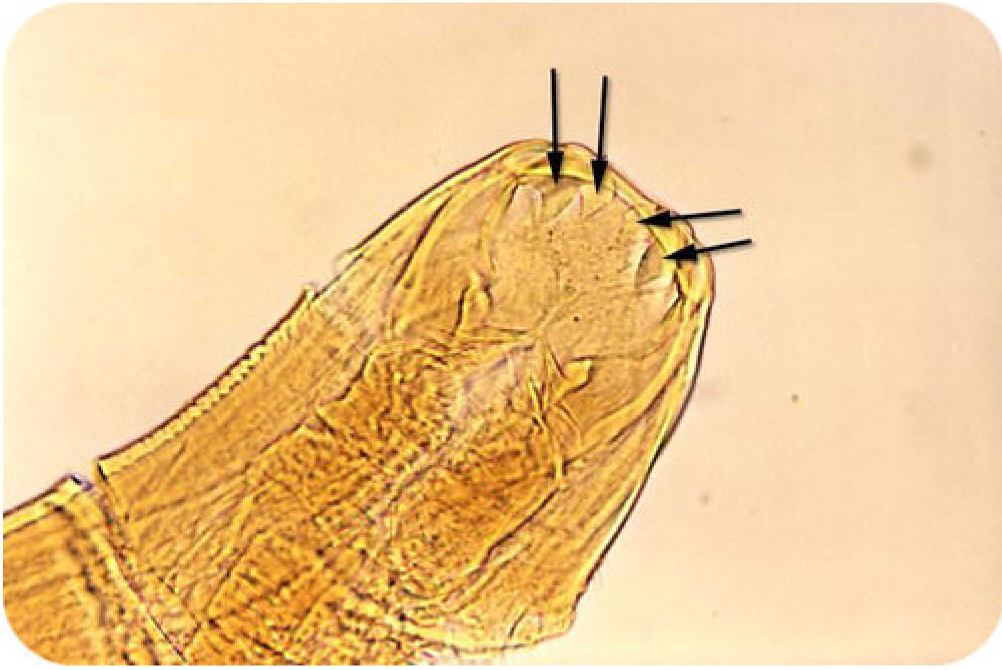
Roundworm Reproduction

Roundworms reproduce sexually. sperm and egg are produced by separate male and female adults. fertilization takes place inside the female organism. Females lay huge numbers of eggs, sometimes as many as 100,000 per day! The eggs hatch into larva, which develop into adults. Then the cycle repeats.

Ecology of Roundworms

Roundworms may be free-living or parasitic. Free-living worms are found mainly in freshwater habitat. Some live in soil. They generally feed on bacterium, fungus, protozoans, or decaying organic matter. By breaking down organic matter, they play an important role in the carbon cycle.

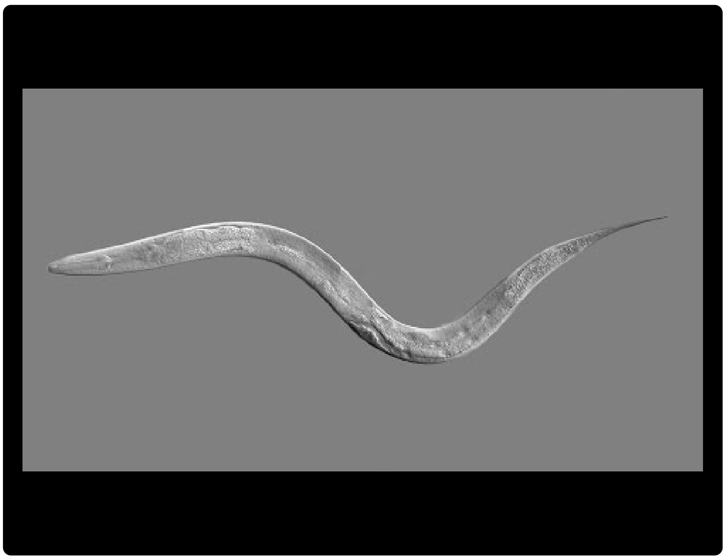
Parasitic roundworms may have plant, vertebrate, or invertebrate hosts. Several species have human hosts. For example, hookworms, like the one in **Figure** below, are human parasite. They infect the human intestine. They are named for the hooks they use to grab onto the host's tissue. Hookworm larvae enter the host through the skin. They migrate to the intestine, where they mature into adults. Adults lay eggs, which pass out of the host in feces. Then the cycle repeats.



[Figure 2]

Hookworm Parasite. Hookworms like this one are common human parasites.

Tiny pinworms are the most common roundworm parasites of people in the U.S. In some areas, as many as one out of three children are infected. Humans become infected when they ingest the nearly microscopic pinworm eggs. The eggs hatch and develop into adults in the host's digestive tract. Adults lay eggs that pass out of the host's body to continue the cycle. Pinworms have a fairly simple life cycle with only one host.



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Summary

- Roundworms make up the phylum Nematoda.
- Roundworms have a pseudocoelom and hydrostatic skeleton. Their body is covered with tough cuticle.
- Free-living roundworms are found mainly in freshwater habitats.
- Parasitic roundworms have a variety of hosts, including humans.

Review

1. How do free-living nematodes contribute to the carbon cycle?
2. Apply what you know about pinworms to develop one or more recommendations for preventing pinworm infections in humans.
3. Platyhelminthes and nematodes are both worms. Justify classifying them in different invertebrate phyla.

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11.8 Mollusks

FlexBooks 2.0 > Biology For High School Diploma > Mollusks

Last Modified: Jul 04, 2019

[Figure 1]

Fish or squid?

Neither. This is a mollusk, a cuttlefish to be specific. What is a mollusk? Well, to start, mollusks are aquatic species that are not fish. There are over 100,000 different mollusks, so there are bound to be some interesting looking organism, like this one.

Mollusks

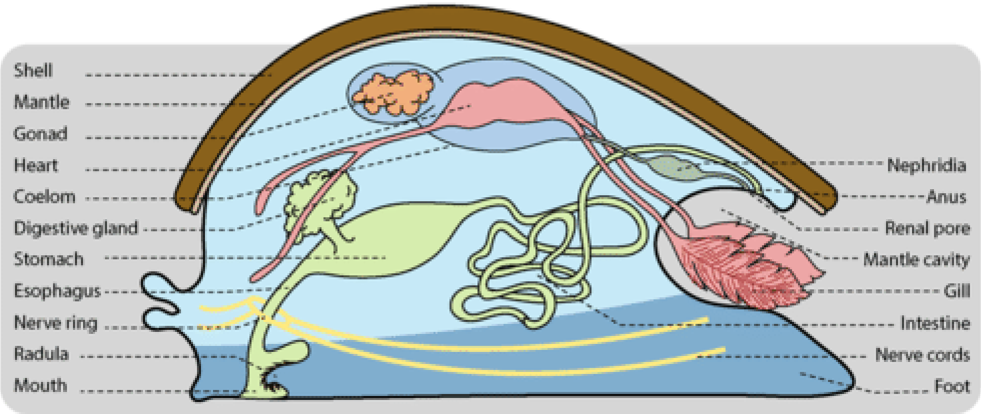
Have you ever been to the ocean or eaten seafood? If you have, then you probably have encountered members of the phylum **Mollusca**. Mollusks include snails, scallops, and squids, as shown in **Figure** below. There are more than 100,000 known species of mollusks. About 80 percent of mollusk species are gastropod.

[Figure 2]

This figure shows some of the more common and familiar mollusks.

Structure and Function of Mollusks

Mollusks are a very diverse phylum. Some mollusks are nearly microscopic. The largest mollusk, a colossal squid, may be as long as a school bus and weigh over half a ton! The basic body plan of a mollusk is shown in **Figure** below. The main distinguishing feature is a hard outer shell. It covers the top of the body and encloses the internal organ. Most mollusks have a distinct head region. The head may have tentacles for sensing the environment and grasping food. There is generally a muscular foot, which may be used for walking. However, the foot has evolved modifications in many species to be used for other purposes.



[Figure 3]

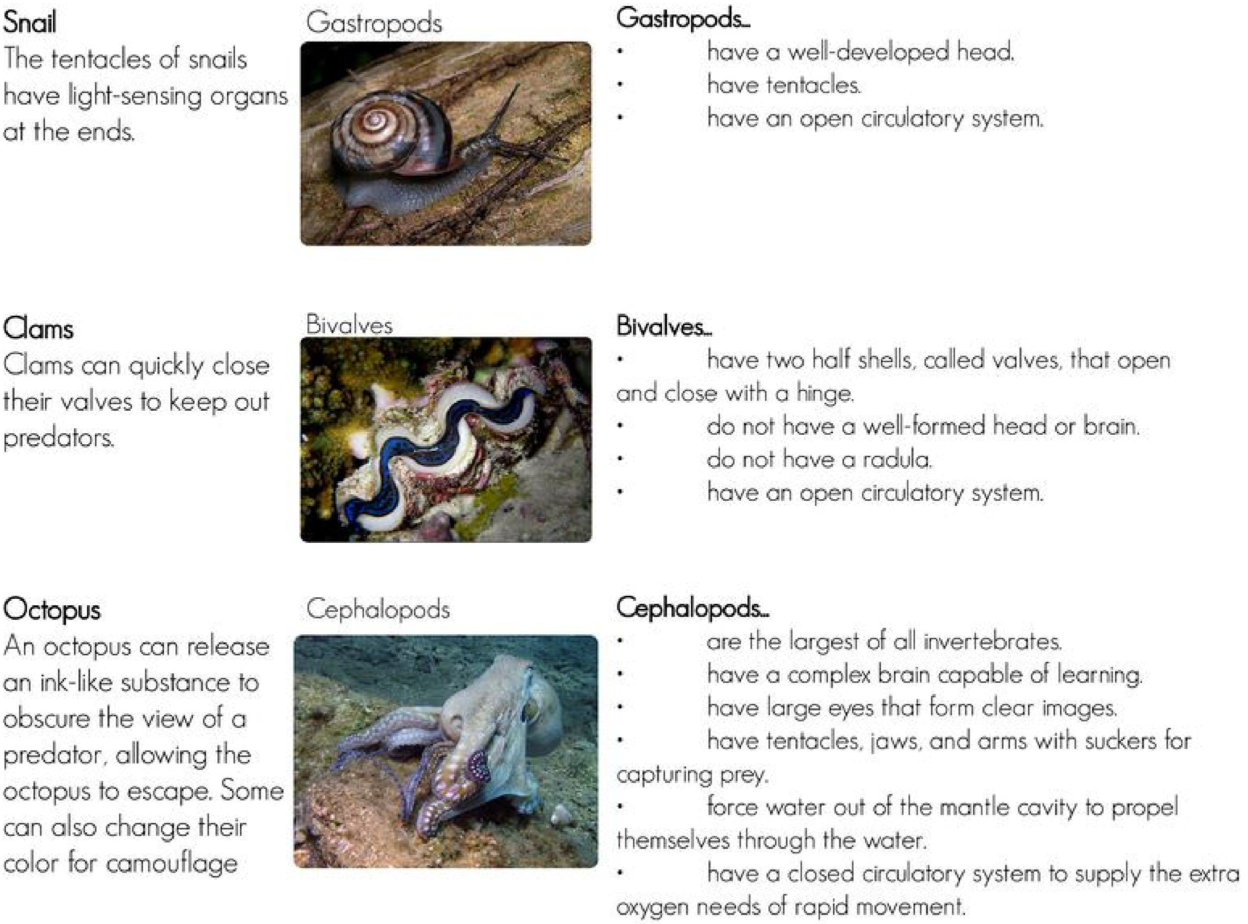
Basic Mollusk Body Plan. The basic body plan shown here varies among mollusk classes. For example, several mollusk species no longer have shells. Do you know which ones?

Two unique features of mollusks are the **mantle** and **radula** (see **Figure** above). The **mantle** is a layer of tissue that lies between the shell and the body. It secretes calcium carbonate to form the shell. It forms a cavity, called the **mantle cavity**, between the mantle and the body. The mantle cavity pumps water for filter feeding. The **radula** is a feeding organ with teeth made of chitin. It is located in front of the mouth in the head region. Herbivorous mollusks use the radula to scrape food such as alga off rocks. Predatory mollusks use the radula to drill holes in the shells of their prey.

Mollusks have a coelom and a complete digestive system. Their excretory system consists of tube-shaped organs called **nephridia** (see **Figure** above). The organs filter waste from body fluids and release the waste into the coelom. Terrestrial mollusks exchange gases with the surrounding air. This occurs across the lining of the mantle cavity. Aquatic mollusks "breathe" under water with **gill**. **Gills** are thin filaments that absorb gases and exchange them between the blood and surrounding water.

Mollusks have a circulatory system with one or two hearts that pump blood. The **heart** is a muscular organ that pumps blood through the circulatory system when its muscles contract. The circulatory system may be open or closed, depending on the species.

The major classes of mollusks vary in structure and function. You can read about some of their differences in **Figure** below.



[Figure 4]

Use this figure to compare and contrast gastropods, bivalves, and cephalopods

Mollusk Reproduction

Mollusks reproduce sexually. Most species have separate male and female sexes. gamete are released into the mantle cavity. fertilization may be internal or external, depending on the species. Fertilized egg develop into larva. There may be one or more larval stages. Each one is different from the adult stage. Mollusks have a unique larval form called a **trochophore**. It is a tiny organism with cilia for swimming.

Ecology of Mollusks

Mollusks live in most terrestrial, freshwater, and marine habitat. However, the majority of species live in the ocean. They can be found in both shallow and deep water and from tropical to polar latitudes. Mollusks are a major food source for other organisms, including humans. You may have eaten mollusks such as clams, oysters, scallops, or mussels.

The different classes of mollusks have different ways of obtaining food.

- **Gastropods** may be herbivore, predator, or internal parasite. They live in both aquatic and terrestrial habitats. Marine species live mainly in shallow coastal waters. Gastropods use their foot to crawl slowly over rocks, reefs, or soil, looking for food.
- **bivalve** are generally sessile filter feeder. They live in both freshwater and marine habitats. They use their foot to attach themselves to rocks or reefs or to burrow into mud. Bivalves feed on plankton and nonliving organic matter. They filter the food out of the water as it flows through their mantle cavity.
- **cephalopod** are carnivore that live only in marine habitats. They may be found in the open ocean or close to shore. They are either predators or scavenger. They generally eat other invertebrate and fish.

KQED: Cool Critters: Dwarf Cuttlefish

What's the coolest critter in the ocean under 4 inches long? The Dwarf Cuttlefish! Cuttlefish are marine animal that belong to the class Cephalopoda. Despite their name, cuttlefish are not fish but mollusks. Recent studies indicate that cuttlefish are among the most intelligent invertebrates, with one of the largest brain-to-body size ratios of all invertebrates. Cuttlefish have an internal shell called the **cuttlebone** and eight arms and two tentacles furnished with suckers, with which they secure their prey.

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KQED: The Fierce Humboldt Squid

The Humboldt squid is a large, predatory invertebrate found in the waters of the Pacific Ocean. A mysterious sea creature up to 7 feet long, with 10 arms, a sharp beak and a ravenous appetite, packs of fierce Humboldt Squid attack nearly everything they see, from fish to scuba divers. Traveling in groups of 1,000 or more and swimming at speeds of more than 15 miles an hour, these animals hunt and feed together, and use jet propulsion to shoot out of the water to escape predators. Humboldt squid live at depths of between 600 and about 2,000 feet, coming to the surface at night to feed. They live for approximately two years and spend much of their short life in the ocean's oxygen-minimum zone, where very little other life exists. Because they live at such depths, little is known about these mysterious sea creatures. The Humboldt squid usually lives in the waters of the Humboldt Current, ranging from the southern tip of South America north to California, but in recent years, this squid has been found as far north as Alaska. Marine biologists are working to discover why they have headed north from their traditional homes off South America.

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Where's the Octopus?

When marine biologist Roger Hanlon captured the first scene in this video, he started screaming. Hanlon, senior scientist at the Marine Biological Laboratory in Woods Hole, studies camouflage in cephalopods: squid, cuttlefish and octopuses. They are masters of optical illusion.

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Science Friday: I, Octopus

With thousands of chemically-sensitive suckers, color-changing skin, and a brain that literally stretches when they eat, octopuses seem like aliens living in our oceans. In this video by science Friday, Frank Grasso explains their physical adaptation and how octopuses might process their own sensations.

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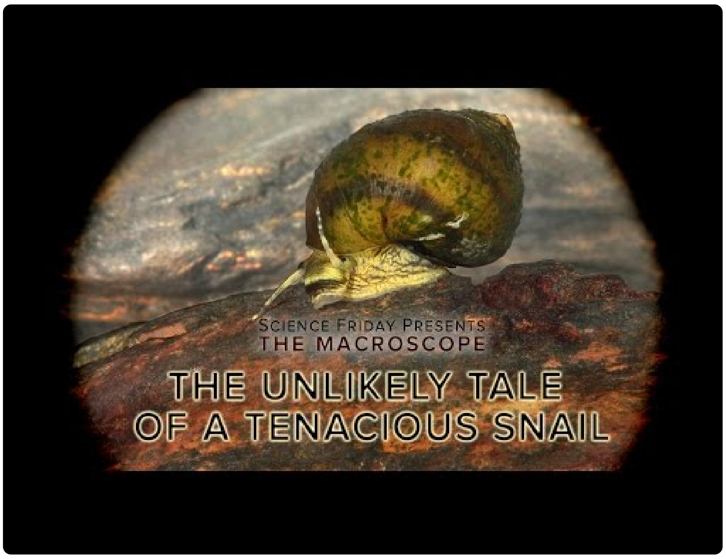
Science Friday: The Unlikely Tale of a Tenacious Snail

For over 70 years, no one had seen the oblong rocksnail. Declared extinct in 2000, the species was considered to be another native Alabaman mollusk gone and forgotten. But one day in the spring of 2011, biology grad student Nathan Whelan picked up a tiny rock and got a big surprise.



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Summary

- Mollusks are invertebrates such as snails, scallops, and squids.
- Mollusks have a hard outer shell. There is a layer of tissue called the mantle between the shell and the body.
- Most mollusks have tentacles for feeding and sensing, and many have a muscular foot.
- Mollusks also have a coelom, a complete digestive system, and specialized organs for excretion.
- The majority of mollusks live in the ocean.
- Different classes of mollusks have different ways of obtaining food.

Review

1. List the three major classes of mollusks.
2. Describe the basic body plan of a mollusk.

3. Describe the mantle and radula.
4. What are gills? What is their function?
5. Create a Venn diagram to show important similarities and differences among the three major classes of mollusks.

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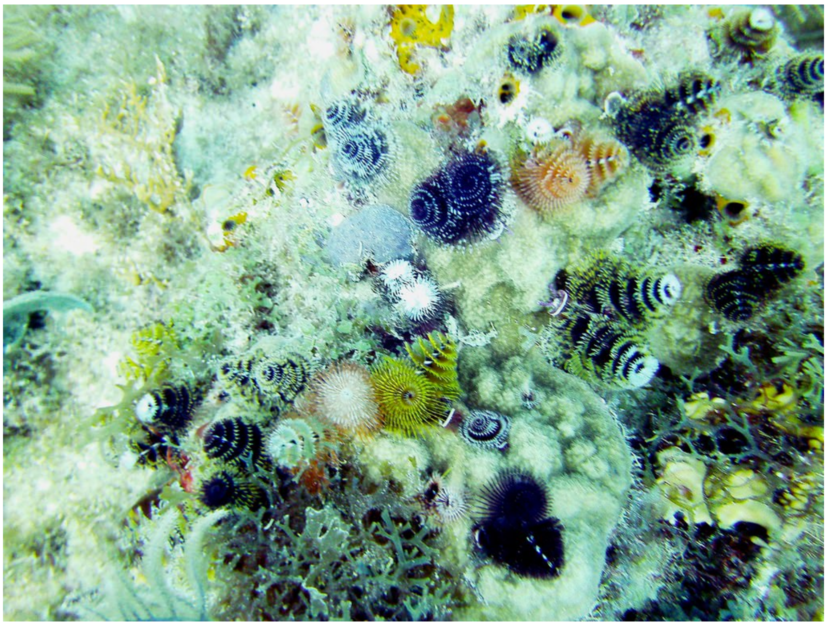
11.9 Annelids

FlexBooks 2.0 > Biology For High School Diploma > Annelids

Last Modified: Feb 08, 2022



[Figure 1]

How can this be an animal?

This is a worm. And even though it is blue, this is a Christmas tree worm. These "Christmas tree" structures are actually specialized mouth appendage. Each spiral is composed of feather-like tentacles which are heavily ciliated. These appendages trap prey and transport the food straight towards the worm's mouth. And these worms are annelids.

Annelids

The phylum **Annelida** is made up of **segmented worm** such as **earthworm**. Segmented worms are divided into many repeating segments. There are roughly 15,000 species of annelids. Most belong to one of three classes. A species in each class is pictured in **Figure** below.

[Figure 2]

Classes of Annelids. The majority of annelids are polychaetes. They live on the ocean floor, so you may not be familiar with them.

Structure and Function of Annelids

Annelids range in length from less than 1 millimeter to over 3 meters. They never attain the large size of some mollusks. Like mollusks, however, they have a coelom. In fact, the annelid coelom is even larger, allowing greater development of internal organ. Annelids have other similarities with mollusks, including:

- A closed circulatory system (like cephalopods).
- An excretory system consisting of tubular nephridia.
- A complete digestive system.
- A brain.
- Sensory organs for detecting light and other stimulus.
- gill for gas exchange (but many exchange gas through their skin).

The **segmentation** of annelids is highly adaptive. For one thing, it allows more efficient movement. Each segment generally has its own nerve and muscle tissue. Thus, localized muscle contractions can move just those segments needed for a particular motion. Segmentation also allows an animal to have specialized segments to carry out particular functions. This allows the whole animal to be more efficient. Annelids have the amazing capacity to regrow segments that break off. This is called **regeneration.**

Annelids have a variety of structures on the surface of their body for movement and other functions. These vary, depending on the species. Several of the structures are described in **Figure** below.

[Figure 3]

Annelid External Structures. Many annelids have bristles and other types of external structures. Each structure is not present in all species.

Annelid Reproduction

Most species of annelids can reproduce both asexually and sexually. However, leech can reproduce only sexually. asexual reproduction may occur by budding or fission. sexual reproduction varies by species.

- In some species, the same individual produces both sperm and egg. But worms mate to exchange sperm, rather than self-fertilizing their own eggs. Fertilized eggs are deposited in a mucous cocoon. Offspring emerge from the cocoon looking like small adults. They grow to adult size without going through a larval stage.
- In **polychaete** species, there are separate sexes. Adult worms go through a major transformation to develop reproductive organs. This occurs in many adults at once. Then they all swim to the surface and release their gamete in the water, where fertilization takes place. Offspring go through a larval stage before developing into adults.

Ecology of Annelids

Annelids live in a diversity of freshwater, marine, and terrestrial habitat. They vary in what they feed on and how they obtain their food.

- Earthworms are **deposit feeder.** They burrow through the ground, eating soil and extracting organic matter from it. Earthworm feces, called worm casts, are very rich in plant nutrient. Earthworm burrows help aerate soil, which is also good for plants.
- **Polychaetes** live on the ocean floor. They may be sedentary filter feeder, active predator, or scavenger. Active species crawl along the ocean floor in search of food.
- **Leeches** are either predators or parasite. As predators, they capture and eat other invertebrate. As parasites, they feed off the blood of vertebrate hosts. They have a tubular organ, called a **proboscis**, for feeding.

Comparison of Worms

The following table compares the three worm phyla (**Table** below).

Phylum	Common Name	Body Cavity	Segmented	Digestive System	Example
Platyhelminthes	flatworm	No	No	Incomplete	Fluke
Nematoda	Roundworm	Yes	No	Complete	Heartworm
Annelida	Segmented worm	Yes	Yes	Complete	Earthworm

Summary

- Annelids are segmented worms such as earthworms and leeches.
- Annelids have a coelom, closed circulatory system, excretory system, and complete digestive system. They also have a brain.
- Earthworms are important deposit feeders that help form and enrich soil.
- Leeches are either predators or parasites. Parasitic leeches feed off the blood of vertebrate hosts.

Review

1. Discuss the advantages of segmentation.
2. Define regeneration.
3. Polychaete worms have an interesting reproductive strategy. Describe this strategy and infer its adaptive significance.
4. What are deposit feeders?

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11.10 Arthropods

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Last Modified: Feb 08, 2022

[Figure 1]

What has more species than any other animal phylum?

Arthropods are not only the largest phylum of invertebrate. They are by far the largest phylum of the animal kingdom. Roughly 80 percent of all animal species living on Earth today are arthropods. Obviously, arthropods have been extremely successful. What accounts for their success?

Arthropods

There are more than a million known species of arthropods. There may actually be ten times that many. **Arthropods** include insects, spiders, lobsters, and centipedes. The arthropods pictured in **Figure** below give just a hint of the phylum's diversity.

A magnified image of a microscopic house mite. The actual size of this animal is about a half a millimeter.

A Japanese spider crab

Barnacles

A millipede

A wasp

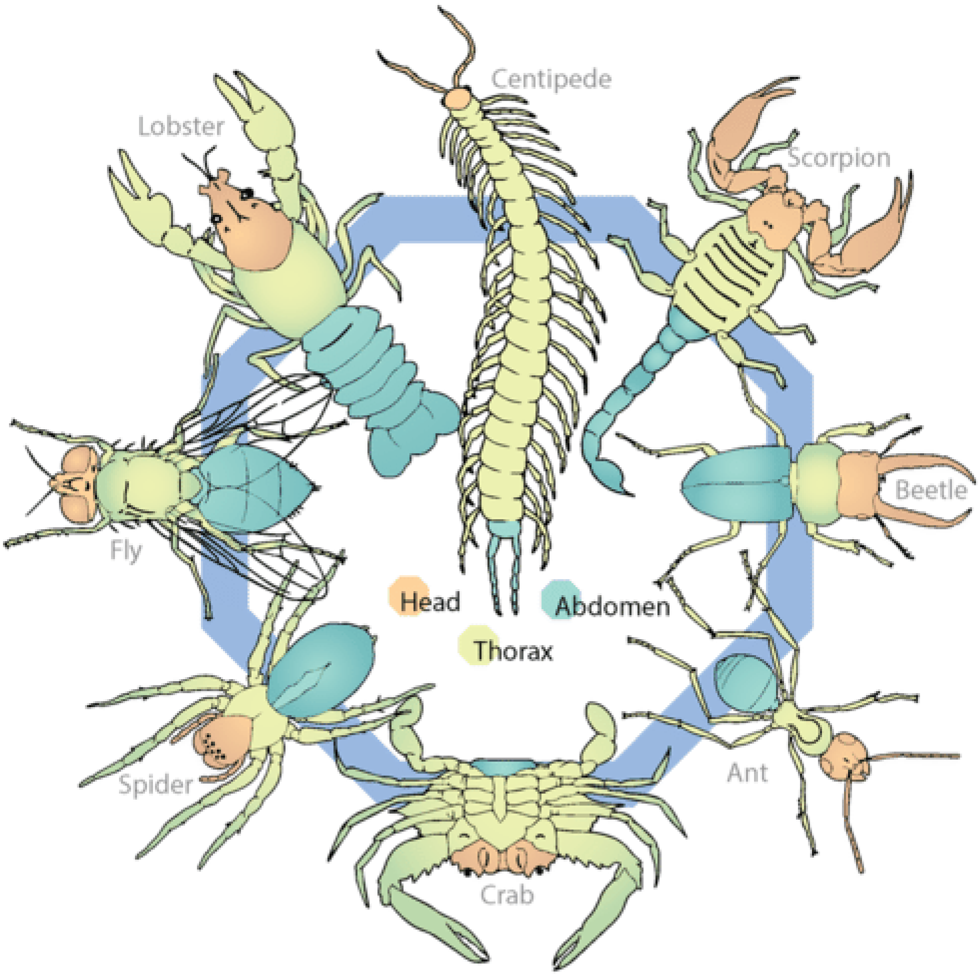
A scorpion

[Figure 2]

Arthropod Diversity. Dust mites are among the smallest of arthropods. Japanese spider crabs are the largest. Besides size, what other differences among arthropods do you see in these photos?

Structure and Function of Arthropods

Arthropods range in length from about 1 millimeter to 4 meters (about 13 feet). They have a segmented body with a hard exoskeleton. They also have jointed appendage. The body segments are the head, thorax, and abdomen (see **Figure** below). In some arthropods, the head and thorax are joined together as a **cephalothorax**.

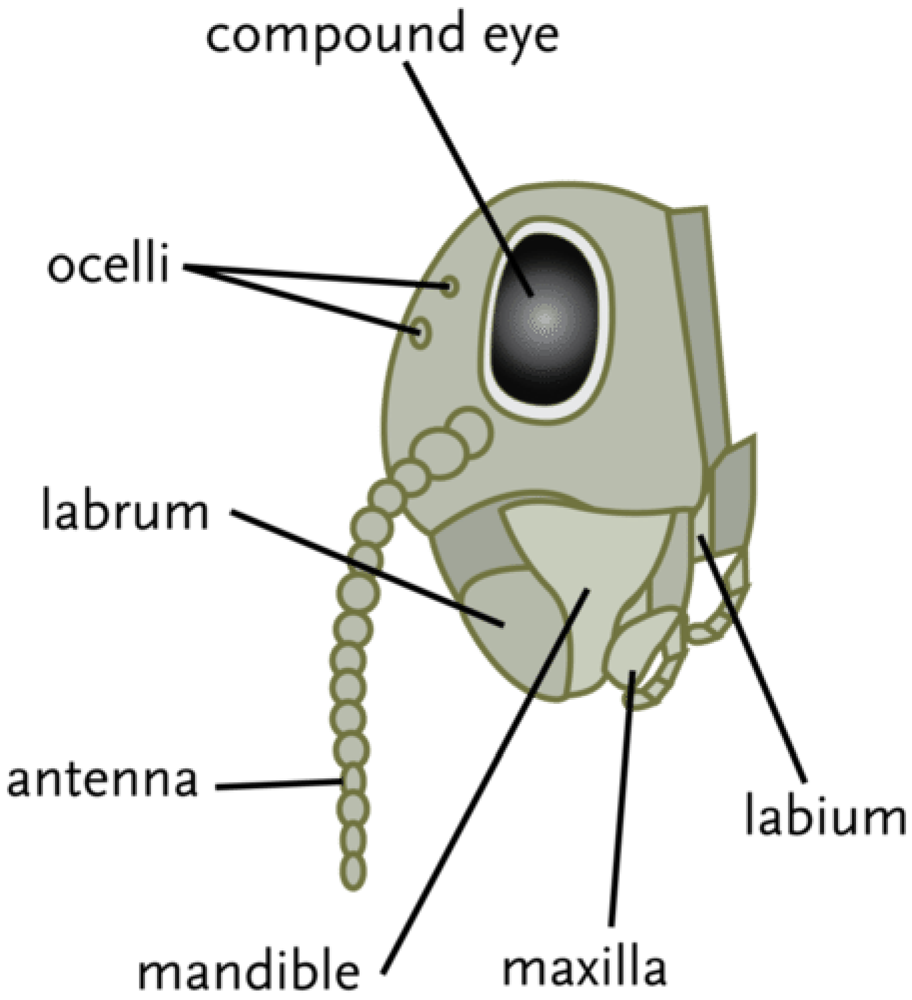


[Figure 3]

Arthropod Body Plan. Notice the three body segments of each organism.

The arthropod exoskeleton consists of several layers of cuticle. The exoskeleton prevents water loss and gives support and protection. It also acts as a counterforce for the contraction of muscles. The exoskeleton doesn't grow as the animal grows. Therefore, it must be shed and replaced with a new one periodically through life. This is called **molting**.

The jointed appendages of arthropods may be used as legs for walking. Being jointed makes them more flexible. Try walking or climbing stairs without bending your knees, and you'll see why joint are helpful. In most arthropods, the appendages on the head have been modified for other functions. **Figure** below shows some of head appendages found in arthropods. Sensory organ such as eyes are also found on the head.

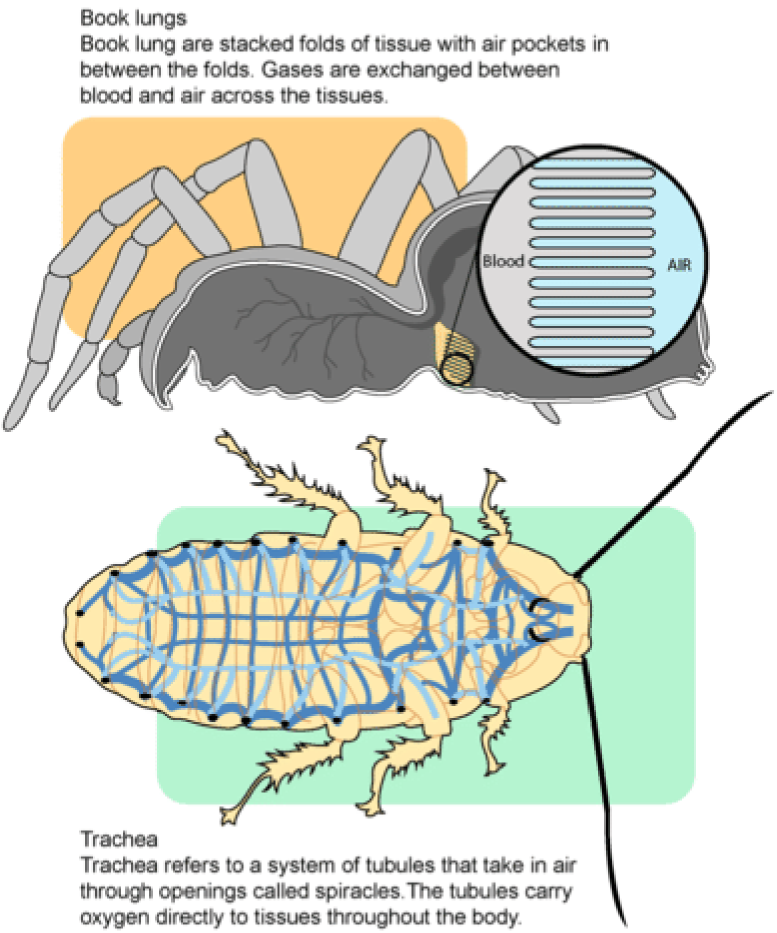


[Figure 4]

Arthropod Head. Arthropods have evolved a variety of specialized appendages and other structures on their head.

Some arthropods have special excretory structures. They are called **coxal gland** and **malpighian tubule**. Coxal glands collect and concentrate liquid waste from blood. They excrete the waste from the body through a pore. Malpighian tubules carry waste from the digestive tract to the anus. The waste is excreted through the anus.

Like mollusks and annelids, aquatic arthropods may have gill to exchange gases with the water (discussed below). Terrestrial arthropods, on the other hand, have special respiratory structures to exchange gases with the air. These are described in **Figure** below.



[Figure 5]

How Terrestrial Arthropods Breathe Air. Terrestrial arthropods have respiratory structures that let them breathe air.

Underwater Spiders

In the ponds of northern Europe lives a tiny brown spider that spends its entire life underwater. But just like land spiders, it needs oxygen to breathe. So, how does this spider breath? Does it use book lung? No. In fact, aquatic spiders, known as "diving bell spiders," have gills. Every so often, the spider leaves its underwater web to visit the surface and bring back a bubble of air that sticks to its hairy abdomen. It deposits the bubble into a little silk air tank. This "diving bell" is a gill that sucks oxygen from the water, allowing the spider to stay underwater for up to 24 hours.

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Arthropod Reproduction

Arthropods have a life cycle with sexual reproduction. Most species go through larval stages after hatching. The larva are very different from the adults. They change into the adult form in a process called **metamorphosis**. This may take place within a cocoon. A familiar example of metamorphosis is the transformation of a caterpillar (larva) into a butterfly (adult). Other arthropod species, in contrast, hatch young that look like small adults. These species lack both larval stages and metamorphosis.

Evolution of Arthropods

The oldest known arthropods are **trilobite**. A fossil trilobite is shown in **Figure** below. Trilobites were marine arthropods. They had many segments with paired appendages for walking. As arthropods continued to evolve, segments fused. Eventually, arthropods with three major segments evolved. Appendages were also lost or modified during the course of arthropod evolution.

[Figure 6]

Trilobite Fossil. This trilobite fossil represents the earliest arthropods. Trilobites first appeared more than 500 million years ago. They lived for at least 200 million years before going extinct. They left behind large numbers of fossils.

Arthropods were the first animals to live on land. The earliest terrestrial arthropods were probably millipedes. They moved to land about 430 million years ago. Early land arthropods evolved adaptation such as book lungs or trachea to breathe air. The exoskeleton was another important adaptation. It prevents an animal from drying out. It also provides support in the absence of buoyant water.

Classification of Arthropods

Living arthropods are divided into four subphyla. They are described in **Table** below. The Hexapoda subphylum includes mainly insects. There are so many insects and they are so important that they are described in greater detail below.

Subphylum (includes)	Description	Example
Myriapoda (centipedes, millipedes)	terrestrial; herbivore or predator; 10–400 walking legs; centipedes possess poison claws for hunting	centipede  [Figure 7]
Chelicerata (spiders, scorpions, mites, ticks, horseshoe crabs, sea spiders)	mainly terrestrial; predators or parasite; 8 walking legs; appendages called **chelicera** for grasping prey; poison fangs for killing prey; no mandibles, maxillae, antennae; two body segments	spider  [Figure 8]
Crustacea (lobsters, crabs, shrimp, barnacles, krill)	mainly aquatic, predators, scavenger, or filter feeder; two pairs of antennae and claws for hunting; unique larval stage (called “nauplius”) with head appendages for swimming	lobster  [Figure 9]
Hexapoda (ants, flies, grasshoppers, beetles, butterflies, moths, bees, springtails)	mainly terrestrial or aerial; herbivores, predators, parasites, scavengers, or decomposer; 6 walking legs; many modified appendages, such as wing for flying	beetle  [Figure 10]

Summary

- Arthropods are the largest phylum in the animal kingdom.
- Most arthropods are insects. The phylum also includes spiders, centipedes, and crustaceans.
- The arthropod body consists of three segments with a hard exoskeleton and jointed appendages.

- Terrestrial arthropods have adaptations for life on land, such as trachea or book lungs for breathing air.
- The earliest arthropods were trilobites. The earliest land arthropods were millipedes.

Review

1. Identify the distinguishing trait of arthropods.
2. What is molting? Why does it occur?
3. What are the Malpighian tubules?
4. Describe two structures that allow arthropods to breathe air.
5. Assume you see a "bug" crawling over the ground. It has two body segments and lacks antennae. Which arthropod subphylum does the "bug" belong to? Explain your answer.

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11.11 Insects

FlexBooks 2.0 > Biology For High School Diploma > Insects

Last Modified: Jul 04, 2019

[Figure 1]

What dominates life on Earth?

Well, by numbers, it's not humans. This may look like a scary creature from your worst nightmare, but it wouldn't hurt a fly. In fact, it is a fly! The picture shows the charming portrait of a horsefly, up close and personal. Those big, striped, colorful orbs are its eyes. Did you ever look through a kaleidoscope? If so, then you have an idea of what the world looks like to a horsefly.

What other organ do insects like this horsefly have? Besides sensing their environment, what other functions do their organs serve?

Insects

Most members of the subphylum **Hexapoda** are insects (class Insecta). In fact, more than half of all known organism are insects. There may be more than 10 million insect species in the world, most of them yet to be identified. It's clear that insects, and not humans, dominate life on Earth.

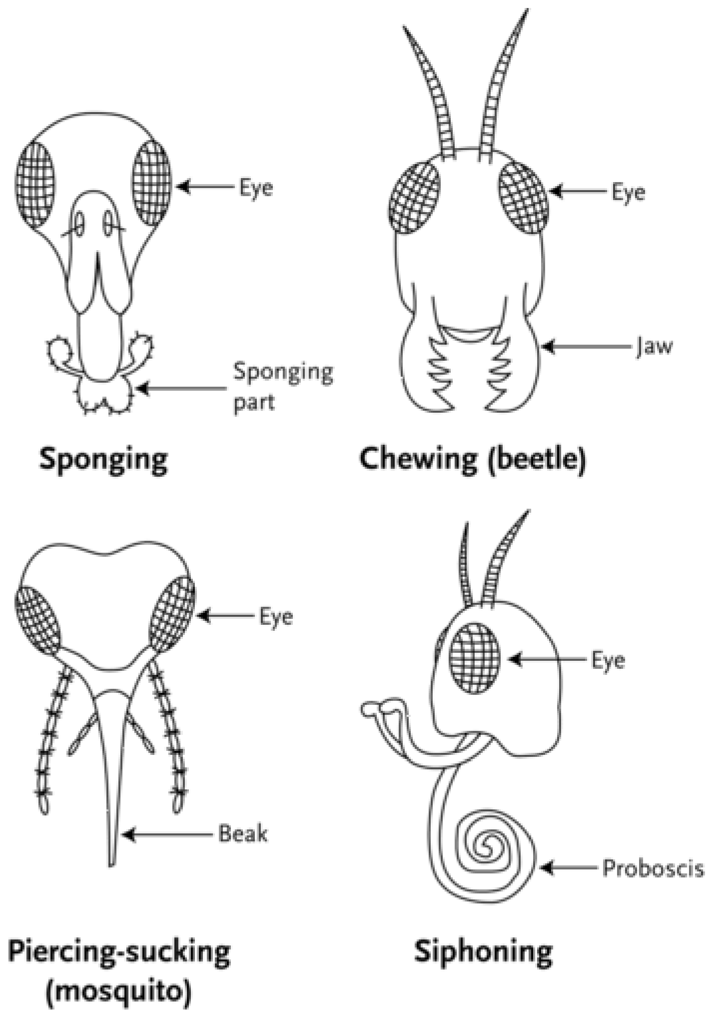
[Figure 2]

Hexapoda. A cricket on green leaf. Can you find the six legs attached to the thorax?

Structure and Function of Insects

Insects range in length from less than a millimeter to about the length of your arm. They can be found in most habitat, but they are mainly terrestrial. Many can fly, so they are also aerial. Like other arthropod, insects have a head, thorax, and abdomen. They have a wide variety of appendage, including six legs attached to the thorax.

Insects have a pair of antennae for “smelling” and “tasting” chemicals. Some insects can also use their antennae to detect sound. Other sensory organs on the head include several simple eyes and a pair of compound eyes. The **compound eyes** let insects see images. Butterflies and bees can even see in color. For feeding, the head contains one pair of **mandibles** and two pairs of **maxillae**. Insects consume a wide range of foods, and their mouthparts have become specialized. Several variations are shown in **Figure** below.



[Figure 3]

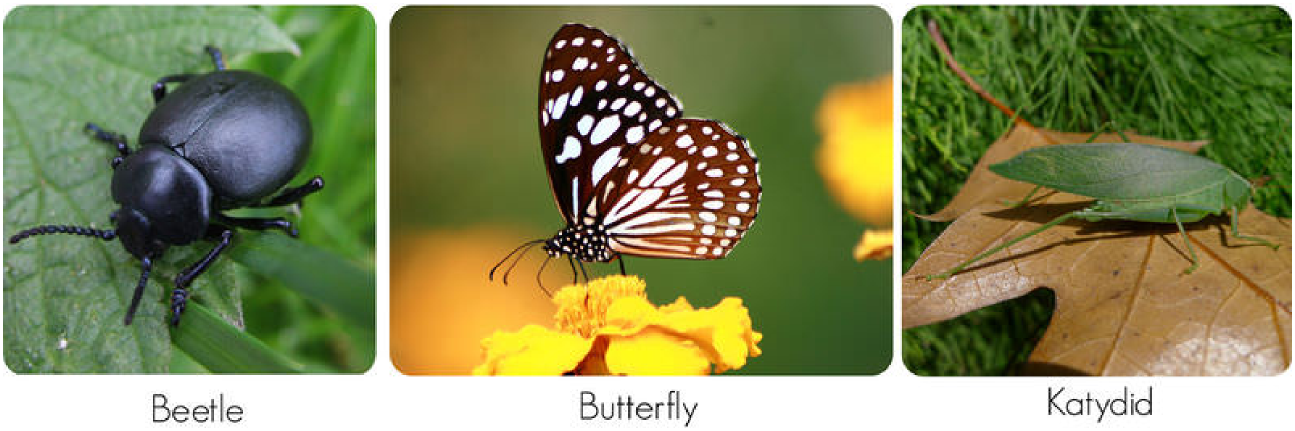
Mouthpart Specialization in Insects. The mouthparts of insects are adapted for different food sources. How do you think the different mouthparts evolved?

An insect's abdomen contains most of the internal organs. Like other arthropods, insects have a complete digestive system. They also have an open circulatory system and central nervous system. Like other terrestrial arthropods, they have trachea for breathing air and malpighian tubule for excretion.

Insect Flight

The main reason that insects have been so successful is their ability to fly. Insects are the only invertebrate that can fly and were the first animal to evolve flight. Flight has important advantages. It's a guaranteed means of escape from nonflying predator. It also aids in the search for food and mates.

Insects generally have two pairs of wing for flight. Wings are part of the exoskeleton and attached to the thorax. Insect wings show a lot of variation. As you can see in **Figure** below, butterfly wings are paper-thin, whereas beetle wings are like armor. Not all insect wings work the same way, either. They differ in how the muscles are attached and whether the two pairs of wings work independently or together. Besides flight, wings serve other functions. They may protect the body (beetles), communicate visually with other insects (butterflies), or produce sounds to attract mates (katydids).

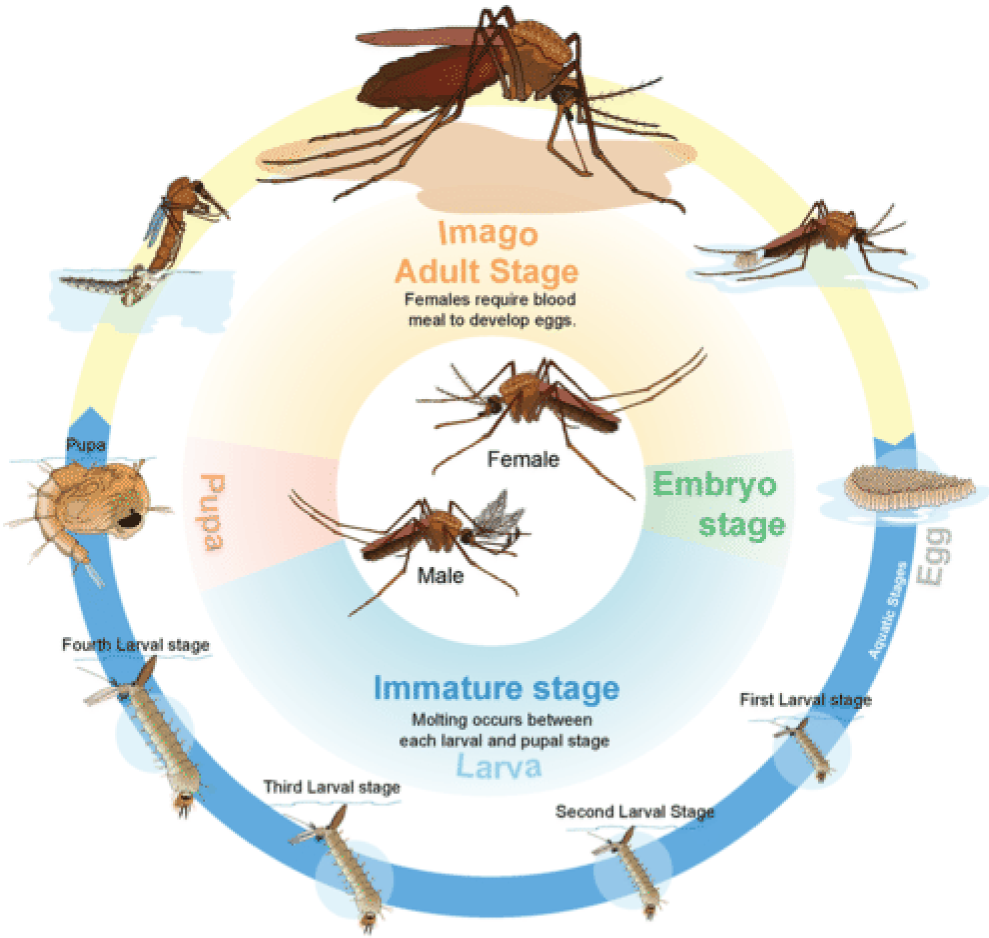


[Figure 4]

Form and Function in Insect Wings. Beetles, butterflies, and katydids all have two pairs of wings that they use for flight. However, the wings are very different because they have other functions as well.

Insect Reproduction

Nearly all insects reproduce sexually. Some can also reproduce asexually. An example of an insect life cycle is shown in **Figure** below.



[Figure 5]

Insect Life Cycle. This diagram represents the life cycle of a mosquito. Most insects have a similar life cycle.

When an insect egg hatches, a larva emerges. The larva eats and grows and then enters the **pupa** stage. The **pupa** is immobile and may be encased in a **cocoon**. During the pupa stage, the insect goes through **metamorphosis**. tissue and appendages of the larva break down and reorganize into the adult form. How did such an incredible transformation evolve? Metamorphosis is actually very advantageous. It allows functions to be divided between life stages. Each stage can evolve adaptation to suit it for its specific functions without affecting the adaptations of the other stage.

Insect Behavior

Insects are capable of a surprising range of behaviors. Most of their behaviors, such as flying and mating, are instinctive. These are behaviors that don't need to be learned. They are largely controlled by gene. However, some insect behaviors are learned. For example, ants and bees can learn where food is located and keep going back for more.

Many species of insects have evolved complex social behaviors. They live together in large, organized colonies (see **Figure** below). This is true of ants, termites, bees, and wasps.

Colonies may include millions of individual insects. Colony members divide up the labor of the colony. Different insects are specialized for different jobs. Some reproduce, while others care for the young. Still others get food or defend the nest.

[Figure 6]

Termite Nest. This cathedral-like structure is the nest of a huge colony of termites in Australia. In fact, it is the world's largest known termite nest. It towers 7.5 meters (25 feet) above the ground and houses millions of termites.

Living in a large colony requires good communication. Ants communicate with chemicals called **pheromone**. For example, an ant deposits pheromones on the ground as it returns to the nest from a food source. It is marking the path so other ants can find the food. Honeybees communicate by doing a "waggle dance."

KQED: Ants: The Invisible Majority

Most of us think ants are just pests. But not Brian Fisher. Known as "The Ant Guy," he's on a mission to show the world just how important and amazing these little creatures are. In the process, he hopes to catalog all of the world's 30,000 ant species before they become casualties of habitat loss.

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KQED: Ladybugs: A Population of Millions

Ladybugs, also known as ladybird beetles, have a life cycle of four to six weeks. In one year as many as six generations of ladybird beetles may hatch. In the spring, each adult female lays up to 300 eggs in small clusters on plants where aphids are present. After a week the wingless larvae hatch. Both the ladybird beetle larvae and adults are active predators, eating only aphids, scales, mites and other plant-eating insects. The ladybugs live on the vegetation where their prey is found, which includes roses, oleander, milkweed and broccoli. Adult ladybugs don't taste very good. A bird careless enough to try to eat one will not swallow it.

By late May to early June, when the larvae have depleted the food supply, the adults migrate to the mountains. There, they eat mainly pollen. The ladybugs gain fat from eating the pollen and this tides them over during their nine-month hibernation. Thousands of adults hibernate overwinter in tight clusters, called **aggregate**, under fallen leaves and ground litter near streams. In the clear, warmer days of early spring, the ladybugs break up the aggregates and begin several days of mating.

Insects and Humans

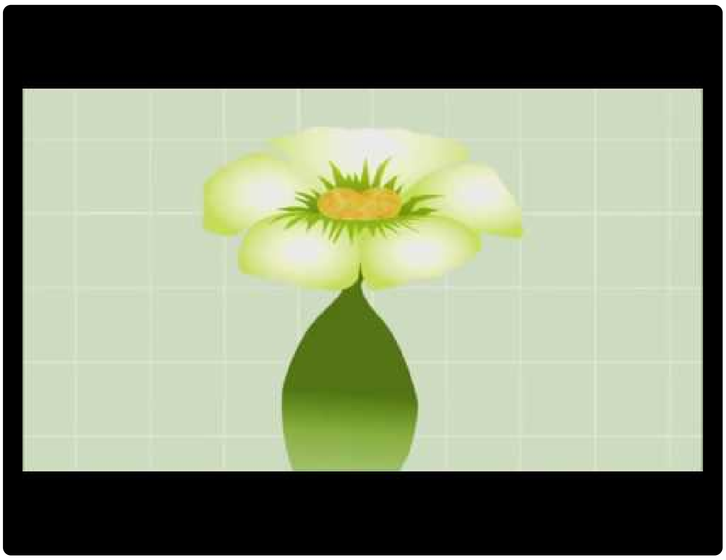
Most humans interact with insects every day. Many of these interactions are harmless and often go unnoticed. However, insects cause humans a lot of harm. They spread human diseases. For example, the deadly bubonic plague of the middle ages was spread by fleas. Today, millions of people die each year from malaria, which is spread by mosquitoes. Insects also eat our crops. Sometimes they travel in huge swarms that completely strip the land of all plant material (see **Figure** below). On the other hand, we depend on insects for the very food we eat. Without insects to pollinate them, flowering plants—including many food crops—could not reproduce.

[Figure 7]

Locust Swarm. A swarm of locusts in the African country of Mauritania darkens the mid-day sky. The hungry insects will eat virtually all the plants in their path.

KQED: Better Bees: Super Bee and Wild Bee

Honeybees are one of the most well-known insects on the planet. Bees are naturalized on every continent except Antarctica. Honeybees have a highly developed social structure and depend on their community, or colony, for survival, with a colony containing up to 20,000 bees. When bees search plants for nectar, pollen sticks to the fuzzy hairs that cover their hind legs. At the next flower, some of the pollen rubs off and fertilizes that flower. In this way, bees help improve fruit production. Bees pollinate an estimated 130 different varieties of fruit, flowers, nuts and vegetables in the United States alone. Farmers obviously depend on bees to pollinate crops, such as fruit and nuts, but in recent years thousands of bee colonies have disappeared. This could be a devastating issue for farmers. Can anything be done? Meet two Northern California researchers looking for ways to make sure we always have bees to pollinate crops.



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science Friday: The Road Best Traveled: A Tale of Ants, slime mold and the New Jersey Turnpike

For most people, getting stuck in a traffic jam on the New Jersey Turnpike is a grueling lesson in futility. However, in this video by Science Friday, Simon Garnier examines our collective behavior and how relatively simple organisms organize themselves so dynamically.

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Summary

- Insects are arthropods in the class Hexapoda. They are the most numerous organisms in the world.
- Most insects are terrestrial, and many are aerial.
- Insects have six legs and a pair of antennae for sensing chemicals. They also have several eyes and specialized mouthparts for feeding.
- Insects are the only invertebrates than can fly. Flight is the main reason for their success.
- Insects may live in large colonies and have complex social behaviors.
- Insects spread disease and destroy crops. However, they are essential for pollinating flowering plants.

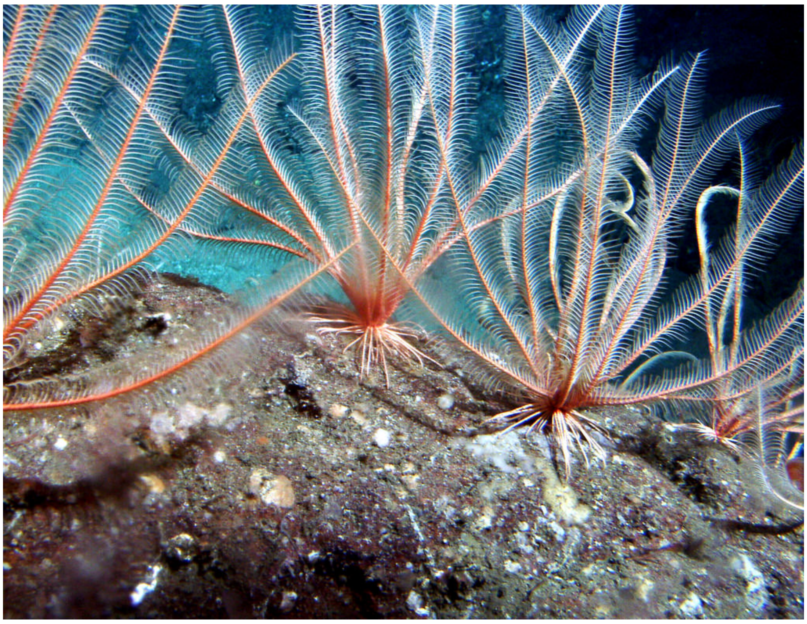
Review

1. List two traits that characterize insects.
2. State two important advantages of flight in insects.
3. Give examples of insect behavior.
4. Present facts and a logical argument to support the following statement: “Insects dominate life on Earth.”
5. Explain why distinctive life stages and metamorphosis are adaptive.
6. Diagram an insect life cycle.

11.12 Echinoderms

FlexBooks 2.0 > Biology For High School Diploma > Echinoderms

Last Modified: Dec 02, 2021



[Figure 1]

Believe it or not, this is an animal. See the mouth and arms?

It is a sea lily, a **crinoid** echinoderm. Crinoids are essentially a mouth on the top surface that is surrounded by feeding arms. Although the basic echinoderm pattern of fivefold symmetry can be recognized, most crinoids have many more than five arms. Crinoids usually have a stem used to attach themselves to a surface, but many become free-swimming as adults.

Echinoderms

Echinoderms are marine organism that make up the phylum Echinodermata. They can be found in the ocean from the equator to the poles. There are roughly 6000 living species of echinoderms. They are among the most distinctive organisms within the animal kingdom. Members of the phylum include sea stars (starfish), sand dollars, and feather stars, shown in **Figure** below.

[Figure 2]

Examples of Echinoderms. You may have seen sea stars and sand dollars at the beach because they live in shallow water near the shore. Other echinoderms, such as feather stars, are less commonly seen because they live in the deep ocean.

Structure and Function of Echinoderms

Echinoderms are named for their “spiny skin.” However, the spines aren’t on their skin. They are part of the endoskeleton. The endoskeleton consists of calcium carbonate plates and spines, covered by a thin layer of skin. Adult echinoderms have **radial symmetry**. This is easy to see in the sea star and sand dollar in **Figure** above. However, echinoderms evolved from an ancestor with **bilateral symmetry**. evidence for this is the bilateral symmetry of their larva.

A unique feature of echinoderms is their **water vascular system**. This is a network of canals that extend along each body part. In most echinoderms, the canals have external projections called **tube feet** (see **Figure** below). The feet have suckers on the ends. Muscle contractions force water into the feet, causing them to extend outward. As the feet extend, they attach their suckers to new locations, farther away from their previous points of attachment. This results in a slow but powerful form of movement. The suckers are very strong. They can even be used to pry open the shells of prey.

[Figure 3]

Tube Feet of a Sea Star. The tube feet of a sea star (in white) are part of its water vascular system. There is a sucker on the end of each foot that allows the animal to “walk” slowly over a surface. The suckers are strong enough to pry open shells.

Echinoderms lack respiratory and excretory systems. Instead, the thin walls of their tube feet allow oxygen to diffuse in and wastes to diffuse out. Echinoderms also lack a centralized nervous system. They have an open circulatory system and lack a heart. On the other hand, echinoderms have a well-developed coelom and a complete digestive system. Echinoderms use **pheromone** to communicate with each other. They detect the chemicals with sensory cell on their body surface. Some echinoderms also have simple eyes (**ocelli**) that can sense light. Like annelids, echinoderms have the ability to regenerate a missing body part.

Echinoderm Reproduction

Some echinoderms can reproduce asexually by fission, but most echinoderms reproduce sexually. They generally have separate sexes and external fertilization. egg hatch into free-swimming larvae. The larvae undergo metamorphosis to change into the adult form. During metamorphosis, their bilateral symmetry changes to radial symmetry.

Echinoderm Classification

Living echinoderms are placed in five classes. These five classes show many similarities. Organisms in each class are described in **Table** below.

Class (includes)	Description	Example
Crinoidea • feather stars • sea lilies	fewer than 100 species; many have more than five arms; earliest and most primitive echinoderms; live on the ocean floor, mainly in deep water; filter feeder	feather star  [Figure 4]
Asteroidea • sea stars	almost 2000 species; most have five arms; many are brightly colored; live on the ocean floor, mainly in shallow water; predator or scavenger	sea star  [Figure 5]
Ophiuroidea • brittle stars	about 2000 species; central disk distinct from arms; move by flapping their arms, which lack suckers; live on the ocean floor in shallow or deep water; predators, scavengers, deposit feeder, or filter feeders	brittle star  [Figure 6]
Echinoidea • sea urchins • sand dollars • sea biscuits • heart urchins	about 100 species; do not have arms but do have tube feet; have a specialized mouth part with teeth to scrape food from rocks; live on the ocean floor in shallow or deep water; predators, herbivore, or filter feeders	sea urchin  [Figure 7]
Holothuroidea • sea cucumbers	about 1000 species; long body without arms; unlike other echinoderms, have a respiratory system; live on the ocean floor in shallow or deep water; deposit feeders, or filter feeders	sea cucumber  [Figure 8]

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Summary

- Echinoderms are marine invertebrates. They include sea stars, sand dollars, and feather stars.
- Echinoderms have a spiny endoskeleton. They have radial symmetry as adults but bilateral symmetry as larvae.
- Echinoderms have a unique water vascular system with tube feet. This allows slow but powerful movement.

Review

1. Describe the echinoderm endoskeleton.
2. Give an example of an organism in each class of living echinoderms.
3. Adult sea stars and other echinoderms have obvious radial symmetry. What evidence supports the claim that echinoderms evolved from an ancestor with bilateral symmetry?
4. Explain the structure and function of the water vascular system.

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11.13 Invertebrate Chordates

FlexBooks 2.0 > Biology For High School Diploma > Invertebrate Chordates

Last Modified: May 21, 2021

[Figure 1]

Would you believe this animal eats its own brain?

This is a sea squirt, which is a **tunicate**. Many physical changes occur to the tunicate's body during metamorphosis into an adult, with one of the most interesting being the digestion of the cerebral ganglion, which controls movement and is the equivalent of the human brain. From this comes the common saying that the sea squirt "eats its own brain."

Invertebrate Chordates

Living species of chordate are classified into three major subphyla: Vertebrata, Urochordata, and Cephalochordata. vertebrate are all chordates that have a backbone. The other two subphyla are invertebrate chordates that lack a backbone. Members of the subphylum Urochordata are **tunicates** (also called sea squirts). Members of the subphylum Cephalochordata are **lancelets**. Both tunicates and lancelets are small and primitive. They are probably similar to the earliest chordates that evolved more than 500 million years ago.

Tunicates

There are about 3,000 living species of tunicates (see **Figure** below). They inhabit shallow marine waters. Larval tunicates are free-swimming. They have all four defining chordate traits (see the "Chordates" concept). Adult tunicates are sessile. They no longer have a notochord or post-anal tail.

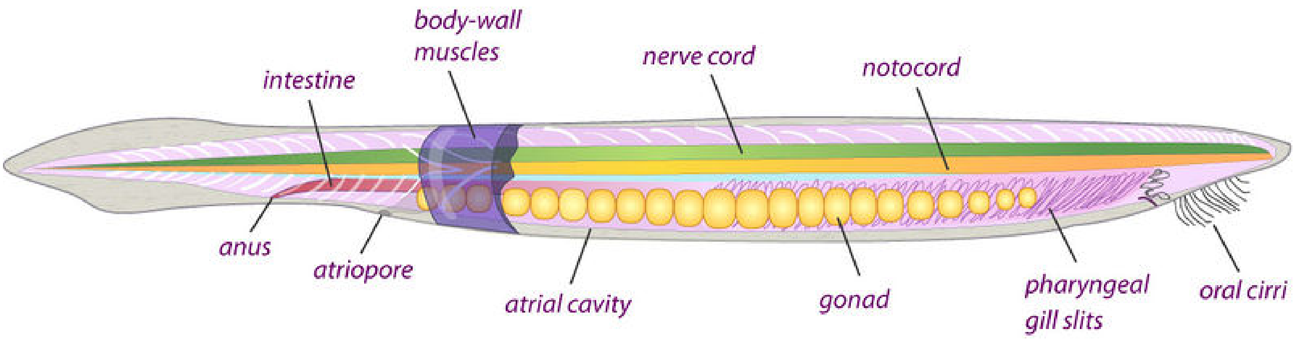
[Figure 2]

Tunicates (Urochordata). Tunicates are one of two subphyla of invertebrate chordates.

Adult tunicates are barrel-shaped. They have two openings that siphon water into and out of the body. The flow of water provides food for filter feeding. Tunicates reproduce sexually. Each individual produces both male and female gamete. However, they avoid self-fertilization. Tunicates can also reproduce asexually by budding.

Lancelets

There are only about 25 living species of lancelets. They inhabit the ocean floor where the water is shallow. **lancelet** larva are free-swimming. The adults can swim but spend most of their time buried in the sand. Like tunicates, lancelets are filter feeder. They take in water through their mouth and expel it through an opening called the **atriopore** (see **Figure** below). Lancelets reproduce sexually and have separates sexes.



[Figure 3]

Lancelet (Cephalochordata). Unlike tunicates, lancelets retain all four defining chordate traits in the adult stage. Can you find them?

Summary

- Chordates include vertebrates and invertebrates that have a notochord.
- Invertebrate chordates do not have a backbone.
- Invertebrate chordates include tunicates and lancelets. Both are primitive marine organisms.

Review

1. Name and describe the two subphyla of invertebrate chordates.

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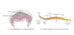
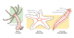
	**Credit:** Christopher AuYeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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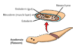
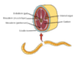
	**Credit:** Christopher AuYeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Christopher AuYeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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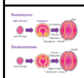	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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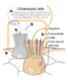
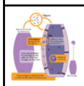
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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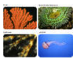
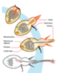
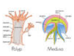
	**Credit:** Laszlo Ilyes, Courtesy of National Oceanic and Atmospheric Administration, Tims/Wikipedia, NBPhotostream **Source:** http://www.flickr.com/photos/laszlo-photo/2110755960/ **License:** CC BY
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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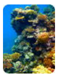	**Credit:** Kyle Taylor **Source:** http://www.flickr.com/photos/kyletaylor/4875051470/ **License:** CC BY 2.0

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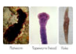	**Credit:** Flatworm: Neville Wootton; Tapeworm: Courtesy of Centers for Disease Control and Prevention; Fluke: User:Anilocra/Wikipedia **Source:** Flatworm: http://www.flickr.com/photos/nevillewootton/9364345716/; Tapeworm: https://www.cdc.gov/dpdx/taeniasis/index.html.; Fluke: http://commons.wikimedia.org/wiki/File:A-ferox_digenean1.jpg **License:** Flatworm: CC BY 2.0; Tapeworm and Fluke: Public Domain
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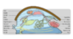	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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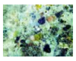	**Credit:** amanderson2 **Source:** https://www.flickr.com/photos/49399018@N00/35090154435 **License:** Public Domain
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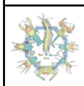
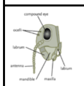
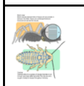
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Christopher AuYeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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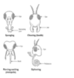	**Credit:** Christopher AuYeung **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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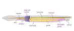
	**Credit:** Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0

CHAPTER 12

Vertebrates

Chapter Outline

12.1 Chordates

FlexBooks 2.0 > Biology For High School Diploma > Chordates

Last Modified: Sep 09, 2019

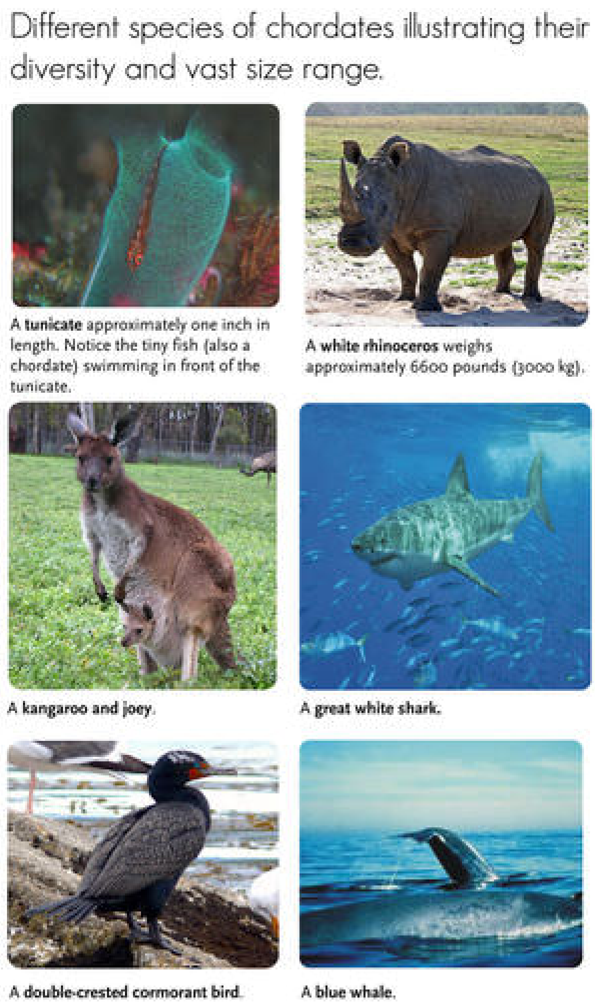
[Figure 1]

What's a chordate?

Most chordates are animal with backbones. These range from small fish to giant whales, from playful dogs to ferocious cats. Not nearly as diverse as the invertebrate. But chordates do have many amazing species. The white tiger (*Panthera tigris*) is a chordate. The tiger is also from the class Mammalia, order Carnivora, and family Felidae, meaning it is a meat-eating cat.

Introduction to Chordates

The phylum Chordata consists of both invertebrate and **vertebrate chordates**. It is a large and diverse phylum. It includes some 60,000 species. Chordates range in length from about a centimeter to over 30 meters (100 feet). They live in marine, freshwater, terrestrial, and aerial habitat. They can be found from the equator to the poles. Several examples of chordates are pictured in **Figure** below.



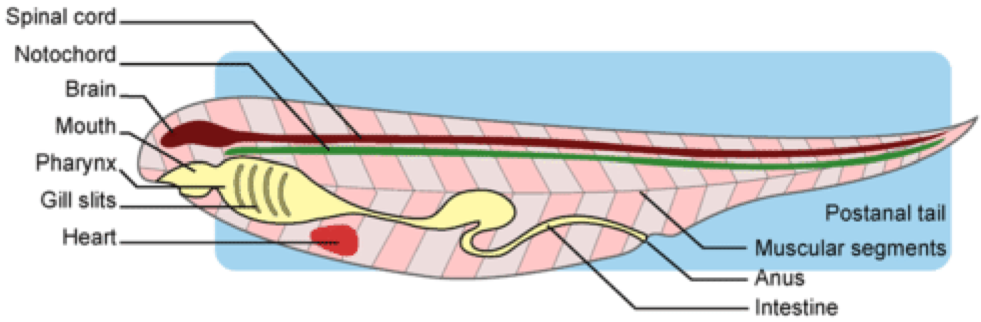
[Figure 2]

Diversity of Chordates. These six species illustrate the diversity of the phylum Chordata.

Characteristics of Chordates

Chordates have three embryonic cell layers. They also have a segmented body with a coelom and bilateral symmetry. Chordates have a complete digestive system and a closed circulatory system. Their nervous system is centralized. There are four additional traits that are unique to chordates. These four traits, shown in **Figure** below, define the chordate phylum.

1. **post-anal tail**: The tail is opposite the head and extends past the anus.
2. **dorsal hollow nerve cord**: The nerve cord runs along the top, or dorsal, side of the animal. (In non chordate animals, the nerve cord is solid and runs along the bottom).
3. **notochord**: The notochord lies between the dorsal nerve cord and the digestive tract. It provides stiffness to counterbalance the pull of muscles.
4. **pharyngeal slit**: Pharyngeal slits are located in the pharynx. The pharynx is the tube that joins the mouth to the digestive and respiratory tracts.



[Figure 3]

Body Plan of a Typical Chordate. The body plan of a chordate includes a post-anal tail, notochord, dorsal hollow nerve cord, and pharyngeal slits.

In some chordates, all four traits persist throughout life and serve important functions. However, in many chordates, including humans, all four traits are present only during the embryonic stage. After that, some of the traits disappear or develop into other organ. For example, in humans, pharyngeal slits are present in embryo and later develop into the middle ear.

Classification of Chordates

Living species of chordates are classified into three major subphyla: Vertebrata, Urochordata, and Cephalochordata. **Vertebrates** are all chordates that have a backbone. The other two subphyla are invertebrate chordates that lack a backbone.

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Summary

- Chordates include vertebrates and invertebrates that have a notochord.
- Chordates also have a post-anal tail, dorsal hollow nerve cord, and pharyngeal slits.
- Vertebrate chordates have a backbone.

Review

1. What is a vertebrate?
2. Identify the four defining traits of chordates.
3. Adult humans lack some of the defining traits of chordates. Why are humans still classified in the chordate phylum?

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12.2 Vertebrate Diversity

FlexBooks 2.0 > Biology For High School Diploma > Vertebrate Diversity

Last Modified: Jul 04, 2019

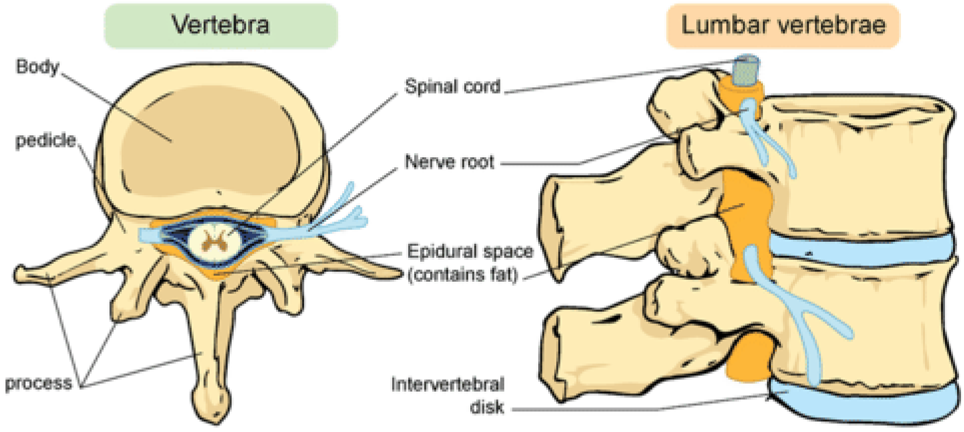
[Figure 1]

What traits set this animal apart from invertebrate chordates?

This small colorful fish is a vertebrate - it has a backbone. And vertebral columns first evolved in fish. Think about the invertebrate chordate. They live in the ocean, so it only makes sense that fish would be the first true vertebrates. Vertebrates are a subphylum of the phylum Chordata. Like all chordates, vertebrates have a notochord, a dorsal hollow nerve cord, pharyngeal slit, and a post-anal tail. What other characteristics do vertebrates have?

Characteristics of Vertebrates

The main distinguishing feature of vertebrates is their **vertebral column**, or **backbone** (see **Figure** below). The backbone runs from the head to the tail along the dorsal (top) side of the body. The vertebral column is the core of the **endoskeleton**. It allows a vertebrate to hold its shape. It also houses and protects the spinal (nerve) cord that passes through it. The vertebral column is made up of repeating units called **vertebra** (singular, **vertebra**). In many species, there are shock-absorbing discs between the vertebrae to cushion them during movement.



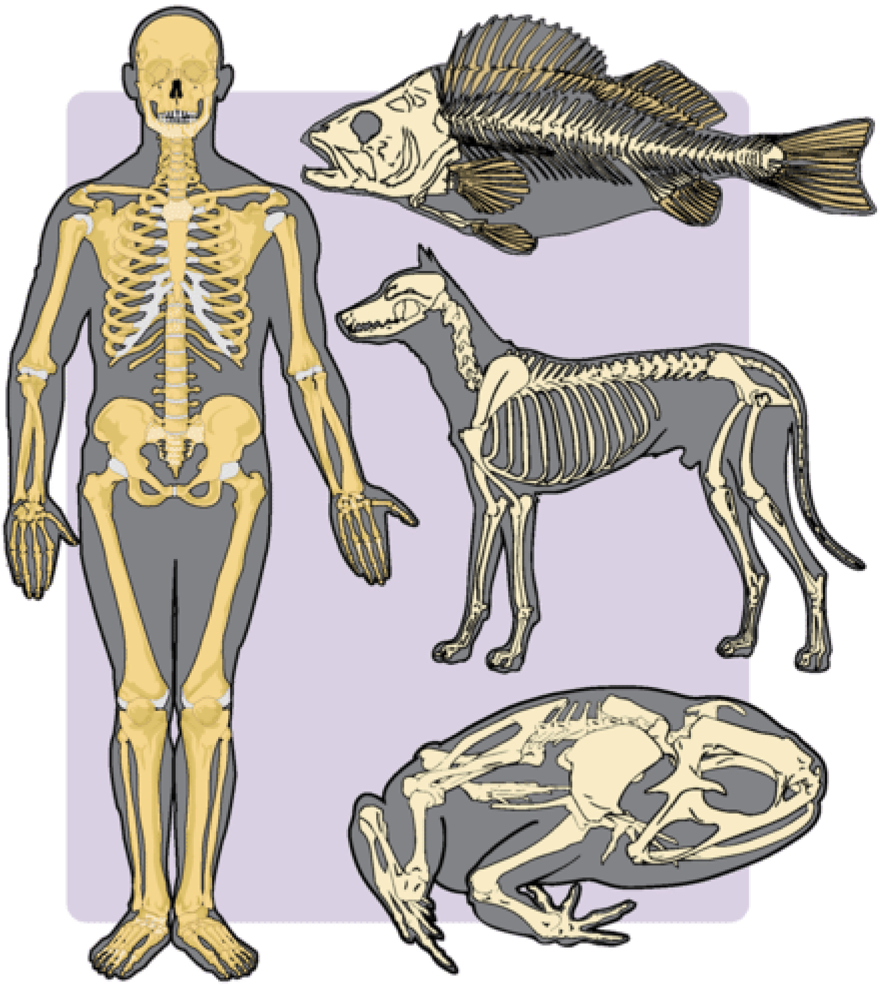
[Figure 2]

Human Vertebral Column and Vertebrae. The human vertebral column consists of 33 vertebrae. Two vertebrae are shown here enlarged.

Vertebrate Endoskeleton

Another distinguishing feature of vertebrates is an endoskeleton made of **bone** or **cartilage**. **Cartilage** is a tough tissue that contains a protein called collagen. **Bone** is a hard tissue that consists of a collagen matrix, or framework, filled in with mineral such as calcium. Bone is less flexible than cartilage but stronger. An endoskeleton made of bone rather than cartilage allows animal to grow larger and heavier. Bone also provides more protection for soft tissues and internal organ.

As shown in **Figure** below, the vertebrate endoskeleton includes a **cranium,** or skull, to enclose and protect the brain. It also generally includes two pairs of limbs. Limb girdles (such as the human hips and shoulders) connect the limbs to the rest of the endoskeleton.



[Figure 3]

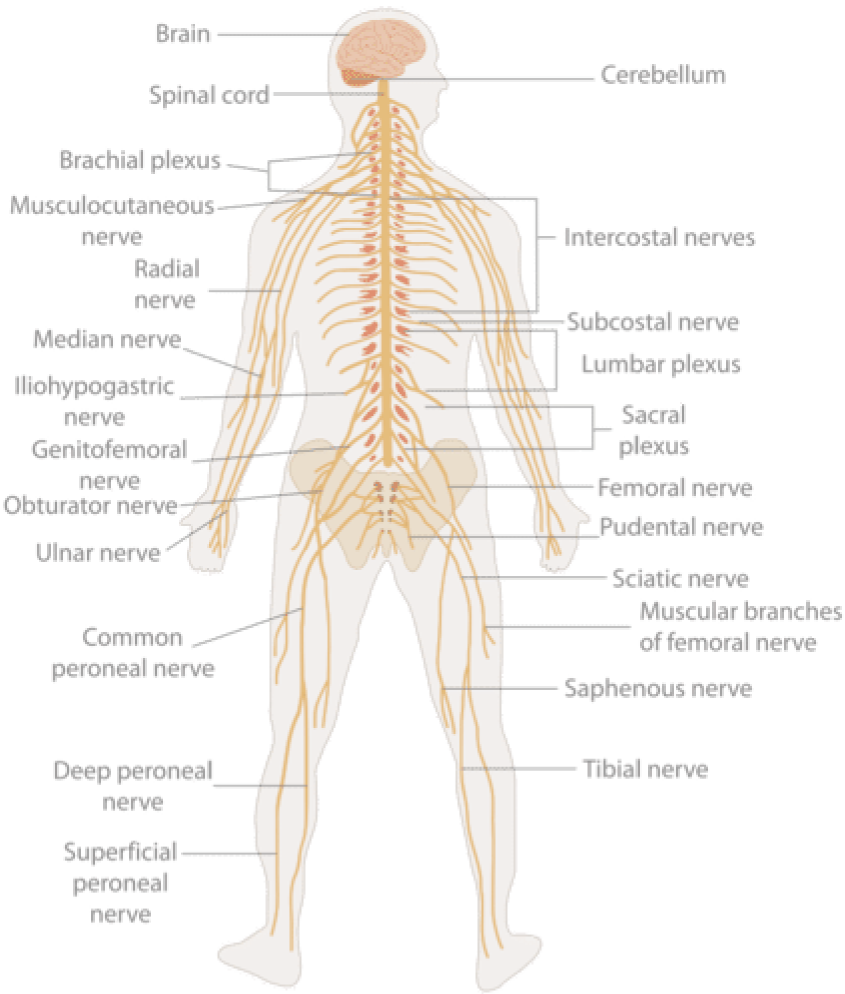
Vertebrate Endoskeletons. The vertebrate endoskeleton includes a vertebral column, cranium, limbs, and limb girdles. Can you find these parts in each endoskeleton shown here?

Other Vertebrate Traits

There are several additional traits found in virtually all vertebrates.

- Vertebrates have a system of muscles attached to the endoskeleton to enable movement. Muscles control movement by alternately contracting (shortening) and relaxing (lengthening). Generally, muscles work together in opposing pairs.
- Vertebrates have a closed circulatory system with a heart. blood is completely contained within blood vessel that carry the blood throughout the body. The heart is divided into chambers that work together to pump blood. There are between two and four chambers in the vertebrate heart. With more chambers, there is more oxygen in the blood and more vigorous pumping action.
- Most vertebrates have skin covered with scales, feather, fur, or hair. These features serve a variety of functions, such as waterproofing and insulating the body.

- Vertebrates have an excretory system that includes a pair of **kidney**. **Kidneys** are organs that filter wastes from blood so they can be excreted from the body.
- Vertebrates have an **endocrine system** of glands that secrete **hormone**. **Hormones** are chemical messengers that control many body functions.
- Vertebrates have an adaptive **immune system**. The **immune system** is the organ system that defends the body from pathogen and other causes of disease. Being adaptive means that the immune system can "learn" to recognize specific pathogens. Then it can produce tailor-made proteins called **antibody** to "attack" them. This allows the immune system to launch a rapid attack whenever the pathogens invade the body again.
- Vertebrates have a centralized nervous system. As shown in **Figure** below, the nervous system consists of a brain in the head region. It also includes a long spinal cord that runs from the brain to the tail end of the backbone. Long nerve fibers extend from the spinal cord to muscles and organs throughout the body.



[Figure 4]

Nervous System (Human). The vertebrate nervous system includes a brain and spinal cord. It also includes a body-wide network of nerves, called peripheral nerves. They connect the spinal cord with the rest of the body.

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Summary

- Vertebrates are a subphylum of chordates that have a vertebral column and an endoskeleton made of cartilage or bone.
- Vertebrates also have complex organ systems, including a closed circulatory system with a heart, an excretory system with a pair of kidneys, and an adaptive immune system.

Review

1. Describe the vertebrate vertebral column, and list its functions.
2. Contrast cartilage and bone, and state the advantages of a bony endoskeleton relative to a cartilaginous endoskeleton.
3. Identify the components of the vertebrate nervous system.
4. What is an adaptive immune system?

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12.3 Vertebrate Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Vertebrate Reproduction

Last Modified: Jul 04, 2019

[Figure 1]

Does the embryo develop in the mother or in an egg?

Is the egg within the mother or not? vertebrate reproduction occurs by one of three methods. These bird eggs demonstrate one of three types of vertebrate reproduction.

Vertebrate Reproduction

Vertebrates reproduce sexually, and almost all of them have separate male and female sexes. Recall that **sexual reproduction** is the joining of gamete during fertilization, producing genetically variable offspring. Generally, aquatic species have external fertilization, whereas terrestrial species have internal fertilization. Can you think of a reason why aquatic and terrestrial vertebrates differ in this way?

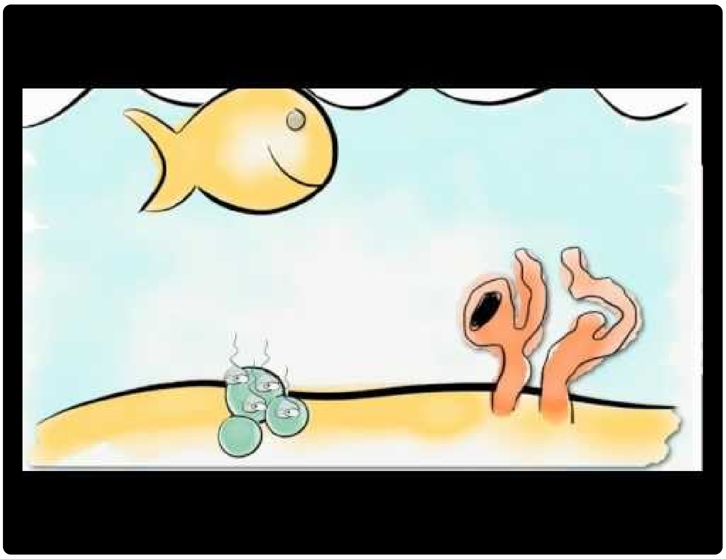
Vertebrates have one of the following three reproductive strategies: **ovipary**, **ovovivipary**, or **vivipary**.

- **Ovipary** refers to the development of an embryo within an egg outside the mother's body. This occurs in most amphibian and reptile and in all birds.
- **Ovovivipary** refers to the development of an embryo inside an egg within the mother's body until it hatches. The mother provides no nourishment to the developing embryo inside the egg. This occurs in some species of fish and reptiles.

- **Vivipary** refers to the development and nourishment of an embryo within the mother's body. Birth may be followed by a period of parental care of the offspring. This reproductive strategy occurs in almost all mammal.

[Figure 2]

What type of reproduction occurs in kangaroos?



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Summary

- Vertebrates reproduce sexually, and almost all have separate male and female sexes.
- Aquatic species generally have external fertilization, whereas terrestrial species usually have internal fertilization.
- Vertebrates have one of three reproductive strategies, known as ovipary, ovovivipary, or vivipary.

Review

1. Define ovipary, ovovivipary, and vivipary.
2. Which vertebrates use each type of reproductive strategy?

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12.4 Vertebrate Classification

FlexBooks 2.0 > Biology For High School Diploma > Vertebrate Classification

Last Modified: Jul 04, 2019

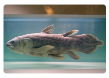
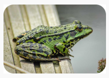
[Figure 1]

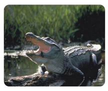
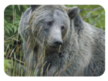
The stingray. Fish?

Of course. But what type? Of the nine classes of vertebrate, five are fish. Each of the five classes has distinguishing characteristics that allow members to be classified appropriately. Stingray are cartilaginous fish, related to sharks.

Vertebrate Classification

There are about 50,000 vertebrate species, and they are placed in nine different classes. Five of the classes are fish. The other classes are amphibian, reptile, bird, and mammal. **Table** below lists some of the distinguishing traits of each class. Classes are listed in order of evolution.

Class	Distinguishing Traits	Example
hagfish	They have a cranium but no backbone; they do not have jaws; their endoskeleton is made of cartilage; they are ectothermic.	hagfish  [Figure 2]
Lampreys	They have a partial backbone; they do not have jaws; their endoskeleton is made of cartilage; they are ectothermic.	lamprey  [Figure 3]
Cartilaginous Fish	They have a complete backbone; they have jaws; their endoskeleton is made of cartilage; they are ectothermic.	shark  [Figure 4]
ray-finned fish	They have a backbone and jaws; their endoskeleton is made of bone; they have thin, bony fins; they are ectothermic.	perch  [Figure 5]
lobe-finned fish	They have a backbone and jaws; their endoskeleton is made of bones; they have thick, fleshy fins; they are ectothermic.	coelacanth  [Figure 6]
Amphibians	They have a bony endoskeleton with a backbone and jaws; they have gill as larva and lung as adults; they have four limbs; they are ectothermic	frog  [Figure 7]
Reptiles	They have a bony endoskeleton with a backbone and jaws; they breathe only with lungs; they have four limbs; their skin is covered with scales; they have amniotic egg; they are ectothermic.	alligator

		 [Figure 8]
Birds	They have a bony endoskeleton with a backbone but no jaws; they breathe only with lungs; they have four limbs, with the two front limbs modified as wing; their skin is covered with feather; they have amniotic eggs; they are endothermic.	bird  [Figure 9]
Mammals	They have a bony endoskeleton with a backbone and jaws; they breathe only with lungs; they have four limbs; their skin is covered with hair or fur; they have amniotic eggs; they have mammary (milk-producing) glands; they are endothermic.	bear  [Figure 10]

Summary

- The 50,000 species of living vertebrates are placed in nine classes: hagfish, lampreys, cartilaginous fish, ray-finned fish, lobe-finned fish, amphibians, reptiles, birds, and mammals.

Review

1. Which was the first and last vertebrate classes to evolve?
2. What are the five fish vertebrate classes?
3. What are the defining characteristics of mammals?
4. What was the first class of vertebrates to live on land?
5. Sharks belong to what vertebrate class?

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12.5 Vertebrate Evolution

FlexBooks 2.0 > Biology For High School Diploma > Vertebrate Evolution

Last Modified: Jul 04, 2019

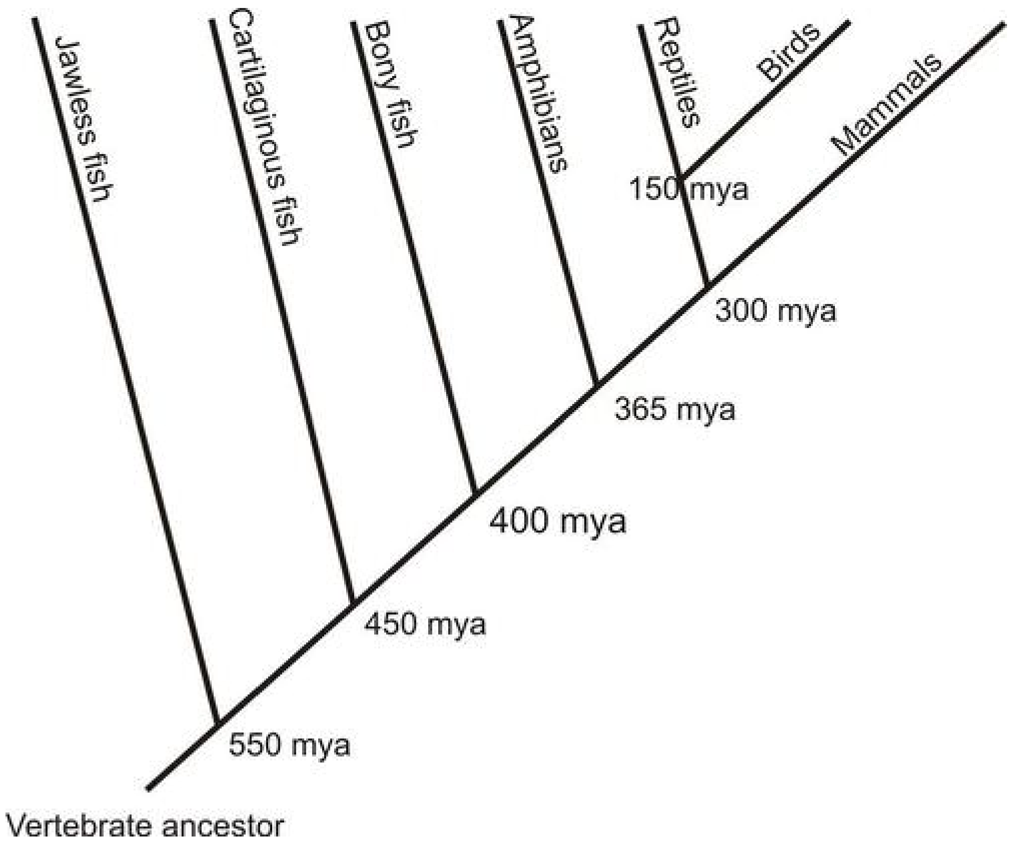
[Figure 1]

What type of fish is a simple perch?

Does it have a partial of complete vertebral column? What about a jaw? Do you think the endoskeleton is made of cartilage or bone? Why are these important evolutionary steps? A bony skeletal could support a larger body. Early bony fish evolved into modern ray-finned and lobe-finned fish, which then evolved into species that could move out of the water.

Vertebrate Evolution

The earliest vertebrate were jawless fish, similar to living hagfish. They lived between 500 and 600 million years ago. They had a cranium but no vertebral column. The **phylogenetic tree** in **Figure** below gives an overview of vertebrate evolution. As more data become available, new ideas about vertebrate evolution emerge.



[Figure 2]

Phylogenetic Tree of Vertebrate Evolution. The earliest vertebrates evolved almost 550 million years ago. Which class of vertebrates evolved last?

Evolution of Fish

Not too long after hagfish first appeared, fish similar to lampreys evolved a partial vertebral column. The first fish with a complete vertebral column evolved about 450 million years ago. These fish also had jaws and may have been similar to living sharks. Up to this point, all early vertebrates had an endoskeleton made of cartilage rather than bone. About 400 million years ago, the first bony fish appeared. A bony skeleton could support a larger body. Early bony fish evolved into modern ray-finned and lobe-finned fish.

Evolution of Other Vertebrate Classes

amphibian, reptile, mammal, and bird evolved after fish.

- The first amphibians evolved from a lobe-finned fish ancestor about 365 million years ago. They were the first vertebrates to live on land, but they had to return to water to reproduce. This meant they had to live near bodies of water.
- The first reptiles evolved from an amphibian ancestor at least 300 million years ago. They laid **amniotic egg** and had internal fertilization. They were the first vertebrates that no longer had to return to water to reproduce. They could live just about anywhere.

- Mammals and birds both evolved from reptile-like ancestors. The first mammals appeared about 200 million years ago and the earliest birds about 150 million years ago.

Evolution of Endothermy

Until mammals and birds evolved, all vertebrates were ectothermic. **ectothermy** means regulating body temperature from the outside through behavioral changes. For example, an ectotherm might stay under a rock in the shade in order to keep cool on a hot, sunny day. Almost all living fish, amphibians, and reptiles are ectothermic. Their metabolic rate and level of activity depend mainly on the outside temperature. They can raise or lower their own temperature only slightly through behavior alone.

Both mammals and birds evolved **endothermy**. **Endothermy** means regulating body temperature from the inside through metabolic or other physical changes. On a cold day, for example, an endotherm may produce more heat by raising its metabolic rate. On a hot day, it may give off more heat by increasing blood flow to the surface of the body. Keeping body temperature stable allows cell to function at peak efficiency at all times. The metabolic rate and activity level can also remain high regardless of the outside temperature. On the other hand, maintaining a stable body temperature requires more energy—and more food.

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Summary

- The earliest vertebrates resembled hagfish and lived more than 500 million years ago.
- As other classes of fish appeared, they evolved traits such as a complete vertebral column, jaws, and a bony endoskeleton.

- Amphibians were the first tetrapod vertebrates as well as the first vertebrates to live on land.
- Reptiles were the first amniotic vertebrates.
- Mammals and birds, which both descended from reptile-like ancestors, evolved endothermy, or the ability to regulate body temperature from the inside.

Review

1. In what order did vertebrates evolve?
2. Birds evolved from what other type of vertebrate?
3. What were the first vertebrates to lay amniotic eggs?
4. Compare and contrast ectothermy and endothermy, including their pros and cons.

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12.6 Fish

FlexBooks 2.0 > Biology For High School Diploma > Fish

Last Modified: Oct 05, 2021

[Figure 1]

What are these geometric shapes?

These are the scales - the skin - of a goldfish, and they almost look like a piece of art. They also look like they form a smooth, streamlined skin. Why is this important to a fish?

Structure and Function in Fish

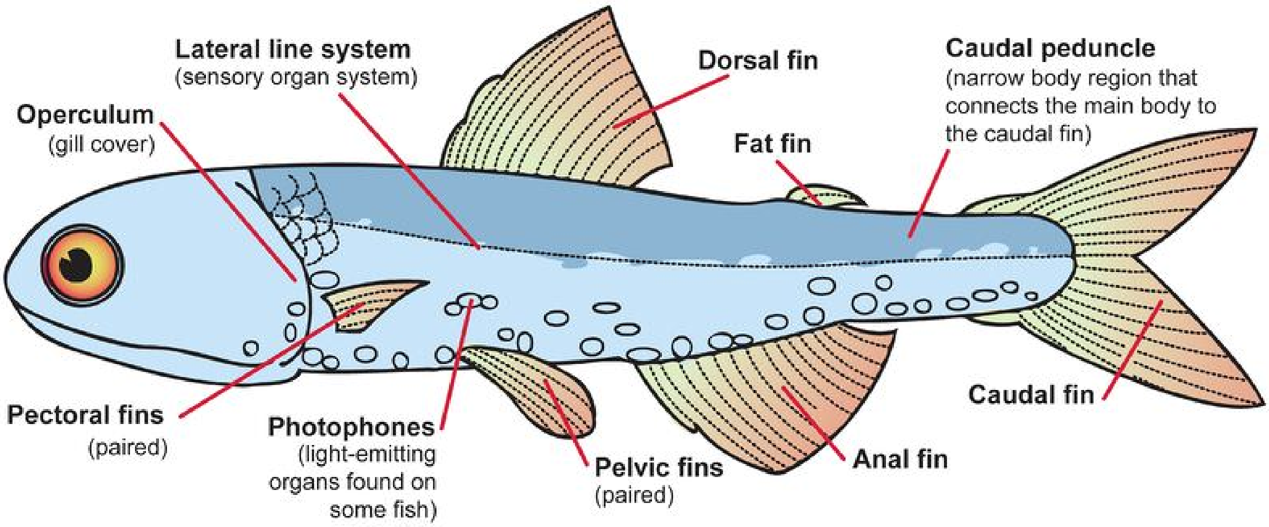
Fish are aquatic vertebrate. They make up more than half of all vertebrate species. They are especially important in the study of vertebrate evolution because several important vertebrate traits evolved in fish. Fish show great diversity in body size. They range in length from about 8 millimeters (0.3 inches) to 16 meters (about 53 feet). Most are ectothermic and covered with scales. **Scales** protect fish from predator and parasite and reduce friction with the water. Multiple, overlapping scales provide a flexible covering that allows fish to move easily while swimming.

Adaptations for Water

Many structures in fish are adaptation for their aquatic lifestyle. Several are described below and shown in **Figure** below.

- Fish have **gill** that allow them to "breathe" oxygen in water. Water enters the mouth, passes over the gills, and exits the body through a special opening. Gills absorb oxygen from the water as it passes over them.

- Fish have a stream-lined body. They are typically long and narrow, which reduces water resistance when they swim.
- Most fish have several fins for swimming. They use some of their fins to propel themselves through the water and others to steer the body as they swim.
- Fish have a system of muscles for movement. Muscle contractions ripple through the body in waves from head to tail. The contractions whip the tail fin against the water to propel the fish through the water.
- Most fish have a **swim bladder.** This is a balloon-like internal organ that contains gas. By changing the amount of gas in the bladder, a fish can move up or down through the water column.



[Figure 2]

General Fish Body Plan. A fish has a stream-lined body with gills and fins.

Fish Organ Systems

Fish have a circulatory system with a two-chambered heart. Their digestive system is complete and includes several organs and glands. Jawed fish use their jaws and teeth to grind up food before passing it to the rest of the digestive tract. This allows them to consume larger prey.

Fish also have a centralized nervous system with a brain. Fish brains are small compared with the brains of other vertebrates, but they are large and complex compared with the brains of invertebrate. Fish also have highly developed sense organ that allow them to see, hear, feel, smell, and taste. Sharks and some other fish can even sense the very low levels of electricity emitted by other animal. This helps them locate prey.

science Friday: No strain, No Gain: Filter Feeding Mantas

Effortlessly, manta rays glide through the ocean gulping down plankton and fish egg by the mouthful. In this video by Science Friday, Dr. Misty Paig-Tran reveals the multiple methods of filtration they use to sift a meal from the water.

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Science Friday: Oarfish: The Ultimate Fish Tale

Thought to be the inspiration of "sea serpent" stories, the monstrously-long Oarfish provokes wonder in nearly all that witness it. In this video by Science Friday, Professor Misty Paig-Tran provides us with insights into this real-life "sea monster's" unusual physiology.

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Summary

- Fish are aquatic, ectothermic vertebrates.
- Many structures in fish are adaptations for their aquatic lifestyle. For example, fish have a stream-lined body that reduces water resistance while swimming.
- Fish have gills for “breathing” oxygen in water and fins for propelling and steering their body through water.

Review

1. What are gills? What purpose do they serve in fish?
2. Describe the function of fish scales.
3. Describe how fish use their muscles to swim.
4. What is a swim bladder? How is it used?

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12.7 Fish Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Fish Reproduction

Last Modified: May 16, 2021

[Figure 1]

How do fish reproduce?

Sockeye salmon are blue tinged with silver in color while living in the ocean. Just prior to **spawning**, both sexes turn red with green heads. Sockeye spawn mostly in streams having lakes in their watershed. The young fish spend up to three years in the freshwater lake before migrating to the ocean. Migratory fish spend from one to four years in salt water, and thus are four to six years old when they return to spawn. Navigation to the home river is thought to be done using the characteristic smell of the stream, and possibly the sun.

Fish Reproduction and Development

Nearly all fish reproduce sexually, and most species have separate sexes. Those without separate sexes avoid self-fertilization by producing sperm and egg at different times. Each fish typically produces a large number of gamete. In most fish species, fertilization takes place externally. These fish are **oviparous**. Eggs are laid and embryo develop outside the mother's body. In a minority of fish, including sharks, eggs develop inside the mother's body but without nourishment from the mother. These fish are **ovoviviparous**.

Spawning

In many species of fish, a large group of adults come together to release their gametes into the water at the same time. This is called **spawning.** It increases the chances that fertilization will take place. It also means that many embryos will form at once, which helps ensure that at least some of them will be able to escape predator.

With spawning, there is no way for fish parents to know which embryos are their own. Therefore, fish generally don't provide any care to their eggs or offspring. There are some exceptions, however, including the fish described in **Figure** below, which is performing **mouth brooding**.

[Figure 2]

Mouth Brooding. Some species of fish carry their fertilized eggs in their mouth until they hatch. This is called mouth brooding. If you look closely, you can see the eggs inside the mouth of the cardinalfish pictured here.

Fish Larvae

Fish eggs hatch into larva that are different from the adult form of the species (see **Figure** below). A larva swims attached to a large yolk sac, which provides the larva with food. The larva eventually goes through **metamorphosis** and changes into the adult form. However, it still needs to mature before it can reproduce.

[Figure 3]

Salmon Larva. This newly hatched salmon larva doesn't look very fish-like. The structure hanging from the larva is the yolk sac.

https://flexbooks.ck12.org/flx/render/embeddedobject/186787

Summary

- Nearly all fish reproduce sexually and have separate sexes.
- Fertilization is generally external, and most fish are oviparous. Many adults of the same species may come together in a group and release gametes into the water at the same time, which is called spawning.
- Fish hatch into larvae that are different from the adult form of the species.

Review

1. Explain why the practice of spawning is adaptive.
2. What is mouth brooding?
3. How are fish larvae different from the adult fish?

Explore More

Use this resource to answer the questions that follow.

https://flexbooks.ck12.org/flx/render/embeddedobject/1747

1. Describe the stages in the life of a salmon.
2. How does a salmon remember where to return to spawn?

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12.8 Fish Classification

FlexBooks 2.0 > Biology For High School Diploma > Fish Classification

Last Modified: Jul 04, 2019

[Figure 1]

What type of animal is a sea horse? Is it actually a fish?

It is, and there are about 50 species of seahorses. Although they are bony fish, they do not have scales, but rather a thin skin stretched over a series of bony plates arranged in rings throughout their body. Each species has a distinct number of rings. Seahorses have a coronet on their head, which is distinct to each individual, much like a human fingerprint. Seahorses also swim upright, a characteristic not shared by other fish. Seahorses are poor swimmers, so they are most likely to be found resting, with their prehensile tail wound around a stationary object. They have long snouts, which they use to suck up food, and eyes that can move independently of each other. Seahorses eat small shrimp, tiny fish, crustaceans, and plankton.

Classification of Fish

There are about 28,000 existing species of fish, and they are placed in five different classes. The classes are commonly referred to as hagfish, lampreys, cartilaginous fish, **ray-finned fish**, and lobe-finned fish (see the table in the previous lesson).

Hagfish

Hagfish are very primitive fish. They retain their notochord throughout life rather than developing a backbone, and they lack scales and fins. They are classified as vertebrate mainly because they have a cranium. Hagfish are noted for secreting large amounts of thick, slimy mucus. The mucus makes them slippery, so they can slip out of the jaws of predator.

Lampreys

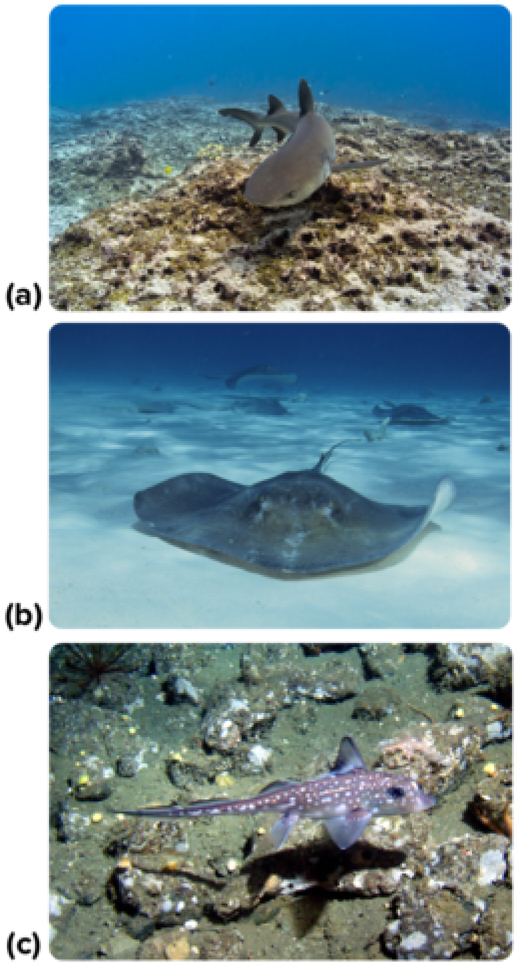
Like hagfish, **lampreys** also lack scales, but they have fins and a partial backbone. The most striking feature of lampreys is a large round sucker, lined with teeth, that surrounds the mouth (see **Figure** below). Lampreys use their sucker to feed on the blood of other fish species.

[Figure 2]

Sucker Mouth of a Lamprey. The mouth of a lamprey is surrounded by a tooth-lined sucker.

Cartilaginous Fish

Cartilaginous fish include sharks, rays, and ratfish (see **Figure** below). In addition to an endoskeleton composed of cartilage, these fish have a complete backbone. They also have a relatively large brain. They can solve problems and interact with other members of their species. They are generally predators with keen senses. Cartilaginous fish lack a swim bladder. Instead, they stay afloat by using a pair of muscular fins to push down against the water and create lift.



[Figure 3]

Cartilaginous Fish. All of these fish belong to the class of cartilaginous fish with jaws. (a) Oceanic whitetip shark (b) Ray (c) Ratfish

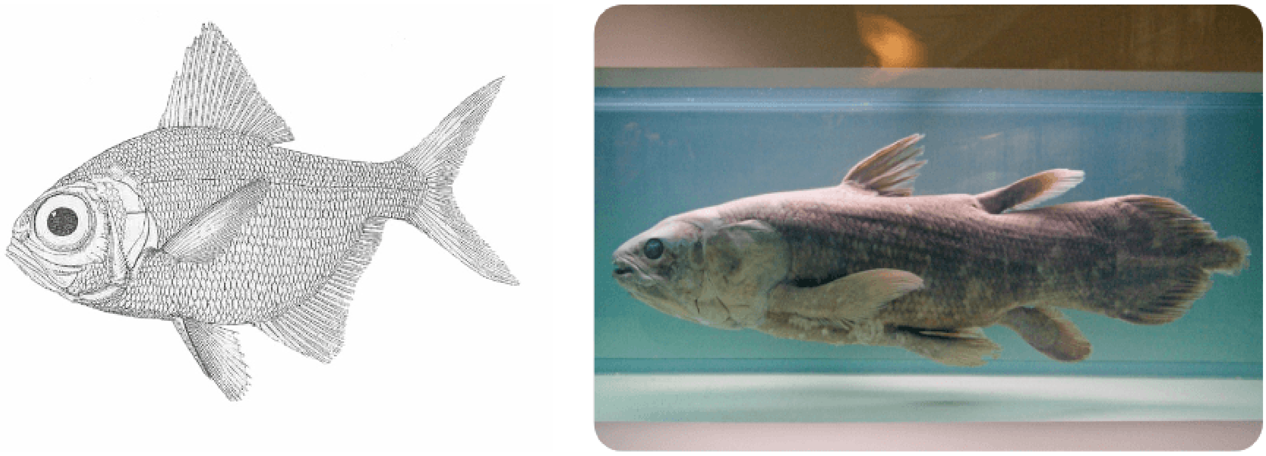
One of the most important traits of cartilaginous fish is their jaws. Jaws allow them to bite food and break it into smaller pieces. This is a big adaptive advantage because it greatly expands the range of food sources they can consume. Jaws also make cartilaginous fish excellent predators. It you've ever seen the film *Jaws,* then you know that jaws make sharks very fierce predators (see also **Figure** below).

[Figure 4]

Jaws of a Shark. Sharks have powerful jaws with multiple rows of sharp, saw-like teeth. Most other fish are no match for these powerful predators.

Ray-Finned Fish

Ray-finned fish include the majority of living fish species, including goldfish, tuna, salmon, perch, and cod. They have a bony endoskeleton and a swim bladder. Their thin fins consist of webs of skin over flexible bony rays, or spines. The fins lack muscle, so their movement are controlled by muscles in the body wall. You can compare their ray fins with the fleshy fins of lobe-finned fish in **Figure** below.



[Figure 5]

Fins of Bony Fish. The fins of ray-finned and lobe-finned fish are quite different. How is the form of the fins related to their different functions in the two classes of fish? Ray Fin (left), Lobe Fin (right)

Lobe-Finned Fish

Lobe-finned fish are currently far fewer in number than ray-finned fish. Their fins, like the one shown in **Figure** above, contain a stump-like appendage of bone and muscle. There are two groups of lobe-finned fish still alive today: coelacanth and lungfish.

1. **Coelacanths** are ancient fish with just two living species. They are at risk of extinction because of their very small numbers.
2. **Lungfish** have a lung-like organ for breathing air. The organ is an adaptation of the swim bladder. It allows them to survive for long periods out of water.

Science Friday: Oarfish: The Ultimate Fish Tale

Thought to the be inspiration of "sea serpent" stories, the monstrously-long Oarfish provokes wonder in nearly all that witness it. In this video by science Friday, Professor Misty Paig-Tran provides us with insights into this real-life "sea monster's" unusual physiology.

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Summary

- There are about 28,000 existing species of fish, and they are placed in five classes: hagfish, lampreys, cartilaginous fish, ray-finned bony fish, and lobe-finned bony fish.

Review

1. Assume that a new species of fish has been discovered deep in the ocean. It has a complete vertebral column made of cartilage. Which class should the new species be

placed in? Name one other trait you would expect to find in the new species of fish. Explain your answers.

2. Fish with jaws may be very large. Infer how their jaws may be related to their large body size.
3. The majority of living fish belong to what class?
4. Describe the lungfish.

12.9 Fish Evolution and Ecology

FlexBooks 2.0 > Biology For High School Diploma > Fish Evolution and Ecology

Last Modified: Mar 04, 2022

[Figure 1]

Are there actually ecosystems in the ocean?

There are. Different types of fish live in different types of ecosystem. Shown above are tropical fish in a coral reef ecosystem. Some fish are deep-ocean bottom dwellers, whereas others live in shallow waters. Other fish may not be able to survive in the ocean, as they need freshwater.

Evolution of Fish

The evolution of fish from hagfish to finned fish is a long and involved process. One step in this evolution involves the change in function of gill. invertebrate chordate use their **gills** to filter food out of water, not to absorb oxygen. In the early evolution of fish, there was a switch to using gills to absorb oxygen instead of to filter food. Gills consist of many thin, folded tissue that provide a large surface area for oxygen uptake. With more oxygen absorbed by the gills, fish could become much larger and more active.

[Figure 2]

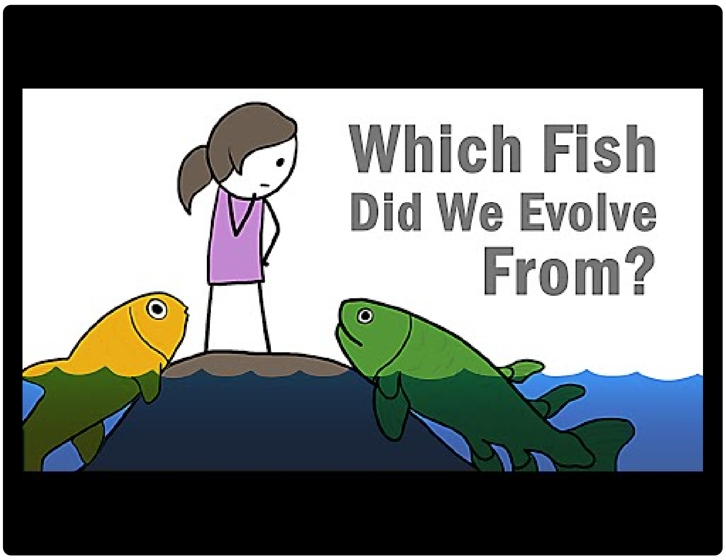
Fossilized fish shown in different sizes.

Timing of Fish Evolution

Ancestors of hagfish are thought to have been the earliest vertebrate. Their fossil date back to about 550 million years ago. Fossils of **cartilaginous fish** with jaws, resembling living sharks, first appeared in the fossil record about 450 million years ago. They were followed about 50 million years later by the bony fish.

The Bony Fish

At first, the **lobe-finned fish** were much more common than the **ray-finned fish** that dominate today. Lobe-finned fish were also ancestral to amphibian. Their stump-like appendage and lung-like organ evolved into amphibian legs and lung. Ray-finned fish may have been the first fish to evolve in freshwater. They eventually became the most diverse and dominant class of fish.



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Ecology of Fish

The habitat and diets of fish are varied. They live throughout the ocean and also in freshwater lakes, ponds, rivers, and streams. However, there is one fish, the Mudskipper, that spends time on land.

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Fish Food

Most fish are **predator**, but the nature of their prey and how they consume it differs from one class to another and even within classes.

- Hagfish are deep-ocean bottom dwellers. They feed on other fish, either living or dead. They enter the body of their prey through the mouth or anus. Then they literally eat their prey from the inside out.
- Lampreys generally live in shallow ocean water or freshwater. They either consume small invertebrates or suck blood from larger fish with their sucker mouth.
- Cartilaginous fish such as sharks may live on the bottom of the ocean. However, most live in the water column. They prey on other fish and aquatic mammal or else consume plankton.
- Bony fish may live in salt water or freshwater. They consume a wide range of foods. For example, they may eat alga, smaller fish, detritus, or dead organism, depending on the species of fish.

Fish at Risk

Today, more than 1,000 species of fish are at risk of extinction. This is mainly because of human actions. Specific causes include over-fishing and habitat destruction caused by water pollution, dam building, and the introduction of non-native species.

Summary

- The evolution of fish included a shift from using the gills for filtering food to using them to absorb oxygen from water.
- The earliest fish, resembling living hagfish, evolved about 550 million years ago.
- Adaptations that eventually evolved in fish include a complete vertebral column, jaws, and an endoskeleton made of bones instead of cartilage.
- Fish live throughout the ocean and in freshwater lakes and streams.
- Most fish are predators, but the nature of their prey and how they consume it may vary.
- Many species of fish are threatened by human actions, such as water pollution and overfishing.

Review

1. Which fish were the ancestors of amphibians?
2. Describe the eating habits of hagfish and lampreys.

Report Content Errors

12.10 Amphibian Structure and Function

FlexBooks 2.0 > Biology For High School Diploma > Amphibian Structure and Function

Last Modified: Feb 18, 2021

[Figure 1]

So how did vertebrates move from the water onto land?

There had to be some major modifications. Modifications in how the animal moves, how the animal breathes, and modifications in the animals skin.

Structure and Function in Amphibians

amphibian are vertebrate that exist in two worlds: they divide their time between freshwater and terrestrial habitat. They share a number of features with air-breathing lungfish, but they also differ from lungfish in many ways. One way they differ is their appendage. Modern amphibians include frog, salamander, and caecilian, as shown **Figure** below.

(a)
(b)
(c)

[Figure 2]

Examples of Living Amphibians. In what ways do these three amphibians appear to be similar? In what ways do they appear to be different?

Amphibians are the first true **tetrapod**, or vertebrates with four limbs. Amphibians have less variation in size than fish, ranging in length from 1 centimeter (0.39 inches) to 1.5 meters (about 5 feet). They generally have moist skin without scales. Their skin contains **keratin**, a tough, fibrous protein found in the skin, scales, feather, hair, and nails of tetrapod vertebrates, from amphibians to humans. Some forms of keratin are tougher than others. The form in amphibian skin is not very tough, and it allows gases and water to pass through their skin.

Amphibian Ectothermy

Amphibians are **ectothermic**, so their internal body temperature is generally about the same as the temperature of their environment. When it's cold outside, their body temperature drops, and they become very sluggish. When the outside temperature rises, so does their body temperature, and they are much more active. What do you think might be some of the pros and cons of **ectothermy** in amphibians?

Amphibian Organ Systems

All amphibians have digestive, excretory, and reproductive systems. All three systems share a body cavity called the **cloaca.** Wastes enter the cloaca from the digestive and excretory systems, and gamete enter the cloaca from the reproductive system. An opening in the cloaca allows the wastes and gametes to leave the body.

Amphibians have a relatively complex circulatory system with a three-chambered heart. Their nervous system is also rather complex, allowing them to interact with each other and their environment. Amphibians have sense organ to smell and taste chemicals. Other sense organs include eyes and ears. Of all amphibians, frogs generally have the best vision and hearing. Frogs also have a **larynx**, or voice box, to make sounds.

Most amphibians breathe with gill as larva and with lung as adults. Additional oxygen is absorbed through the skin in most species. The skin is kept moist by mucus, which is secreted by mucous glands. In some species, mucous glands also produce toxins, which help protect the amphibians from predator. The golden frog shown in **Figure** below is an example of a toxic amphibian.

[Figure 3]

Toxic Frog. This golden frog is only about 5 centimeters (2 inches) long, but it's the most poisonous vertebrate on Earth. One dose of its toxin can kill up to 20 humans!

Summary

- Amphibians are ectothermic vertebrates that divide their time between freshwater and terrestrial habitats.
- Amphibians are the first true tetrapods, or vertebrates with four limbs.

- Amphibians breathe with gills as larvae and with lungs as adults. They have a three-chambered heart and relatively complex nervous system.

Review

1. What is a tetrapod?
2. How does the temperature of the environment affect the level of activity of an amphibian?
3. What is the cloaca? What functions does it serve in amphibians?
4. Describe the different ways that amphibians may obtain oxygen.

Resources

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Report Content Errors

12.11 Amphibian Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Amphibian Reproduction

Last Modified: May 16, 2021

[Figure 1]

What changes must occur for these tadpoles to move onto land?

These are **tadpole**. Of course these tadpoles are born in the water. You can see the beginning of the formation of the hind limbs.

Amphibian Reproduction and Development

amphibian reproduce sexually with either external or internal fertilization. They attract mates in a variety of ways. For example, the loud croaking of frog is their mating call. Each frog species has its own distinctive call that other members of the species recognize as their own. Most salamander use their sense of smell to find a mate. The males produce a chemical odor that attracts females of the species.

Amphibian Eggs

Unlike other tetrapod vertebrate (reptile, bird, and mammals), amphibians do not produce amniotic egg. Therefore, they must lay their egg in water so they won't dry out. Their eggs are usually covered in a jelly-like substance, like the frog eggs shown in **Figure** below. The "jelly" helps keep the eggs moist and offers some protection from predator.

[Figure 2]

Frog Eggs. Frog eggs are surrounded by “jelly.” What is its function?

Amphibians generally lay large number of eggs. Often, many adults lay eggs in the same place at the same time. This helps to ensure that eggs will be fertilized and at least some of the embryo will survive. Once eggs have been laid, most amphibians are done with their parenting.

Amphibian Larvae

The majority of amphibian species go through a larval stage that is very different from the adult form, as you can see from the frog in **Figure** below. The early larval, or **tadpole**, stage resembles a fish. It lacks legs and has a long tail, which it uses to swim. The tadpole also has gill to absorb oxygen from water. As the larva undergoes **metamorphosis**, it grows legs, loses its tail, and develops lung. These changes prepare it for life on land as an adult frog.

[Figure 3]

Frog Development: From Tadpole to Adult. A frog larva (tadpole) goes through many changes by adulthood. Notice the visible changes that occur at each stage. How do these changes prepare it for life as an adult frog?

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Summary

- Amphibians reproduce sexually with either external or internal fertilization.

- Amphibians may attract mates with calls or scents.
- Amphibians do not produce amniotic eggs, so they must reproduce in water.
- Amphibian larvae go through metamorphosis to change into the adult form.

Review

1. Describe the life cycle of frogs.
2. Describe the parental involvement of most amphibians.
3. Define metamorphosis.

Report Content Errors

12.12 Amphibian Classification

FlexBooks 2.0 > Biology For High School Diploma > Amphibian Classification

Last Modified: Jun 13, 2022

[Figure 1]

Frog, toad, or salamander? What's the difference?

Look closely at the face of this **salamander**. It is strikingly similar to that of a frog or **toad**. As the first vertebrate to evolve from life in the sea to life on land, amphibian share a number of important evolutionary adaptation.

Classification of Amphibians

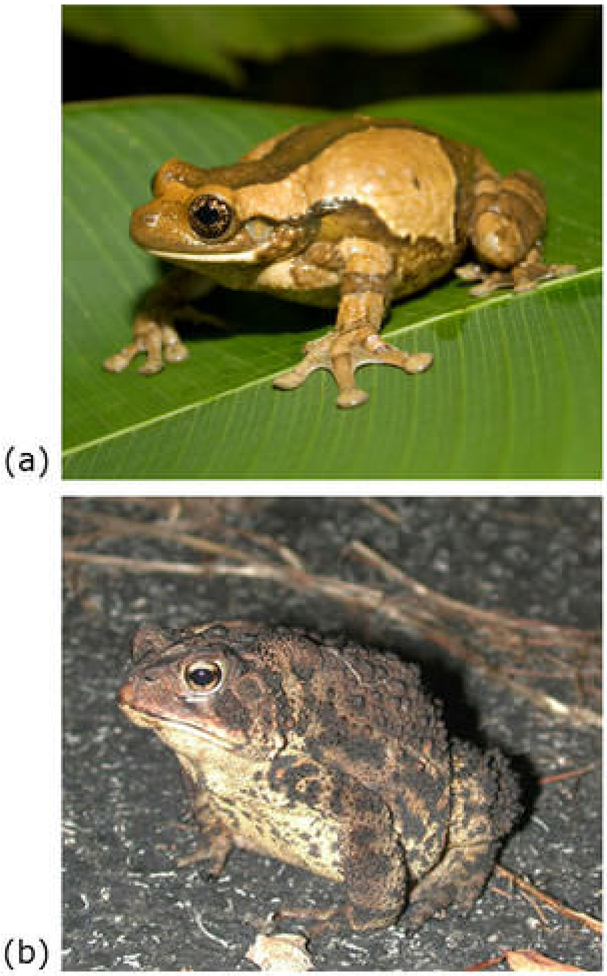
There are about 6,200 known species of living amphibians. They belong to the class Amphibia. There are three orders:

1. Urodela, containing salamanders and newts.
2. Anura, containing frogs and toads.
3. Apoda, containing caecilian.

Frogs and Toads

One feature that distinguishes **frogs** and **toads** from other amphibians is lack of a tail in adulthood. Frogs and toads also have much longer back legs than other amphibians. Their back legs are modified for jumping. Frogs can jump up to 20 times their own body length. That's the same as you jumping at least 100 feet, or more than the length of a basketball court. Think how fast you could move if you could travel that far on one jump!

Frogs and toads are closely related, but they differ in several ways. Generally, frogs spend more time in water, and toads spend more time on land. As you can see from **Figure** below, frogs also have smoother, moister skin than toads, as well as longer hind legs.



[Figure 2]

Frog and Toad. Frogs (a) and toads (b) are placed in the same amphibian order. What traits do they share?

Salamanders and Newts

Unlike frogs and toads, **salamanders** and **newts** keep their tails as adults (see **Figure** below). They also have a long body with short legs, and all their legs are about the same length. This is because they are adapted for walking and swimming rather than jumping. An unusual characteristic of salamanders is their ability to regenerate, or regrow, legs that have been lost to predator.

[Figure 3]

Salamander and Newt. Salamanders and newts can walk or swim. Salamander on a leaf (left), newt swimming in the water (right).

Caecilians

Caecilians are most closely related to salamanders. As you can see from **Figure** below, they have a long, worm-like body without legs. Caecilians evolved from a tetrapod ancestor, but they lost their legs during the course of their evolution.

[Figure 4]

Swimming Caecilian. Caecilians are the only amphibians without legs.

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Summary

- There are about 6,200 known species of living amphibians. They are classified into three orders: frogs and toads, salamanders and newts, and caecilians.
- Frogs and toads are adapted for jumping. Salamanders and newts may walk or swim. Caecilians live in the water or soil and are the only amphibians without legs.

Review

1. Distinguish frogs from toads.
2. What is an unusual characteristic of salamanders.
3. Compare and contrast the three orders of living amphibians.

Report Content Errors

12.13 Amphibian Evolution and Ecology

FlexBooks 2.0 > Biology For High School Diploma > Amphibian Evolution and Ecology

Last Modified: Jul 04, 2019

[Figure 1]

Why were amphibians so successful?

They might not have had many predator on land 365 million years ago. Given plenty of land and food, they had the resources to thrive. This is a frog fossil from the Eocene epoch. The vertebral column and four limbs are easily identifiable.

Evolution of Amphibians

Fossil evidence shows that amphibian evolved about 365 million years ago from a lobe-finned lungfish ancestor. As the earliest land vertebrate, they were highly successful. Some of them were much larger than today's amphibians. For more than 100 million years, amphibians remained the dominant land vertebrates. Then some of them evolved into reptile. Once reptiles appeared, with their amniotic egg, they replaced amphibians as the dominant land vertebrates.

Ecology of Amphibians

Amphibians can be found in freshwater and moist terrestrial habitat throughout the world. The only continent without amphibians is Antarctica. Amphibians are especially numerous in temperate lakes and ponds and in tropical rainforests.

Amphibians as Prey and Predators

Amphibians are an important food source for animal such as bird, snakes, raccoons, and fish. Amphibians are also important predators. As larva, they feed mainly on small aquatic animals such as water insects. They may also feed on alga. As adults, amphibians are completely **carnivorous**. They may catch and eat worms, snails, and insects, as the frog in **Figure** below is doing. Unlike other amphibians, caecilian are **burrower**. They use their head to dig in the soil, and they feed on earthworm and other annelids. Caecilians can be found in moist soil near rivers and streams in tropical regions.

[Figure 2]

Frog Predator. A frog eating its insect prey.

The Threat of Amphibian Extinction

Currently, almost one third of all amphibian species face the threat of extinction. The reasons include habitat loss, pollution, climate change, and the introduction of non-native species. Most of these problems are the result of human actions.

Amphibians have permeable skin that easily absorbs substances from the environment. This may explain why they seem to be especially sensitive to pollution. Monitoring the health and survival of amphibians may help people detect pollution early, before other organism are affected.

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Summary

- Amphibians evolved about 365 million years ago from a lobe-finned fish ancestor.
- As the earliest land vertebrates, amphibians were highly successful for more than 100 million years until reptiles took over as the dominant land vertebrates.
- Amphibians are found throughout the world except in Antarctica and Greenland.
- Amphibians are important prey for animals such as birds, snakes, and raccoons. They are important predators of insects, worms, and other invertebrates.
- Up to one third of all amphibian species are at risk of extinction because of human actions, such as habitat destruction, climate change, and pollution.

Review

1. Explain why amphibians were able to become the dominant land vertebrates for millions of years.
2. What was the ancestor of amphibians?
3. Why were amphibians replaced by reptiles as the dominant land vertebrate?

Report Content Errors

12.14 Reptile Structure and Function

FlexBooks 2.0 > Biology For High School Diploma > Reptile Structure and Function

Last Modified: Jul 04, 2019

[Figure 1]

Why did amphibians evolve into reptiles?

It probably has to do with food and land. Having to live close to water limits the resources available to a species. Having the ability to live away from water allowed **reptile** to search for additional food.

Structure and Function in Reptiles

Reptiles are a class of tetrapod vertebrate that produce amniotic egg. They include crocodiles, alligators, lizards, snakes, and turtles. The reptile class is one of the largest classes of vertebrates. It consists of all amniote except bird and mammal. Reptiles have several adaptation for living on dry land that amphibian lack. For example, as shown in **Figure** below, the skin of most reptiles is covered with scales. The scales, which are made of very tough **keratin**, protect reptiles from injury and prevent them from losing water.

[Figure 2]

Crocodile Scales. These crocodiles are covered with tough, waterproof scales.

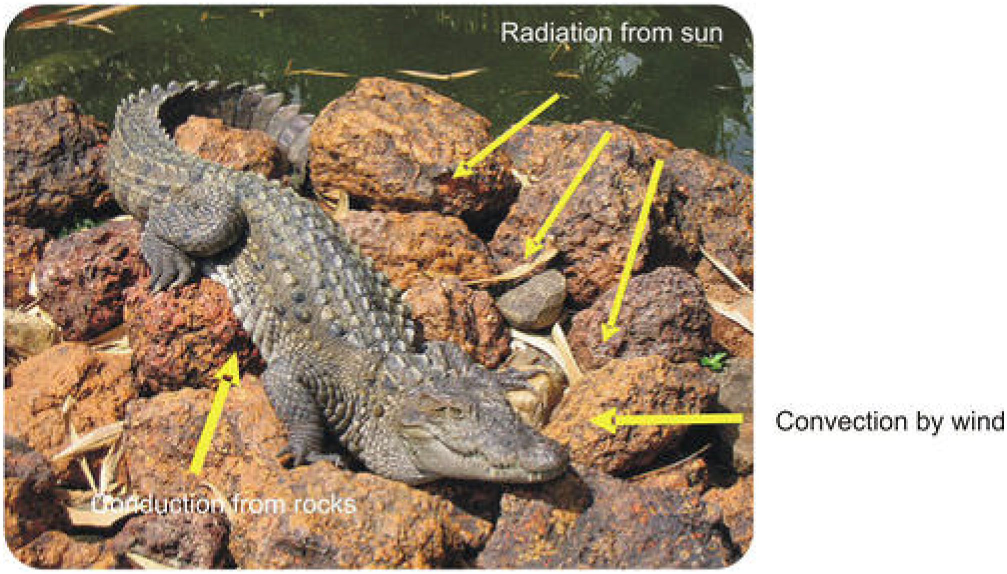
Reptile Respiration

The scales of reptiles prevent them from absorbing oxygen through their skin, as amphibians can. Instead, reptiles breathe air only through their lung. However, their lungs are more efficient than the lungs of amphibians, with more surface area for gas exchange. This is another important reptile adaptation for life on land.

Reptiles have various ways of moving air into and out of their lungs. Lizards and snakes use muscles of the chest wall for this purpose. These are the same muscles used for running, so lizards have to hold their breath when they run. Crocodiles and alligators have a large sheet of muscle below the lungs, called a **diaphragm,** that controls their breathing. This is a structure that is also found in mammals.

Ectothermy in Reptiles

Like amphibians, reptiles are **ectotherm** with a slow metabolic rate. Their metabolism doesn't generate enough energy to keep their body temperature stable. Instead, reptiles regulate their body temperature through their behavior. For example, the crocodile in **Figure** below is soaking up heat from the environment by basking in the sun. Because of their **ectothermy**, reptiles can get by with as little as one tenth the food needed by endotherms such as mammals. Some species of reptiles can go several weeks between meals.



[Figure 3]

Heat Transfer to an Ectothermic Reptile. This crocodile is being warmed by the environment in three ways. Heat is radiating directly from the sun to the animal's back. Heat is also being conducted to the animal from the rocks it rests on. In addition, convection currents are carrying warm air from surrounding rocks to the animal's body.

Other Reptile Structures

Like amphibians, most reptiles have a heart with three chambers, although crocodiles and alligators have a four-chambered heart like birds and mammals. The reptile brain is also similar in size to the amphibian brain, taking into account overall body size. However, the parts of the reptile brain that control the senses and learned behavior are larger than in amphibians.

Most reptiles have good eyesight and a keen sense of smell. Snakes smell scents in the air using their forked tongue (see **Figure** below). This helps them locate prey. Some snakes have heat-sensing organ on their head that help them find endothermic prey, such as small mammals and birds.

[Figure 4]

Snake "Smelling" the Air. A snake flicks its tongue in and out to capture scent molecules in the air.

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Summary

- Reptiles are a class of ectothermic, tetrapod vertebrates.
- Reptiles have several adaptations for living on dry land, such as tough keratin scales and efficient lungs for breathing air.

- Reptiles have a three-chambered heart and relatively well-developed brain.

Review

1. Describe reptile scales and the functions they serve.
2. What is a diaphragm? What does it do?
3. Describe two senses that snakes may use to locate prey.
4. Pretend you are a reptile such as a lizard. Explain how you might stay warm on a cold day.

Report Content Errors

12.15 Reptile Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Reptile Reproduction

Last Modified: May 16, 2021

[Figure 1]

What are the advantages of a water-tight egg?

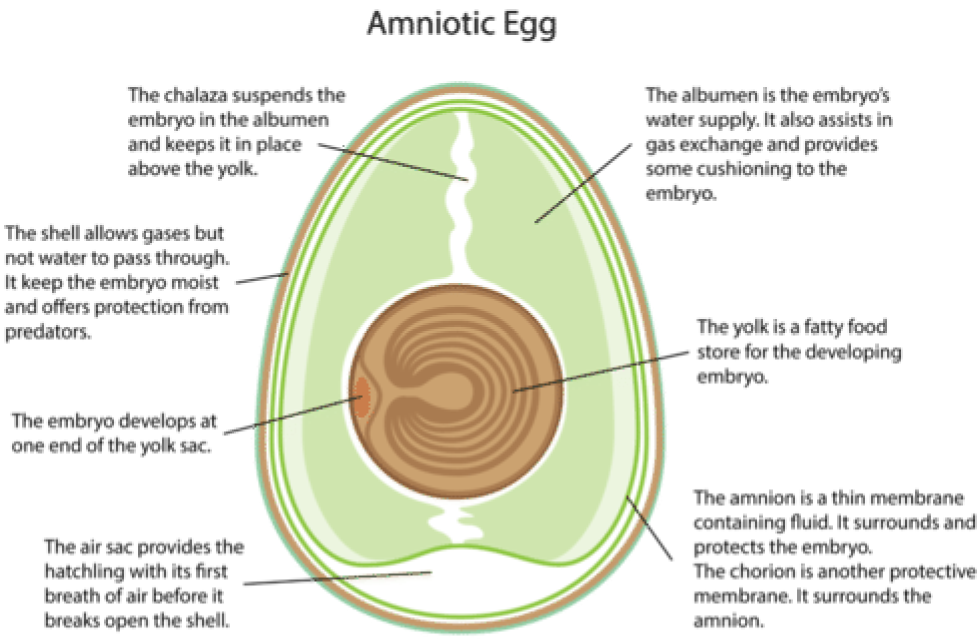
Obviously, water-tight egg can be laid anywhere. They do not have to be kept constantly moist. There is no danger of the developing fetus dehydrating. Shown above is a desert tortoise hatching.

Reptile Reproduction

Most reptile reproduce sexually and have **internal fertilization**. Males have one or two penises that pass sperm from their **cloaca** to the cloaca of a female. fertilization occurs within the cloaca, and fertilized eggs leave the female's body through the opening in the cloaca. In a minority of species, the eggs are retained inside the female's body until they hatch. Then the offspring leave the mother's body through the cloaca opening.

Amniotic Eggs

Unlike amphibian, reptiles produce **amniotic egg** (see **Figure** below). The shell, membranes, and other structures of an amniotic egg protect and nourish the embryo. They keep the embryo moist and safe while it grows and develops. They also provide it with a rich, fatty food source (the **yolk**).



[Figure 2]

The amniotic egg is an important adaptation in fully terrestrial vertebrates. It first evolved in reptiles. The shells of reptile eggs are either hard or leathery.

Reptile Young

Unlike amphibians, reptiles do not have a larval stage. Instead, newly hatched reptiles look like smaller versions of the adults. They are able to move about on their own, but they are vulnerable to predator. Even so, most reptile parents provide no care to their hatchling. In fact, most reptiles don't even take care of their eggs. For example, female sea turtles lay their eggs on a sandy beach and then return to the ocean. The only exceptions are female crocodiles and alligators. They may defend their nest from predators and help the hatchlings reach the water. If the young remain in the area, the mother may continue to protect them for up to a year.

Summary

- Most reptiles reproduce sexually and have internal fertilization.
- Reptile eggs are amniotic, so they can be laid on land instead of in water.
- Reptiles do not have a larval stage, and their hatchlings are relatively mature.
- Reptile parents provide little if any care to their young.

Review

1. Outline the structure and function of an amniotic egg.
2. Describe young reptiles.

Report Content Errors

12.16 Reptile Classification

FlexBooks 2.0 > Biology For High School Diploma > Reptile Classification

Last Modified: Dec 15, 2020

[Figure 1]

With so many possible colors, how would a chameleon be classified?

Chameleons are a distinctive and highly specialized type of lizard. They are distinguished partly by their parrot-like feet, their separately mobile and stereoscopic eyes, their very long, highly modified, and rapidly extrudable tongues, crests or horns on their distinctively shaped heads, and the ability of some to change color. But there are approximately 160 species of chameleons. So how are they classified?

Classification of Reptiles

There are more than 8,200 living species of reptile, with the majority being snakes or lizards. They are commonly placed in four different orders. The four orders are described in **Table** below.

Order	Characteristics	Example
Crocodilia: crocodiles, alligators, caimans, gharials	They have four sprawling legs that can be used to gallop; they replace their teeth throughout life; they have strong jaws and a powerful bite; they have a more advanced brain and greater intelligence than other reptiles; they have a four-chambered heart.	caiman  [Figure 2]
Sphenodontia: tuataras	They are the least specialized of all living reptiles; their brain is very similar to the amphibian brain; they have a three-chambered heart, but it is more primitive than the heart of other reptiles.	tuatara  [Figure 3]
Squamata: lizards, snakes	Lizards: most have four legs for running or climbing, and they can also swim; many change color when threatened; they have a three-chambered heart. Snakes: they do not have legs, although they evolved from a tetrapod ancestor; they have a very flexible jaw for swallowing large prey whole; some inject venom into their prey through fangs; they have a three-chambered heart.	lizard  [Figure 4]
Testudines: turtles, tortoises, terrapins	They have four legs for walking; they have a hard shell covering most of their body; they have a three-chambered heart.	terrapin  [Figure 5]

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Summary

- There are more than 8,200 living species of reptiles, and they are placed in four orders: Crocodilia, which includes crocodiles and alligators; Sphenodontia, or tuataras; Squamata, which includes lizards and snakes; and Testudines, such as turtles and tortoises.

Review

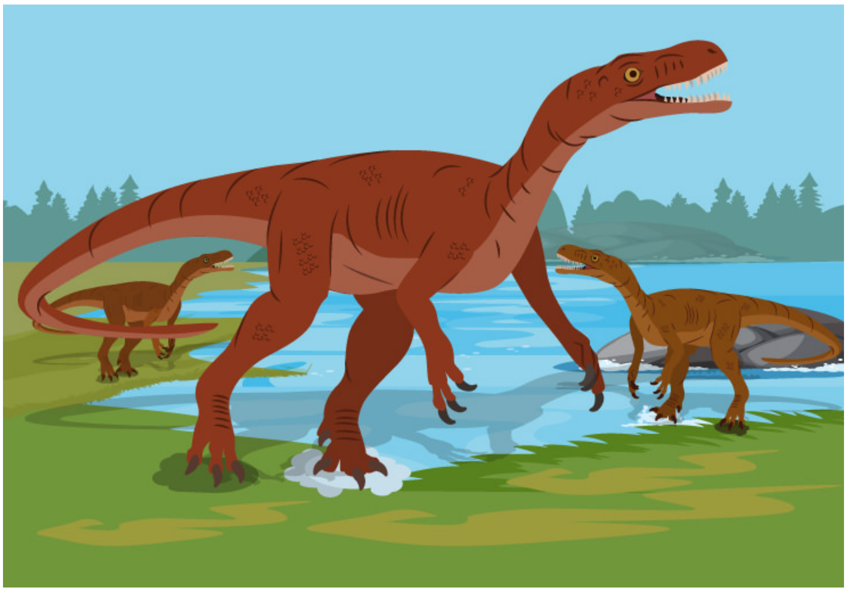
1. Compare and contrast crocodilians with other orders of reptiles.

Report Content Errors

12.17 Reptile Evolution

FlexBooks 2.0 > Biology For High School Diploma > Reptile Evolution

Last Modified: Jul 04, 2019



[Figure 1]

So what exactly is a dinosaur?

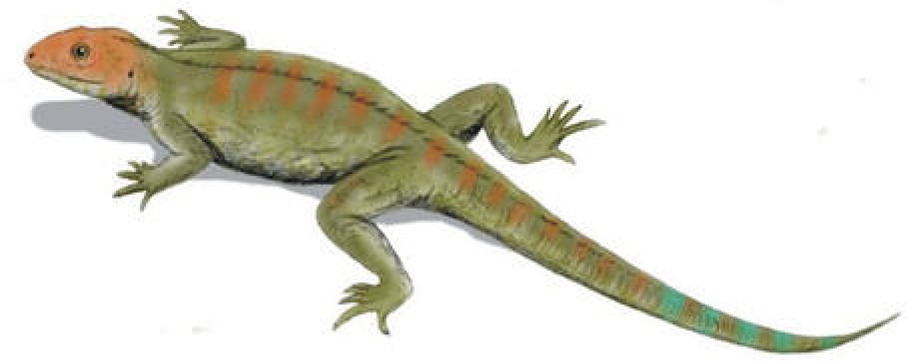
dinosaur were not lizards. Rather, they were a separate group of reptile with a distinct upright posture not found in lizards. Dinosaurs can be described as large, powerful reptiles. And many were very big. But dinosaurs were more than that. They were a varied group of animal with over 1,000 non-avian species.

Evolution of Reptiles

The earliest amniote evolved about 350 million years ago. They resembled small lizards, but they were not yet reptiles. Their amniotic egg allowed them to move away from bodies of water and become larger. They soon became the most important land vertebrate.

Synapsids and Sauropsids

By about 320 million years ago, early amniotes had diverged into two groups, called synapsids and **sauropsida**. **Synapsids** were amniotes that eventually gave rise to mammal. **Sauropsids** were amniotes that evolved into reptiles, dinosaurs, and bird. The two groups of amniotes differed in their skulls. The earliest known reptile, pictured in **Figure** below, dates back about 315 million years.



[Figure 2]

Earliest Reptile: *Hylonomus*. The earliest known reptile is given the genus name *Hylonomus*. It was about 20 to 30 centimeters (8 to 12 inches) long, lived in swamps, and ate insects and other small invertebrates.

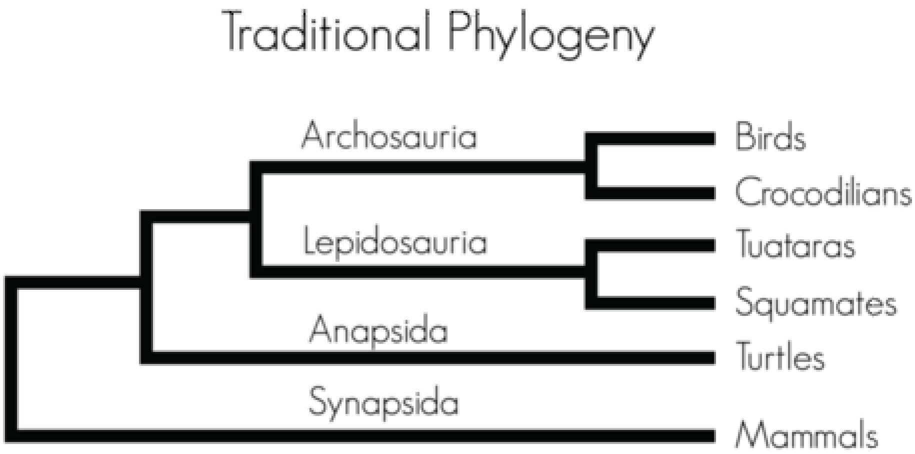
At first, synapsids were more successful than sauropsids. They became the most common vertebrates on land. However, during the Permian mass extinction 245 million years ago, most synapsids went extinct. Their niches were taken over by sauropsids, which had been relatively unimportant until then. This is called the **Triassic takeover**.

Rise and Fall of the Dinosaurs

By the middle of the Triassic about 225 million years ago, sauropsids had evolved into **dinosaurs**. Dinosaurs became increasingly important throughout the rest of the Mesozoic Era, as they radiated to fill most terrestrial niches. This is why the Mesozoic Era is called the **Age of the Dinosaurs.** During the next mass extinction, which occurred at the end of the Mesozoic Era, all of the dinosaurs went extinct. Many other reptiles survived, however, and they eventually gave rise to modern reptiles.

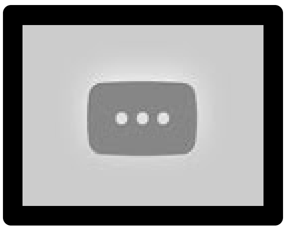
Evolution of Modern Reptile Orders

Figure below shows a traditional **phylogenetic tree** of living reptiles. Based on this tree, some of the earliest reptiles to diverge were ancestors of turtles. The first turtle-like reptiles are thought to have evolved about 250 million years ago. Ancestral crocodilians evolved at least 220 million years ago. Tuataras may have diverged from squamates (snakes and lizards) not long after that. Finally, lizards and snakes went their separate ways about 150 million years ago.



[Figure 3]

Traditional Reptile Phylogenetic Tree. This phylogenetic tree is based on physical traits of living and fossil reptiles. Trees based on DNA comparisons may differ from the traditional tree and from each other, depending on the DNA sequences used. Reptile evolution is currently an area of intense research and constant revision.



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Summary

- The earliest amniotes appeared about 350 million years ago, and the earliest reptiles evolved from a sauropsida ancestor by about 315 million years ago.
- Dinosaurs evolved around 225 million years ago and dominated animal life on land until 65 million years ago, when they all went extinct.
- Other reptiles survived and evolved into the classes of reptiles that exist today.

Review

1. Identify amniotes called synapsids and sauropsids.
2. Give a brief overview of reptile evolution.
3. Explain why reptiles were able to replace amphibians as the dominant land vertebrates.

Report Content Errors

12.18 Reptile Ecology

FlexBooks 2.0 > Biology For High School Diploma > Reptile Ecology

Last Modified: Jul 04, 2019

[Figure 1]

Where do reptiles live?

Anywhere and everywhere. Shown here is a sea turtle. Obviously, this reptile lives in the ocean. But reptiles can also live in the desert, jungle, forest, or even your backyard. Reptiles live in practically every type of habitat.

Ecology of Reptiles

Today, reptiles live in a wide range of habitats. They can be found on every continent except Antarctica. Many turtles live in the ocean, while others live in freshwater or on land. Lizards are all **terrestrial**, but their habitats may range from deserts to rainforests, and from underground burrows to the tops of trees. Most snakes are terrestrial and live in a wide range of habitats, but some snakes are **aquatic**. Crocodilians live in and around swamps or bodies of freshwater or salt water.

Reptile Diets

What reptiles eat is also very diverse, but the majority of reptiles are **carnivore**. Large reptiles such as crocodilians are the top predator in their ecosystem, preying on bird, fish, deer, turtles, and sometimes domestic livestock. Their powerful jaws can crush bone and even turtle shells. Smaller reptiles—including tuataras, snakes, and many lizards—are also important predators, preying on insects, frog, birds, and small mammal such as mice.

Most terrestrial turtles are **herbivore**. They graze on grasses, leaves, flower, and fruit. Marine turtles and some species of lizards are **omnivore**, feeding on plants as well as insects, worms, amphibian, and small fish.

Reptiles at Risk

Many species of reptiles, especially marine reptiles, are at risk of extinction. Some are threatened by habitat loss. For example, many beaches where turtles lay their egg have been taken over and developed by people. Other marine reptiles have been over-hunted by humans. Marine turtles and their eggs are still eaten in some countries despite being protected species.

Some reptiles are preyed upon by non-native species introduced by humans. For example, marine iguanas on the Galápagos Islands are threatened by dogs and cats that people have brought to the islands. The iguanas are slow and tame and have no adaptation to these new predators.

Summary

- Reptiles can be found on every continent except Antarctica.
- Reptiles may live in terrestrial, freshwater, or marine habitats.
- Most reptiles are carnivores, and large reptiles are the top predators in their ecosystems.
- Many species of reptiles, especially marine reptiles, are at risk of extinction.

Review

1. Describe the habitats of most lizards.
2. What do reptiles eat? Describe the diet of a crocodilian.
3. Why are some reptiles at risk?

Explore More

Use this resource to answer the questions that follow.

https://flexbooks.ck12.org/flx/render/embeddedobject/138746

1. What makes a good meal for giant anaconda?
2. How do anaconda sense their prey?
3. Describe how anaconda hunt and kill their prey.
4. Why is a good meal important for anaconda?
5. How long may a pregnant female anaconda go between meals?
6. How long might it take an anaconda to ingest and digest a large meal?

Report Content Errors

12.19 Bird Structure and Function

FlexBooks 2.0 > Biology For High School Diploma > Bird Structure and Function

Last Modified: Jul 04, 2019

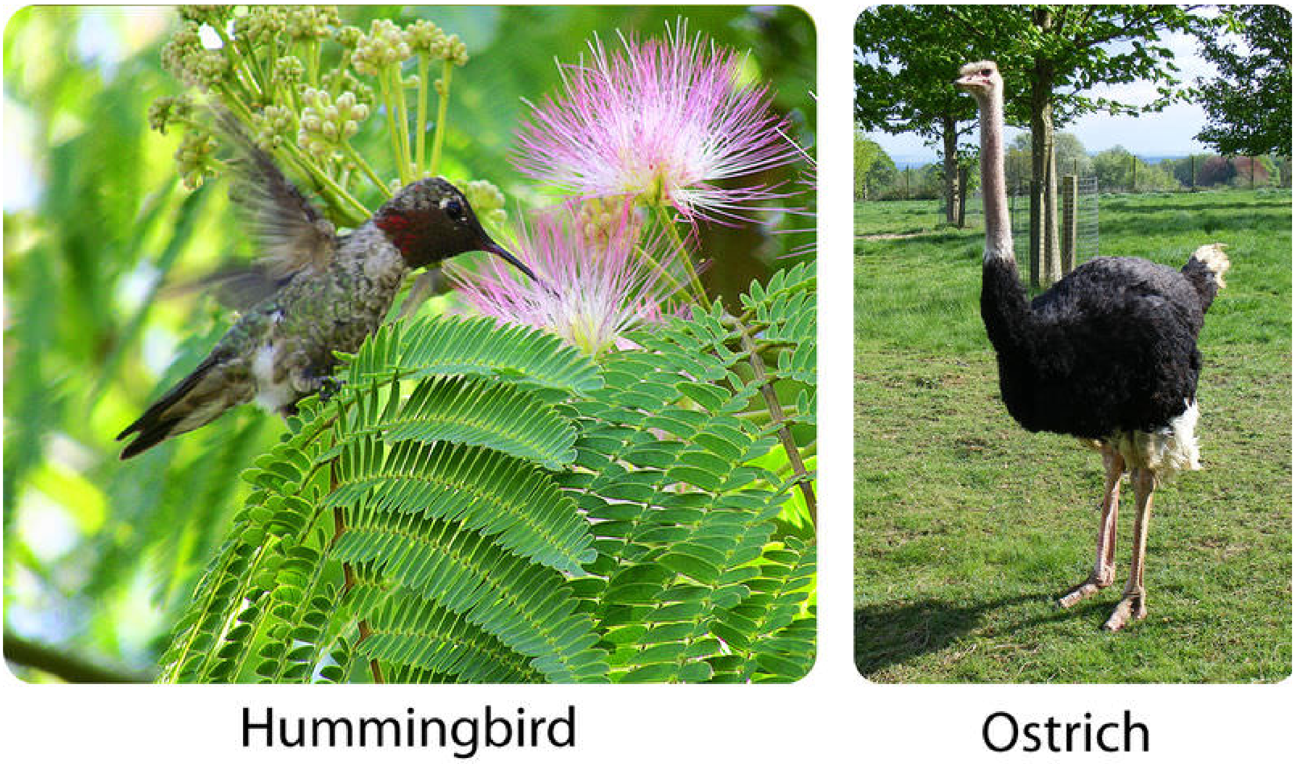
[Figure 1]

Why is flight so important to birds?

One of the defining traits of many **bird** is the ability to fly. Obviously, flight is a major evolutionary advantage. But together with the ability to fly must come a number of structural modifications. What do you think these might be?

Structure and Function in Birds

Birds are endothermic tetrapod vertebrate. They are bipedal, which means they walk on two legs. Birds also lay amniotic egg with hard, calcium carbonate shells. Although birds are the most recent class of vertebrates to evolve, they are now the most numerous vertebrates on Earth. Why have birds been so successful? What traits allowed them to increase and diversify so rapidly? Birds can vary considerably in size, as you can see from the world's smallest and largest birds, pictured in **Figure** below. The tiny bee hummingbird is just 5 centimeters (2 inches) long, whereas the ostrich towers over people at a height of 2.7 meters (9 feet). All modern birds have **wing**, feather, and beak. They have a number of other unique traits as well, most of which are adaptation for flight. **Flight** is used by birds as a means of locomotion in order to find food and mates and to avoid predator. Although not all modern birds can fly, they all evolved from ancestors that could.



[Figure 2]

Range of Body Size in Birds. The bee hummingbird is the smallest bird. The ostrich is the largest.

Wings and Feathers

Wings are an obvious adaptation for flight. They are actually modified front legs. Birds move their wings using muscles in the chest. These muscles are quite large, making up as much as 35 percent of a bird's body weight.

Feathers help birds fly and also provide insulation and serve other purposes. Birds actually have two basic types of feathers: flight feather and down feather. Both are shown in **Figure** below. **Flight feathers** are long, stiff and waterproof. They provide lift and air resistance without adding weight. **Down feathers** are short and fluffy. They trap air next to a bird's skin for insulation.

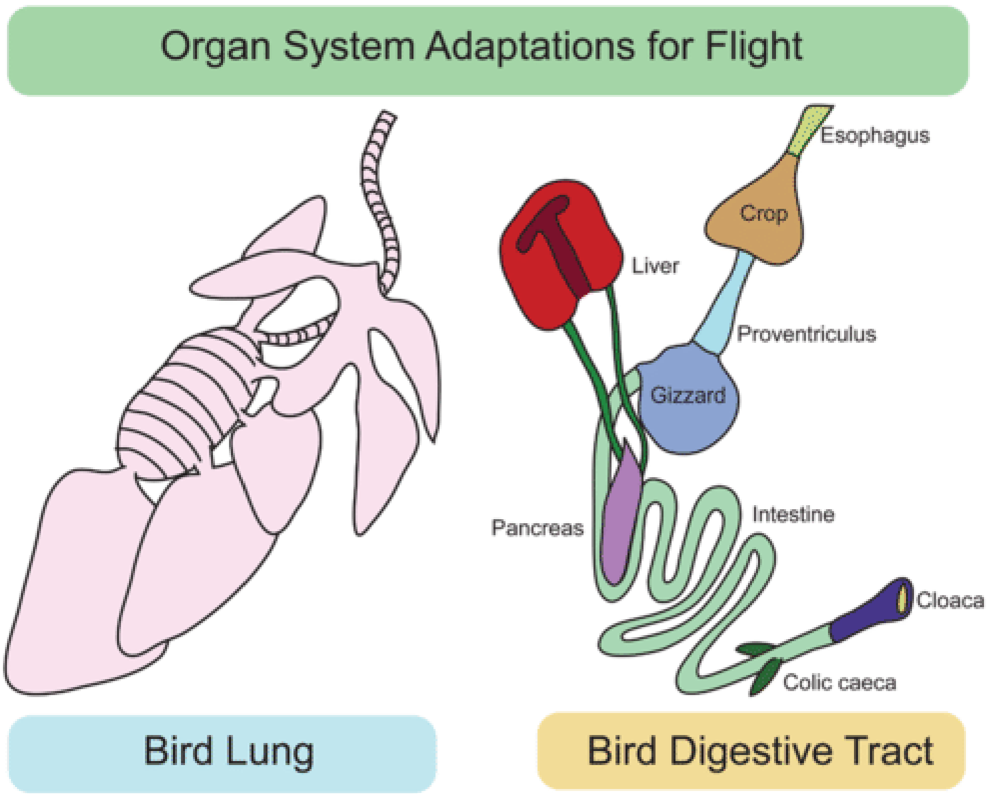
[Figure 3]

Types of Bird Feathers. These two types of bird feathers have different uses. How is each feather's structure related to its function?

Organ Systems Adapted for Flight

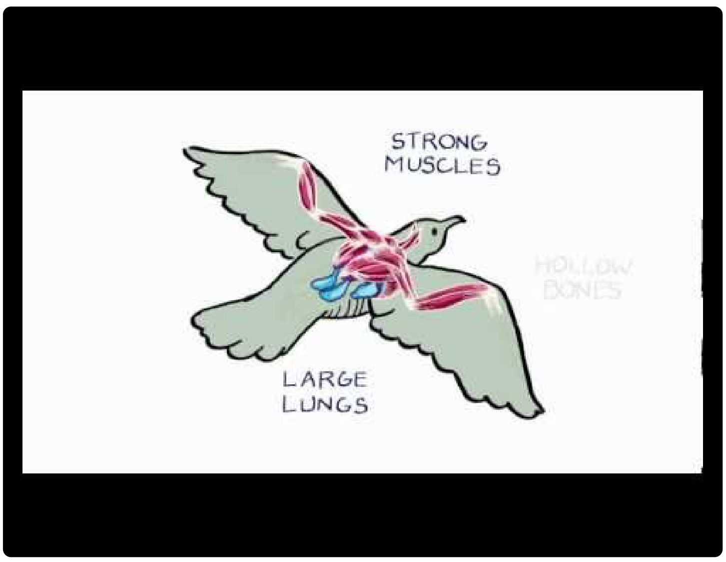
Birds need a light-weight body in order to stay aloft. Even so, flying is hard work, and flight muscles need a constant supply of oxygen- and nutrient-rich blood. The organ system of birds are adapted to meet these needs.

- Birds have light-weight bone that are filled with air. They also lack a jaw, which in many vertebrates is a dense, heavy bone with many teeth. Instead, birds have a light-weight keratin **beak** without teeth.
- Birds have **air sac** that store inhaled air and push it into the lung like bellows. This keeps the lungs constantly filled with oxygenated air. The lungs also contain millions of tiny passages that create a very large surface area for gas exchange with the blood (see **Figure** below).
- Birds have a relatively large, four-chambered heart. The heart beats rapidly to keep oxygenated blood flowing to muscles and other tissue. Hummingbirds have the fastest heart rate at up to 1,200 beats per minute. That's almost 20 times faster than the human resting heart rate!
- Birds have a sac-like structure called a **crop** to store and moisten food that is waiting to be digested. They also have an organ called a **gizzard** that contains swallowed stones. The stones make up for the lack of teeth by grinding food, which can then be digested more quickly. Both structures make it easier for the digestive system to produce a steady supply of nutrient from food.



[Figure 4]

Organ System Adaptations for Flight. The intricate passageways in a bird's lung are adapted for efficient gas exchange. Find the crop and gizzard in the digestive tract diagram. What are their functions? Bird Lung (left), Bird Digestive Tract (right)



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Nervous System and Sense Organs

Birds have a large brain relative to the size of their body. Not surprisingly, the part of the brain that controls flight is the most developed part. The large brain size of birds is also reflected by their high level of intelligence and complex behavior. In fact, birds such as crows and ravens may be more intelligent than many mammal. They are smart enough to use objects such as twigs for tools. They also demonstrate planning and cooperation. Most birds have a poor sense of smell, but they make up for it with their excellent sense of sight. Predatory birds have especially good eyesight. Hawks, for example, have vision that is eight times sharper than human vision.

Summary

- Birds are endothermic tetrapod vertebrates. They are bipedal and have wings and feathers.
- Bird organ systems are adapted for flight. For example, they have light-weight air-filled bones and a large four-chambered heart.
- Birds also have relatively large brains and a high level of intelligence.

Review

1. Why do birds fly?
2. List two functions of feathers in birds.
3. Describe the bird crop and gizzard. What are their functions?
4. How do birds keep their lungs filled with oxygenated air?
5. Give an example of bird behavior that shows their relatively great intelligence.

Report Content Errors

12.20 Bird Reproduction

FlexBooks 2.0 > Biology For High School Diploma > Bird Reproduction

Last Modified: Jul 20, 2020

[Figure 1]

Is this pair of birds actually a "couple"?

Yes. bird do actually pair up each mating season, if not for life. And the male better be prepared to treat his female properly. There is actually an elaborate process in which the female chooses her mate.

Bird Reproduction

reproduction in birds may be quite complicated and lengthy. Birds reproduce sexually and have separate sexes and internal fertilization, so males and females must mate for fertilization to occur. Mating is generally preceded by **courtship**. In most species, parents also take care of their egg and hatchling.

Courtship and Mating

Courtship is behavior that is intended to attract a mate. It may involve singing specific courtship songs or putting on some type of visual display. For example, a bird may spread out and display its tail feather or do a ritualized mating "dance." Typically, males perform the courtship behavior, and females choose a mate from among competing males.

During mating, a male bird presses his **cloaca** against his mate's cloaca and passes sperm from his cloaca to hers. After fertilization, eggs pass out of the female's body, exiting through the opening in the cloaca.

Nesting and Incubation

Eggs are usually laid in a nest. The nest may be little more than a small depression in the ground, or it may be very elaborate, like the weaver bird nest in **Figure** below. Eggs that are laid on the ground may be camouflaged to look like their surroundings (also shown in **Figure** below). Otherwise, eggs are usually white or pastel colors such as pale blue or pink.

[Figure 2]

Variation in Bird Nests. A weaver bird uses grasses to weave an elaborate nest (left). The eggs of a ground-nesting gull are camouflaged to blend in with the nesting materials (right).

After birds lay their eggs, they generally keep the eggs warm with their body heat while the embryo inside continue to develop. This is called **incubation,** or **brooding**. In most species, parents stay together for at least the length of the breeding season. In some species, they stay together for life. By staying together, the males as well as females can incubate the eggs and later care for the **hatchlings**. Birds are the only nonhuman vertebrate with this level of male parental involvement.

Hatchlings

[Figure 3]

Nest of a marsh warbler (*Acrocephalus palustris*) with baby birds

Ground-nesting birds, such as ducks and chickens, have hatchlings that are able to run around and feed themselves almost as soon as they break through the eggshell. Being on the ground makes them vulnerable to predator, so they need to be relatively mature when they hatch in order to escape. In contrast, birds that nest off the ground—in trees, bushes, or buildings—have hatchlings that are naked and helpless. The parents must protect and feed the immature offspring for weeks or even months. However, this gives the offspring more time to learn from the parents before they leave the nest and go out on their own.

Parental Care

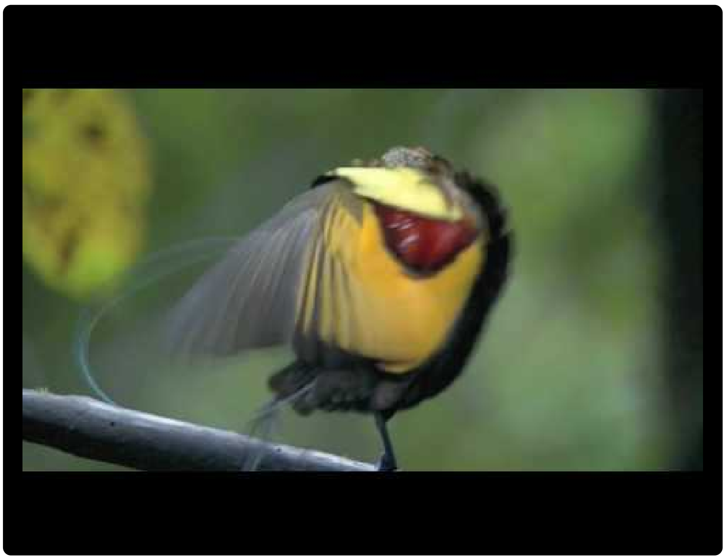
In birds, 90% to 95% of species are **monogamous**, meaning the male and female remain together for breeding for a few years or until one mate dies. Birds of all types, from parrot to eagles and falcons, are monogamous. Usually, the parents take turns incubating the eggs. Birds usually incubate their eggs after the last one has been laid. In **polygamous** species, where there is more than one mate, one parent does all of the incubating. The wild turkey is an example of a polygamous bird.

The length and type of parental care varies widely amongst different species of birds. At one extreme, in a group of birds called the megapodes (which are chicken-like birds), parental care ends at hatching. In this case, the newly-hatched chick digs itself out of the nest mound without parental help and can take care of itself right away. These birds are called **precocial**. Other precocial birds include the domestic chicken and many species of ducks and geese. At the other extreme, many seabirds care for their young for extended periods of time. For example, the chicks of the Great Frigatebird receive intensive parental care for six months, or until they are ready to fly, and then take an additional 14 months of being fed by the parents (**Figure** below). These birds are the opposite of precocial birds and are called **altricial**.

In most animal, male parental care is rare. But it is very common in birds. Often both parents share tasks such as defense of territory and nest site, incubation, and the feeding of chicks. Since birds often take great care of their young, some birds have evolved a behavior called **brood parasitism.** This happens when a bird leaves her eggs in another bird's nest. The host bird often accepts and raises the parasite bird's eggs.

[Figure 4]

Great Frigatebird adults are known to care for their young for up to 20 months after hatching, the longest in a bird species. Here, a young bird is begging for food.



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Summary

- Birds reproduce sexually and have internal fertilization.
- Mating is generally preceded by courtship.
- Birds' amniotic eggs have hard shells and are laid in a nest. The eggs are usually incubated until they hatch.
- Most species have a relatively long period of parental care.

Review

1. What is courtship? Give an example.
2. Contrast hatchling maturity in birds that are ground-nesting and those that nest off the ground.

Report Content Errors

12.21 Bird Classification

FlexBooks 2.0 > Biology For High School Diploma > Bird Classification

Last Modified: Mar 28, 2022

[Figure 1]

Raptor vs. landfowl. Any obvious differences?

Of course there are. That is like comparing a turkey to an owl. And there are also flightless bird, birds that live near water, and **parrot**. With almost 10,000 species of birds, there are bound to be significant differences.

Classification of Birds

There are about 10,000 living species of birds. Almost all of them can fly, but there are several exceptions.

Flightless Birds

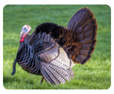
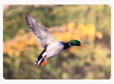
Some birds have lost the ability to fly during the course of their evolution. Several flightless birds are shown in **Figure** below. They include the ostrich, kiwi, rhea, cassowary, and moa. All of these birds have long legs and are adapted for running. The penguins shown in the figure are also flightless birds, but they have a very different body shape. That's because they are adapted for swimming rather than running.

[Figure 2]

Flightless Birds. Flightless birds that are adapted for running include the ostrich, kiwi, rhea, cassowary, and moa. Penguins are flightless birds adapted for swimming.

Flying Birds

Birds that are able to fly are divided into 29 orders that differ in their physical traits and behaviors. **Table** below describes seven of the most common orders. As shown in the table, the majority of flying birds are **perching bird**, like the honeyeater described in the last row of the table. The order of perching birds has more species than all the other bird orders combined. In fact, this order of birds is the largest single order of land vertebrate.

Order (common name)	Description	Example
landfowl: turkeys, chickens, pheasants	They are large in size; they spend most of their time on the ground; they usually have a thick neck and short, rounded wing; their flight tends to be brief and close to the ground.	turkey  [Figure 3]
waterfowl: ducks, geese, swans	They are large in size; they spend most of their time on the water surface; they have webbed feet and are good swimmers; most are strong flyers.	ducks  [Figure 4]
shorebird: puffins, gulls, plovers	They range from small to large; most live near the water, and some are sea birds; they have webbed feet and are good swimmers; most are strong flyers.	puffin  [Figure 5]
diurnal raptor: hawks, falcons, eagles	They range from small to large; they are active during the day and sleep during the night; they have a sharp, hooked beak and strong legs with clawed feet; they hunt by sight and have excellent vision.	hawk  [Figure 6]
nocturnal raptor: burrowing owls, barn owls, horned owls	They range from small to large; they are active during the night and sleep during the day; they have a sharp, hooked beak and strong legs with clawed feet; they have large, forward-facing eyes; they have excellent hearing and can hunt with their sense of hearing alone.	burrowing owl  [Figure 7]
Parrots: cockatoos, parrots, parakeets	They range from small to large; they are found in tropical regions; they have a strong, curved bill; they stand upright on strong legs with clawed feet; many are brightly colored; they are very intelligent.	cockatoo  [Figure 8]
Perching Birds: honeyeaters,	They are small in size; they perch above the ground in trees and on buildings and wires; they have four toes for grasping a perch; many are songbirds.	honeyeater

sparrows, crows		 [Figure 9]

Summary

- There are about 10,000 living species of birds, almost all of which can fly.
- Flying birds are divided into 29 orders. The most common orders include landfowl, waterfowl, shorebirds, diurnal and nocturnal raptors, parrots, and perching birds.

Review

1. Name and describe flightless birds.
2. Compare and contrast nocturnal and diurnal raptors.
3. Give examples of landfowl and waterfowl.
4. Describe parrots.

Report Content Errors

12.22 Bird Evolution

FlexBooks 2.0 > Biology For High School Diploma > Bird Evolution

Last Modified: Jul 04, 2019

[Figure 1]

Did birds really evolve from dinosaurs?

One is an ostrich, the other is a mononykus dinosaur. The structural relationship is obvious. Mononykus moved about on two legs, was very nimble, and could run at high speeds, something that would have been useful in the open desert plains where they lived. It had a small skull, and its teeth were small and pointed, suggesting that it ate insects and small animal, such as lizards and mammal.

Evolution of Birds

bird are thought to have evolved from a group of bipedal dinosaurs called **theropod**. The ancestor of birds was probably similar to the theropod called *Deinonychus,* which is represented by the sketch in **Figure** below. fossil of *Deinonychus* were first identified in the 1960s. This was an extremely important discovery. It finally convinced most scientists that birds had descended from dinosaurs, which had been debated for almost a century.

[Figure 2]

Extinct Bird Relative: Deinonychus. Deinonychus shared many traits with birds. What similarities with birds to you see?

What was *Deinonychus*?

Deinonychus is the genus name of an extinct dinosaur that is considered to be one of the closest non-bird relatives of modern birds. It lived about 110 million years ago in what is now North America. *Deinonychus* was a predatory carnivore with many bird-like features. For example, it had feather and wing. It also had strong legs with clawed feet, similar to modern raptor. Its respiratory, circulatory, and digestive systems were similar to those of birds as well. The location of fossilized egg near *Deinonychus* fossils suggests that it may have brooded its eggs. This would mean that it was **endothermic**. (Can you explain why?) On the other hand, *Deinonychus* retained a number of reptile-like traits, such as jaws with teeth, and hands with claws at the tips of its wings.

Evolution of Flight

Scientists have long speculated about the evolution of flight in birds. They wonder how and why birds evolved wings from a pair of front limbs. Several hypothesis have been suggested. Here are just two:

1. Wings evolved in a bird ancestor that leapt into the air to avoid predator or to capture prey. Therefore, wings are modified arms that helped the animal leap higher.
2. Wings evolved in a bird ancestor that lived in trees. Thus, wings are modified arms that helped the animal glide from branch to branch.

Scientists still don't know how or why wings and flight evolved, but they continue to search for answers. In addition to fossils, they are studying living vertebrate such as bats that also evolved adaptation for flight.

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Summary

- Birds are thought to have evolved from theropod dinosaurs around 150 million years ago.
- Bird ancestors may have been similar to the extinct theropod *Deinonychus*, whose fossils convinced most scientists that birds evolved from dinosaurs.
- Scientists still don't know how or why wings and flight evolved, but they continue to search for answers.

Review

1. What was the bird ancestor?
2. What was *Deinonychus*? What bird-like traits were evident in *Deinonychus*?
3. What are the two ideas associated with the evolution of flight?

Report Content Errors

12.23 Bird Ecology

FlexBooks 2.0 > Biology For High School Diploma > Bird Ecology

Last Modified: Jul 04, 2019

[Figure 1]

Where do birds live?

Practically anywhere they want. From some of the coldest regions on the planet to the warmest. Look at these penguins and where they live. Would you want to live there?

Ecology of Birds

bird live and breed in most terrestrial habitat on all seven continents, from the Arctic to Antarctica. Because they are endothermic, birds can live in a wider range of climates than reptile or amphibian, although the greatest diversity of birds occurs in tropical regions. Birds are important members of every ecosystem in which they live, occupying a wide range of ecological positions.

Bird Diets

Some birds are **generalist**. A **generalist** is an organism that can eat many different types of food. Other birds are highly specialized in their food needs and can eat just one type of food.

raptor such as hawks and owls are carnivore. They hunt and eat mammal and other birds. Vultures are **scavenger**. They eat the remains of dead animal, such as roadkill. Aquatic birds generally eat fish or water plants. perching bird may eat insects, fruit, honey, or nectar. Many fruit-eating birds play a key role in seed dispersal, and some nectar-feeding birds are important **pollinator**.

Bird beak are generally adapted for the food they eat. For example, the sharp, hooked beak of a raptor is well suited for killing and tearing apart prey. The long beak of the hummingbird in **Figure** below co-evolved with the tube-shaped flower from which it sips nectar.

[Figure 2]

Hummingbird Sipping Nectar. A hummingbird gets nectar from flowers and pollinates the flowers in return. What type of relationship exists between the bird and the flowering plant?

Birds at Risk

Hundreds of species of birds have gone extinct as a result of human actions. A well-known example is the passenger pigeon. It was once the most common bird in North America, but overhunting and habitat destruction led to its extinction in the 1800s. Habitat destruction and use of the pesticide DDT explain the recent extinction of the dusky seaside sparrow. This native Florida bird was declared extinct in 1990.

Today, some 1,200 species of birds are threatened with extinction by human actions. Humans need to take steps to protect this precious and important natural resource. What can you do to help?

The Golden Eagle

Although not as famous as its bald cousin, Golden Eagles are much easier to find in Northern California - one of the largest breeding population for Golden Eagles. The largest of the raptors, Golden Eagles weigh typically between 8 and 12 pounds, and their wing span is around 6 to 7 feet. These eagles dive towards earth to catch prey, and can reach speeds of up to 200 mph!

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The Great Horned Owl

Owls are amazing creatures. They have many adaptation that allow them to thrive in their environments. Their claws are enormous and powerful, they have excellent hearing, and fantastic vision in low light. And the Great Horned Owl can fly almost silently due to "fringes" on their feather that help to break up the sound of air passing over their wings.

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Summary

- Birds live and breed in most terrestrial habitats on all seven continents. They occupy a wide range of ecological positions.
- Raptors are carnivores; aquatic birds eat fish or water plants; and perching birds may eat insects, fruit, honey, or nectar.
- Some birds are pollinators that co-evolved with plants.
- Human actions have caused the extinction of hundreds of species of birds, and some 1,200 species are threatened with extinction today.

Review

1. What is a generalist?

2. Why did the hummingbird pictured sipping nectar above evolve such a long, pointed beak?
3. What bird would eat insects, fruit, honey, or nectar?
4. Draw a sketch of a hypothetical bird that preys on small mammals. The bird must exhibit traits that suit it for its predatory role.

Report Content Errors

12.24 Mammal Overview

FlexBooks 2.0 > Biology For High School Diploma > Mammal Overview

Last Modified: May 21, 2021

[Figure 1]

One of these is not a mammal. Which one?

mammal are a class of endothermic vertebrate. They have four limbs and produce amniotic egg. Examples of mammals include bats, whales, mice, and humans. Clearly, mammals are a very diverse group. Nonetheless, they share many traits that set them apart from other vertebrates.

Characteristics of Mammals

Two characteristics are used to define the **mammal** class. They are **mammary gland** and body hair (or fur).

1. Female mammals have **mammary glands**. The glands produce milk after the birth of offspring. Milk is a nutritious fluid. It contains disease-fighting molecules as well as all the nutrient a baby mammal needs. Producing milk for offspring is called **lactation**.
2. Mammals have hair or fur. It insulates the body to help conserve body heat. It can also be used for sensing and communicating. For example, cats use their whiskers to sense their surroundings. They also raise their fur to look larger and more threatening (see **Figure** below).

[Figure 2]

Cat Communicating a Warning. By raising its fur, this cat is “saying” that it’s big and dangerous. This might discourage a predator from attacking.

Most mammals share several other traits. The traits in the following list are typical of, but not necessarily unique to, mammals.

- The skin of many mammals is covered with sweat gland. The glands produce sweat, the salty fluid that helps cool the body.
- Mammalian lung have millions of tiny air sac called **alveolus**. They provide a very large surface area for gas exchange.
- The heart of a mammal consists of four chambers. This makes it more efficient and powerful for delivering oxygenated blood to tissue.
- The brain of a mammal is relatively large and has a covering called the **neocortex**. This structure plays an important role in many complex brain functions.
- The mammalian middle ear has three tiny bone that carry sound vibrations from the outer to inner ear. The bones give mammals exceptionally good hearing. In other vertebrates, the three bones are part of the jaw and not involved in hearing.
- Mammals have four different types of teeth. The teeth of other vertebrates, in contrast, are all alike.

[Figure 3]

Dolphins are mammals that have adapted to swimming and reproducing in water.

Summary

- Mammals are a class of endothermic vertebrates.
- Mammals have four limbs and produce amniotic eggs.
- The mammal class is defined by the presence of mammary glands and hair (or fur).
- Other traits of mammals include sweat glands in their skin, alveoli in their lungs, a four-chambered heart, and a brain covering called the neocortex.

Review

1. List five traits that are shared by all mammals, including the two traits that are used to define the mammal class.

Report Content Errors

12.25 Mammal Structure and Function

FlexBooks 2.0 > Biology For High School Diploma > Mammal Structure and Function

Last Modified: Jul 04, 2019

[Figure 1]

Does this mammal breathe like all other mammals?

Essentially, yes it does. A whale is a mammal, so it has a pair of lung, not gill like fish. As shown here, whales take oxygen out of the air, not out of water.

Eating and Digesting Food

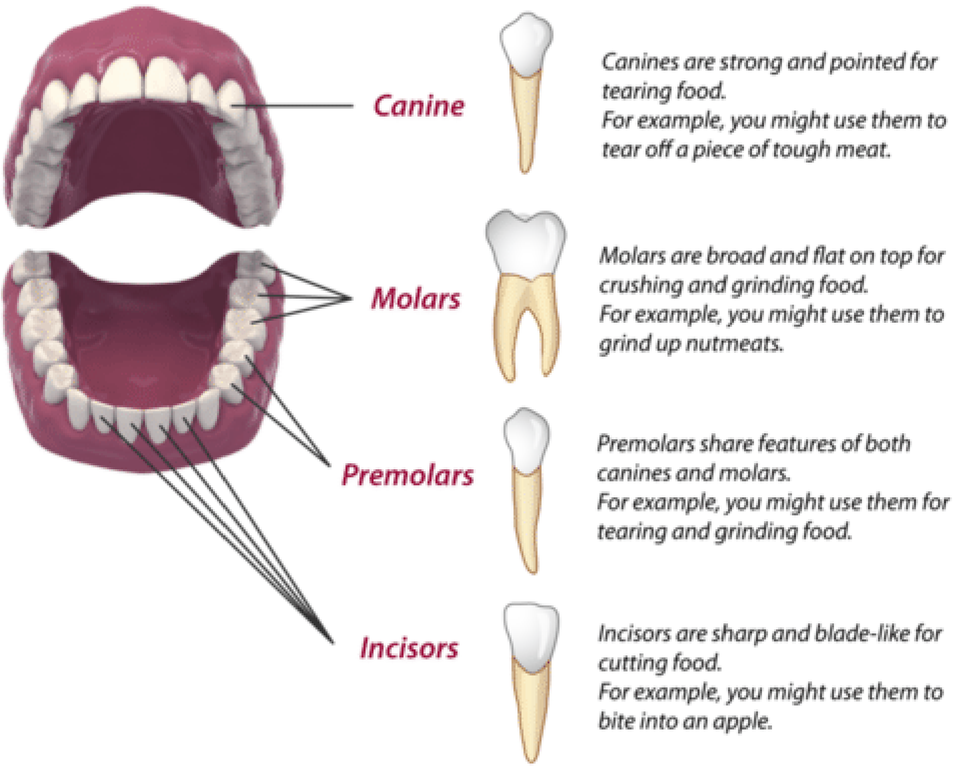
Maintaining a high metabolic rate takes a lot of energy. The energy must come from food. Therefore, mammals need a nutritious and plentiful diet. The diets of mammals are diverse. Except for leaf litter and wood, almost any kind of organic matter may be eaten by mammals.

Some mammals are strictly **herbivore** or strictly **carnivore**. However, most mammals will eat other foods if necessary. Some mammals are **omnivore**. They routinely eat a variety of both plant and animal foods. Most mammals also feed on a variety of other species. The few exceptions include koalas, which feed only on eucalyptus plants, and giant pandas, which feed only on bamboo. Types of mammalian diets and examples of mammals that eat them are given in **Table** below. How would you classify your own diet?

Type of Diet	Foods Eaten	Examples of Mammals with this Type of Diet
herbivorous diet: plants	leaves, grasses, shoots, stem, roots, tubers, seed, nuts, fruit, bark, conifer needle, flower	rabbit, mouse, sea cow, horse, goat, elephant, zebra, giraffe, deer, elk, hippopotamus, kangaroo, monkey  [Figure 2]
carnivorous diet: animals	other mammals, bird, reptile, amphibian, fish, mollusks, worms, insects	aardvark, anteater, whale, hyena, dog, jackal, dolphin, wolf, weasel, seal, walrus, cat, otter, mole  [Figure 3]
omnivorous diet: plants and animals	any of the foods eaten in herbivorous and carnivorous diets	bear, badger, mongoose, fox, raccoon, human, rat, chimpanzee, pig  [Figure 4]

Different diets require different types of digestive systems. Mammals that eat a carnivorous diet generally have a relatively simple digestive system. Their food consists mainly of protein and fats that are easily and quickly digested. Herbivorous mammals, on the other hand, tend to have a more complicated digestive system. Complex plant carbohydrate such as cellulose are more difficult to digest. Some herbivores have more than one stomach. The stomachs store and slowly digest plant foods.

Mammalian teeth are also important for digestion. Mammals have four different types of teeth. The teeth of other vertebrate, in contrast, are all alike. The four types of teeth are specialized for different feeding functions, as shown in **Figure** below. Together, the four types of teeth can cut, tear, and grind food. This makes food easier and quicker to digest.



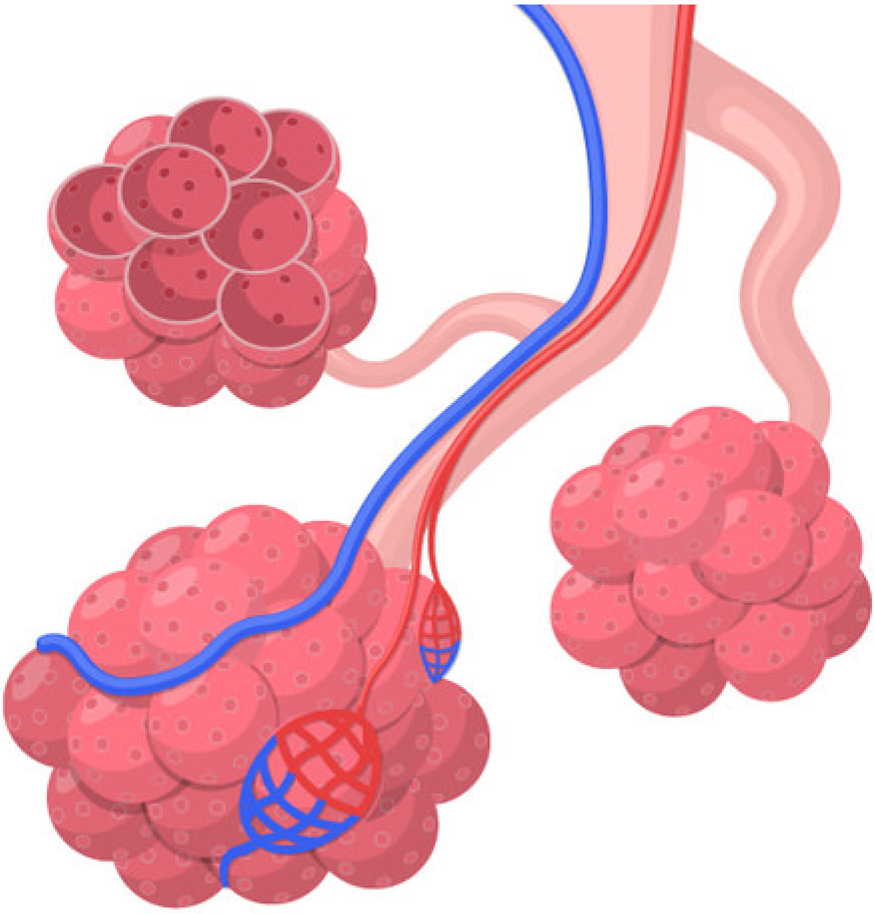
[Figure 5]

Mammalian Teeth (Human). With their different types of teeth, mammals can eat a wide range of foods.

Lungs and Heart of Mammals

Keeping the rate of metabolism high takes a constant and plentiful supply of oxygen. That's because **cellular respiration**, which produces energy, requires oxygen. The lungs and heart of mammals are adapted to meet their oxygen needs.

The lungs of mammals are unique in having **alveolus**. These are tiny, sac-like structures. Each alveolus is surrounded by a network of very small blood vessel (see **Figure** below). Because there are millions of alveoli in each lung, they greatly increase the surface area for gas exchange between the lungs and bloodstream. Human lungs, for example, contain about 300 million alveoli. They give the lungs a total surface area for gas exchange of up to 90 square meters (968 square feet). That's about as much surface area as one side of a volleyball court!



[Figure 6]

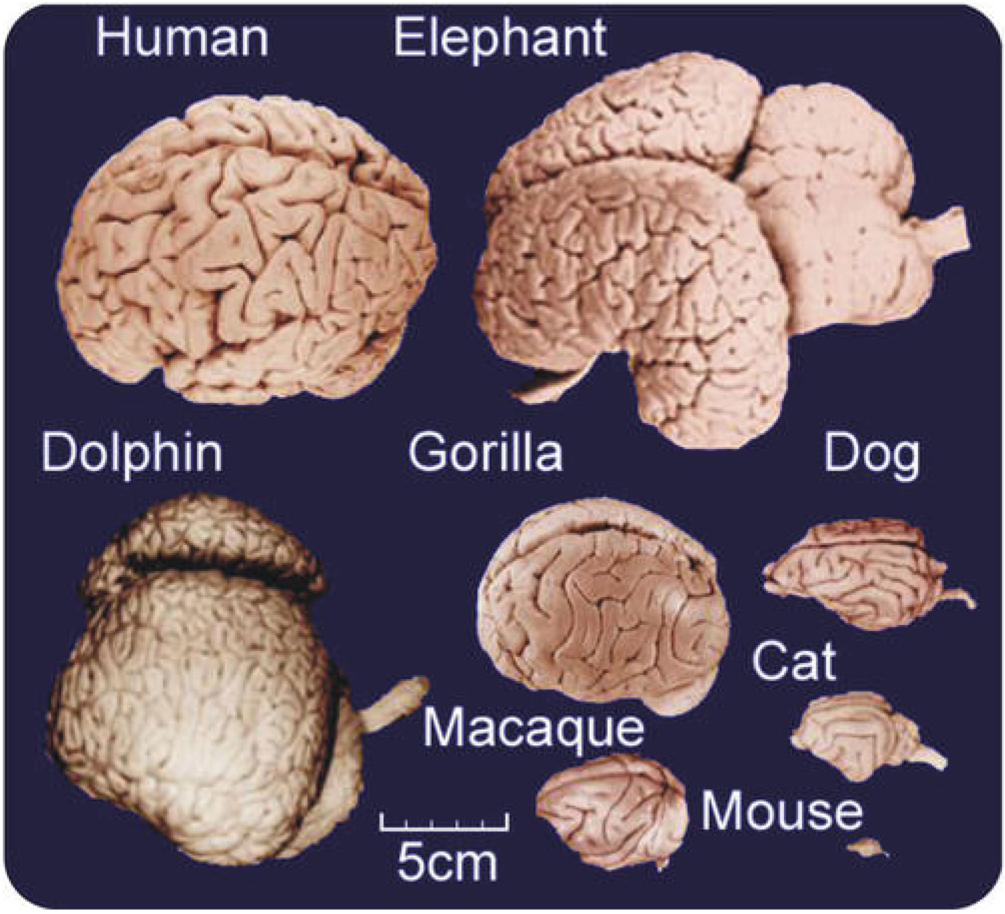
Alveoli of Mammalian Lungs. Clusters of alveoli resemble tiny bunches of grapes. They are surrounded by many blood vessels for gas exchange.

Mammals breathe with the help of a **diaphragm**. This is the large muscle that extends across the bottom of the chest below the lungs. When the diaphragm contracts, it increases the volume of the chest. This decreases pressure on the lungs and allows air to flow in. When the diaphragm relaxes, it decreases the volume of the chest. This increases pressure on the lungs and forces air out.

The four-chambered mammalian heart can pump blood in two different directions. The right side of the heart pumps blood to the lungs to pick up oxygen. The left side of the heart pumps blood containing oxygen to the rest of the body. Because of the dual pumping action of the heart, all of the blood going to body cell is rich in oxygen.

The Mammalian Brain

Of all vertebrates, mammals have the biggest and most complex brain for their body size (see **Figure** below). The front part of the brain, called the **cerebrum**, is especially large in mammals. This part of the brain controls functions such as memory and learning.



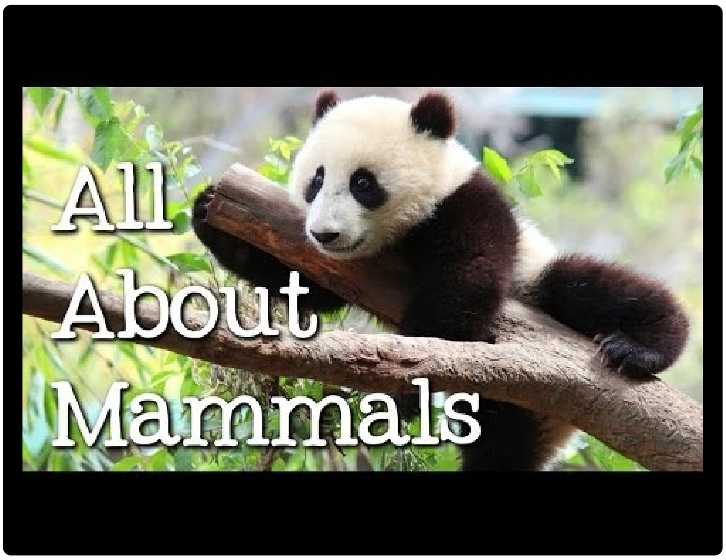
[Figure 7]

Vertebrate Brains. Vertebrate brains come in a range of sizes. Even the brains of mammals show a lot of variation in size. The area of the neocortex is greatest in humans.

The brains of all mammals have a unique layer of nerve cells covering the cerebrum. This layer is called the **neocortex** (the pink region of the brains in **Figure** above). The neocortex plays an important role in many complex brain functions. In some mammals, such as rats, the neocortex is relatively smooth. In other mammals, especially humans, the neocortex has many folds. The folds increase the surface area of the neocortex. The larger this area is, the greater the mental abilities of an animal.

Intelligence of Mammals

Mammals are very intelligent. Of all vertebrates, they are the animals that are most capable of learning. Mammalian offspring are fed and taken care of by their parents for a relatively long time. This gives them plenty of time to learn from their parents. By learning, they can benefit from the experiences of their elders. The ability to learn is the main reason that the large mammalian brain evolved. It's also the primary reason for the success of mammals.



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Summary

- Mammals may be herbivores, carnivores, or omnivores. They have four types of teeth, so they can eat a wide range of foods.
- Traits of the heart and lungs keep the cells of mammals well supplied with oxygen and nutrients.
- Mammals have a relatively large brain and a high level of intelligence.

Review

1. Identify three mammals that are herbivores, three that are carnivores, and three that are omnivores.
2. What are alveoli? What is their function?
3. Explain how mammalian teeth differ from the teeth of other vertebrates.
4. Compare and contrast the mammalian brain with the brains of other vertebrates. How is the brain of mammals related to their ability to learn?

Report Content Errors

12.26 Endothermy

FlexBooks 2.0 > Biology For High School Diploma > Endothermy

Last Modified: Jul 04, 2019

[Figure 1]

Is this bear cold?

Not really. Like all mammal, polar bears maintain a stable internal temperature. They do not need to stay warm by lying in the sun. This allows them to live in cold climates.

Endothermy in Mammals

Many structures and functions in mammals are related to **endothermy**. Mammals can generate and conserve heat when it's cold outside. They can also lose heat when they become overheated. How do mammals control their body temperature in these ways?

How Mammals Stay Warm

Mammals generate heat mainly by keeping their metabolic rate high. The cell of mammals have many more **mitochondrion** than the cells of other animal. The extra mitochondria generate enough energy to keep the rate of metabolism high. Mammals can also generate little bursts of heat by **shivering**. **Shivering** occurs when many muscles contract a little bit all at once. Each muscle that contracts produces a small amount of heat.

Conserving heat is also important, especially in small mammals. A small body has a relatively large surface area compared to its overall size. Because heat is lost from the surface of the body, small mammals lose a greater proportion of their body heat than large mammals. Mammals conserve body heat with their hair or fur. It traps a layer of warm air next to the skin. Most mammals can make their hair stand up from the skin, so it becomes an even better insulator. Even humans automatically contract these muscles when they are cold, causing **goosebump** (see **Figure** below). Mammals also have a layer of fat under the skin to help insulate the body. This fatty layer is not found in other vertebrate.

[Figure 2]

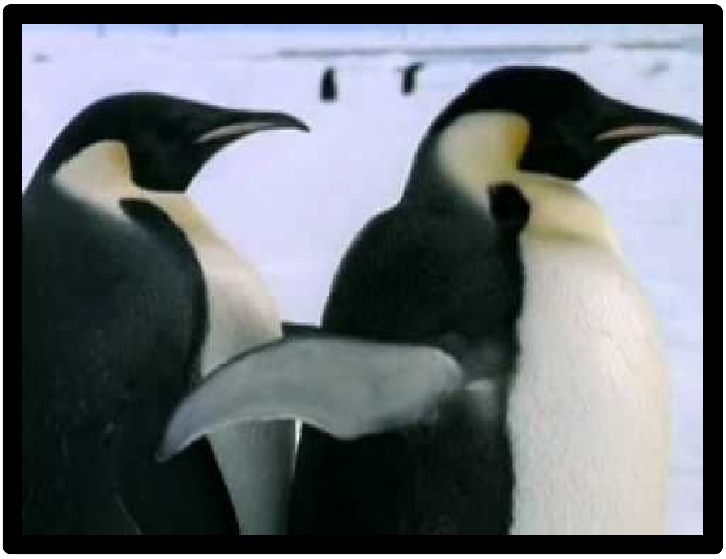
Mammals raise their hair with tiny muscles in the skin. Even humans automatically contract these muscles when they are cold. They cause "goosebumps," as shown here.

How Mammals Stay Cool

One way mammals lose excess heat is by increasing blood flow to the skin. This warms the skin so heat can be given off to the environment. That's why you may get flushed, or red in the face, when you exercise on a hot day. You are likely to sweat as well. Sweating also reduces body heat. Sweat wets the skin, and when it evaporates, it cools the body. evaporation uses energy, and the energy comes from body heat. Animals with fur, such as dogs, use **panting** instead of sweating to lose body heat (see **Figure** below). Evaporation of water from the tongue and other moist surfaces of the mouth and throat uses heat and helps cool the body.

[Figure 3]

Panting Dog. This dog is overheated. It is losing excess body heat by panting.



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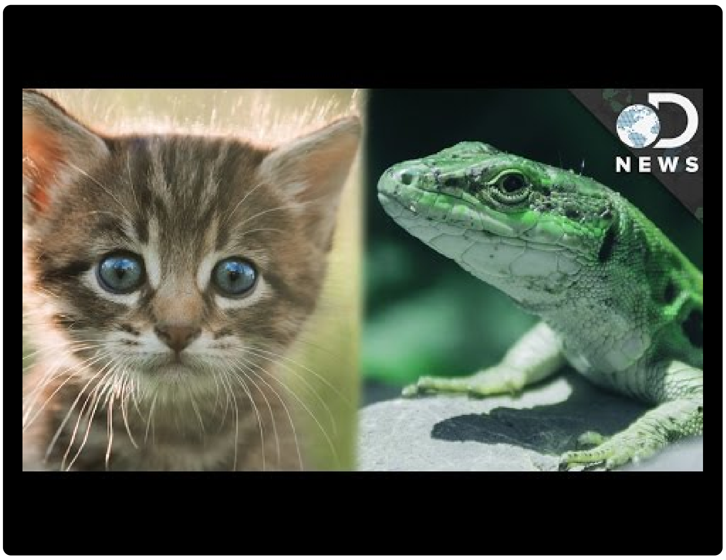
Summary

- Mammals have several ways of generating and conserving heat, such as a high metabolic rate and hair to trap heat.
- Mammals also have several ways to stay cool, including sweating or panting.

Review

1. Describe how mammals stay warm and conserve heat?
2. What is the function of sweating? Explain your answer.
3. How do animals with fur lose excess heat?

Resources



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Report Content Errors

12.27 Locomotion

FlexBooks 2.0 > Biology For High School Diploma > Locomotion

Last Modified: Mar 28, 2022

[Figure 1]

What allows this cheetah to be so fast?

Do you think it has something to do with the placement of the limbs? Well, it does. Look closely at the cheetah's body. Can you describe why it is so fast?

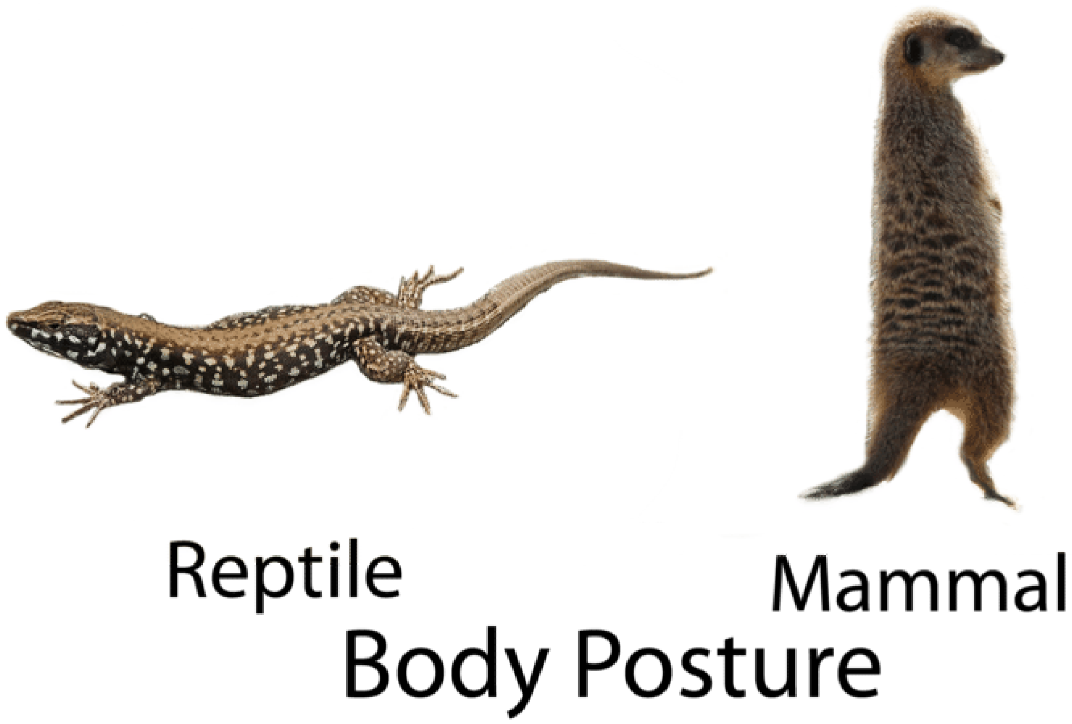
Social Living in Mammals

Many mammal live in social groups. Social living evolved because it is adaptive. Consider these two examples:

1. herbivore such as zebras and elephants live in **herd**. Adults in the herd surround and protect the young, who are most vulnerable to predator.
2. Lions live in social groups called **pride**. Adult females in the pride hunt cooperatively, which is more efficient than hunting alone. Then they share the food with the rest of the pride. For their part, adult males defend the pride's territory from other predators.

Locomotion in Mammals

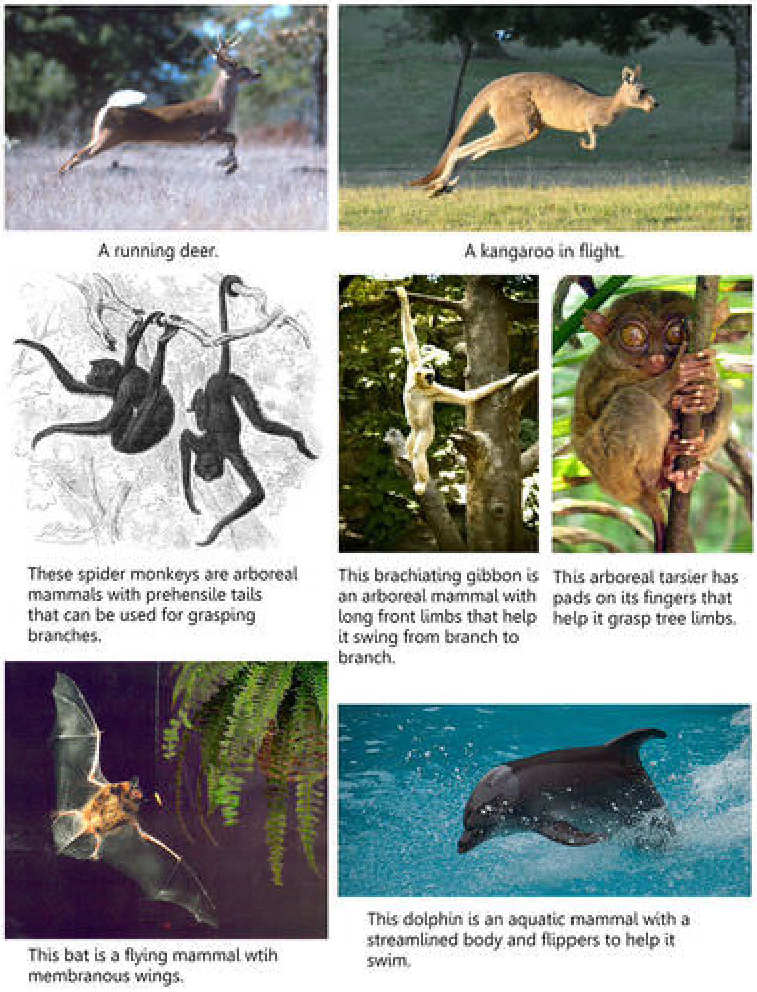
Mammals are noted for the many ways they can move about. Generally, their limbs are very mobile. Often, they can be rotated. Many mammals are also known for their speed. The fastest land animal is a predatory mammal. Can you guess what it is? Racing at speeds of up to 112 kilometers (70 miles) per hour, the cheetah wins hands down. In addition, the limbs of mammals let them hold their body up above the ground. That's because the limbs are attached beneath the body, rather than at the sides as in reptile (see **Figure** below).



[Figure 2]

Limb Positions in Reptiles and Mammals. The sprawling limbs of a reptile keep it low to the ground. A mammal has a more upright stance.

Mammals may have limbs that are specialized for a particular way of moving. They may be specialized for running, jumping, climbing, flying, or swimming. Mammals with these different modes of **locomotion** are pictured in **Figure** below.



[Figure 3]

Mammalian Locomotion. Mammals have many different modes of locomotion.

The deer in the **Figure** above is specialized for running. Why? It has long legs and hard hooves. Can you see why the other animals in the figure are specialized for their particular habitat? Notice how **arboreal**, or tree-living animals, have a variety of different specializations for moving in trees. For example, they may have:

- A **prehensile tail** (or grasping tail). This is used for climbing and hanging from branches.
- Very long arms for swinging from branch to branch. This way of moving is called **brachiation**.
- Sticky pads on their fingers. The pads help them cling to tree trunks and branches.

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Summary

- Mammals live in social groups, which are an adaptive beneficial trait.
- Mammals have many ways of moving about and may move very quickly.

Review

1. Name five types of movement found in mammals?
2. A certain mammal has very long forelimbs. What does that suggest about where the animal lives and how it moves?
3. What type of movement is found in the above question.
4. What is the purpose of a prehensile tail?

Report Content Errors

12.28 Placental Mammals

FlexBooks 2.0 > Biology For High School Diploma > Placental Mammals

Last Modified: Jul 04, 2019

[Figure 1]

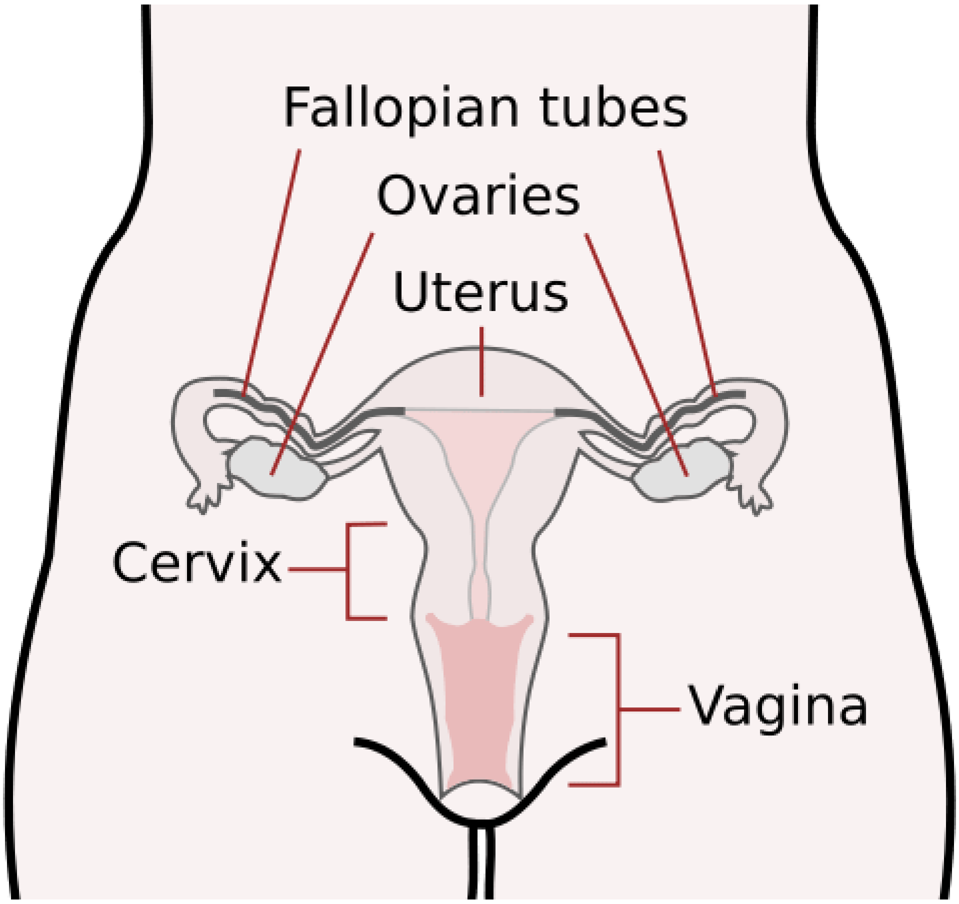
Is this kangaroo a placental mammal?

You know that female kangaroos have a pouch for the final development of their babies. So, no, kangaroos are not placental mammals. What is a placental mammal?

Therian Mammals

Like other female vertebrate, all female mammal have **ovary**. These are the organ that produce egg (see **Figure** below). **therian mammal** also have two additional female reproductive structures that are not found in other vertebrates. They are the **uterus** and **vagina**.

- The **uterus** (plural, uteri) is a pouch-like, muscular organ. The embryo or fetus develops inside the uterus. Muscular contractions of the uterus push the offspring out during birth.
- The **vagina** is a tubular passageway through which the embryo or fetus leaves the mother's body during birth. The vagina is also where the male deposits sperm during mating.



[Figure 2]

Female Reproductive System of a Therian Mammal (Human). Therian mammals are **viviparous**, giving birth to an embryo or infant rather than laying eggs. The female reproductive system of all therian mammals is similar to that of humans.

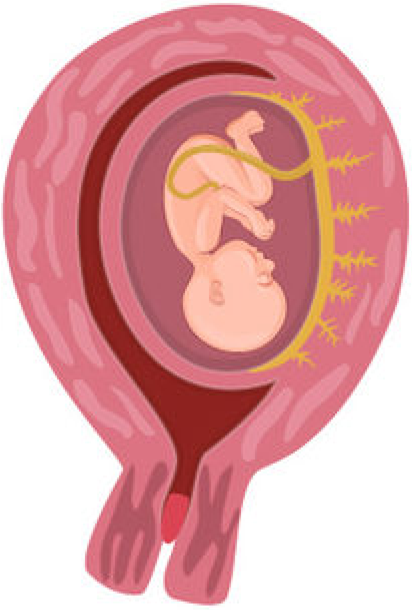
Therian mammals are divided into two groups: placental mammals and marsupial mammals. Each group has a somewhat different reproductive strategy.

Placental Mammals

Placental mammals are therian mammals in which a **placenta** develops during pregnancy. The placenta sustains the fetus while it grows inside the mother's uterus. Placental mammals give birth to relatively large and mature infant. Most mammals are placental mammals.

The Placenta

The **placenta** is a spongy structure. It consists of membranes and blood vessel from both mother and embryo (see **Figure** below). The placenta passes oxygen, nutrient, and other useful substances from the mother to the fetus. It also passes carbon dioxide and other wastes from the fetus to the mother. The placenta lets blood from the fetus and mother exchange substances without actually mixing. Thus, it protects the fetus from being attacked by the mother's immune system as a "foreign parasite."



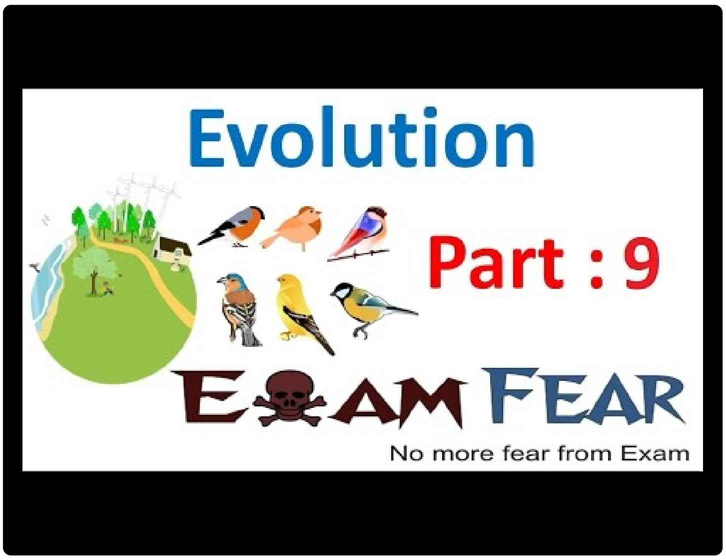
[Figure 3]

Placenta of a Placental Mammal (Human). The placenta allows the exchange of gases, nutrients, and other substances between the fetus and mother.

Pros and Cons of Placental Reproduction

The placenta permits a long period of fetal growth in the uterus. As a result, the fetus can become large and mature before birth. This increases its chances of surviving.

On the other hand, supporting a growing fetus is very draining and risky for the mother. The mother has to eat more food to nourish the fetus. She also becomes heavier and less mobile as the fetus gets larger. As a result, she may be less able to escape from predator. Because the fetus is inside her, she can't abandon it to save her own life if she is pursued or if food is scarce. Giving birth to a large infant is also risky. It may even result in the mother's death.



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Summary

- Therian mammals are viviparous. They give birth to an embryo or infant rather than laying eggs.
- The female reproductive system of a therian mammal includes a uterus and a vagina.
- There are two groups of therian mammals: placental mammals and marsupials.
- Placental mammals give birth to a relatively large and mature fetus. This is possible because they have a placenta to nourish the fetus and protect it from the mother's immune system. This allows for a long period of growth and development before birth.
- Because the offspring of placental mammals is relatively large and mature at birth, it has a good chance of surviving. However, carrying and giving birth to a large fetus is risky for the mother. It also requires her to eat more food.

Review

1. What are therian mammals? What structures are found in these mammals that are absent in other vertebrates?
2. What are the functions of the uterus and vagina in therian mammals?
3. What is the placenta?
4. Describe how the placenta functions?
5. Placental mammals greatly outnumber the other two groups of mammals. Infer why placental mammals have been so successful.

Report Content Errors

12.29 Marsupials

FlexBooks 2.0 > Biology For High School Diploma > Marsupials

Last Modified: Jul 04, 2019

[Figure 1]

Is it really a bear?

The koala. Or sometimes called the koala bear. The koala is a marsupial native to Australia. And it is very different to any other bear.

Marsupials

Marsupials have a different way of reproducing that reduces the mother's risks. A **marsupial** is a therian mammal in which the embryo is born at an early, immature stage. The embryo completes its development outside the mother's body in a pouch on her belly. Only a minority of therian mammals are marsupials. They live mainly in Australia. Examples of marsupials are pictured in **Figure** below.

[Figure 2]

Marsupials. Marsupials include the kangaroo, koala, and opossum.

The Marsupial Embryo

The marsupial embryo is nourished inside the uterus with food from a **yolk sac** instead of through a placenta. The **yolk sac** stores enough food for the short period of time the embryo remains in the uterus. After the embryo is born, it moves into the mother's pouch, where it clings to a nipple. It remains inside the pouch for several months while it continues to grow and develop. Even after the offspring is big enough to leave the pouch, it may often return to the pouch for warmth and nourishment. Eventually, the offspring is mature enough to remain outside the pouch on its own.

Pros and Cons of Marsupial Development

In marsupials, the short period of development within the mother's uterus reduces the risk of her immune system attacking the embryo. In addition, the marsupial mother doesn't have to eat extra food or carry a large fetus inside her. The risks of giving birth to a large fetus are also avoided. Another pro is that the mother can expel the embryo from her pouch if she is pursued by a predator or if food is scarce. On the other hand, a newborn marsupial is tiny and fragile. Therefore, it may be less likely to survive than a newborn placental mammal.

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The North American Marsupial: The Opossum

Most people think of opossums as scary creatures. Is this because they look kind of funny, walk kind of funny, have beady eyes and sharp teeth, and can emit a very foul odor? Maybe. But what is so different about opossums is that they are the only marsupial in North America.

These opossums, however, can be beneficial to humans. They use their sharp teeth to crush bone – which means that they are good getting rid of unwanted rodent in your neighborhood. They have excellent immune systems and they emit that terrible odor for protection.

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Summary

- Marsupials give birth to a tiny, immature embryo. The embryo then continues to grow and develop in a pouch on the mother's belly.
- Marsupial development is less risky for the mother. However, the embryo is fragile, so it may be less likely to survive than the fetus of a placental mammal.

Review

1. What is a marsupial?
2. Where does a marsupial embryo develop? How is it nourished?
3. Name two advantages of marsupial development?

Report Content Errors

12.30 Monotremes

FlexBooks 2.0 > Biology For High School Diploma > Monotremes

Last Modified: Jul 04, 2019

[Figure 1]

Can a mammal lay an egg?

This is a mammal. But it is unlike placental or marsupial mammals. If a mammal does not develop within a placenta or a pouch, what type of development is left? Eggs!

Monotremes

Only five living species of mammals are not therian mammal. They are called monotremes. **Monotremes** are mammals that reproduce by laying egg. The only living monotreme species are the platypus and echidnas (see **Figure** below and **Figure** below). They are found solely in Australia and New Guinea (an island not far from Australia).

[Figure 2]

This egg-laying, venomous, duck-billed, beaver-tailed, otter-footed mammal is a platypus, a monotreme mammal that reproduces by laying eggs.

[Figure 3]

Like the platypus, the echidna is a monotreme. The only living monotreme species inhabit Australia and New Guinea.

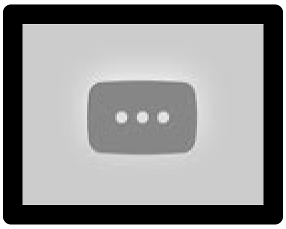
Eggs and Lactation in Monotremes

Female monotremes lack a uterus and vagina. Instead, they have a **cloaca** with one opening, like the cloacas of reptile and bird. The opening is used to excrete wastes as well as lay eggs.

Monotreme eggs have a leathery shell, like the eggs of reptiles. The eggs are retained inside the mother's body for at least a couple of weeks. During that time, the mother provides the eggs with nutrient. Platypus females lay their eggs in a burrow. Echidna females have a pouch in which they store their eggs. Female monotremes have mammary gland but lack nipples. Instead, they "sweat" milk from a patch on their belly.

Pros and Cons of Monotreme Reproduction

The mother's risks are less in monotremes than in therian mammals. The mother doesn't need to eat more or put herself at risk by carrying and delivering a fetus or an embryo. On the other hand, externally laid eggs are more difficult to protect than an embryo in a pouch or a fetus in a uterus. Therefore, monotreme offspring may be less likely to survive than the offspring of therian mammals.



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Summary

- Monotremes reproduce by laying eggs.
- Monotremes have a cloaca instead of a uterus and vagina. The eggs pass through the opening of the cloaca.
- Monotreme reproduction is the least risky for the mother. However, eggs are harder to protect than is an embryo or a fetus in a pouch or uterus. Therefore, monotreme offspring may have a lower chance of surviving than the offspring of therian mammals.

Review

1. What are monotremes?
2. Describe eggs and egg laying in monotremes.
3. How does lactation differ in monotremes and therian mammals?
4. Create a chart that you could use to explain to a younger student the different ways that mammals reproduce.

12.31 Mammal Ancestors

FlexBooks 2.0 > Biology For High School Diploma > Mammal Ancestors

Last Modified: Jul 04, 2019

[Figure 1]

Which mammalian trait evolved first? What was the first mammal like? When did the earliest mammal live?

Detailed answers to these questions are still in dispute, though it is probably safe to say the earliest mammal were not like this giraffe. Obviously, the giraffe has some specialized traits.

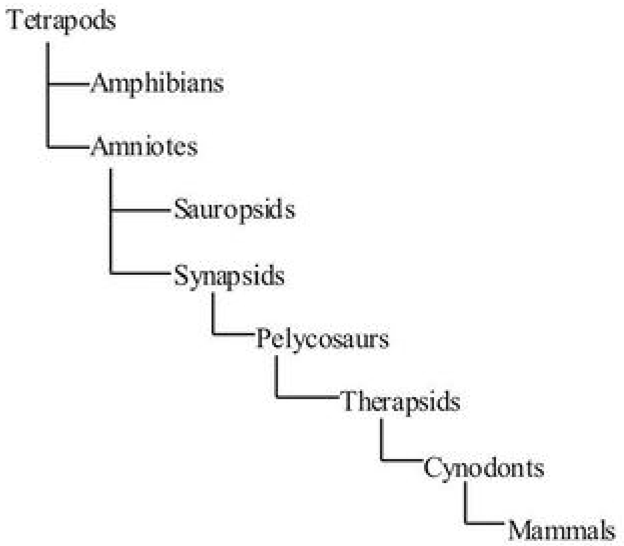
Major Events in Mammalian Evolution

Scientists do generally agree on the major events in the evolution of mammals. These are summarized in **Table** below. Refer back to the table as you read about the events in this concept. *mya = millions of years ago

Era	Period	Epoch	Major Events	Start (mya)*
Cenozoic	Neogene	Holocene	Rise of human civilization; spread and dominance of modern humans	0.01
-	-	Pleistocene	Spread and then extinction of many large mammals; appearance of modern humans	1.8
-	-	Pliocene	Appearance of many existing genera of mammals, including the genus *Homo*	5.3
-	-	Miocene	Appearance of remaining modern mammal families; diversification of horses and mastodons; first apes	23.0
-	Paleogene	Oligocene	Rapid evolution and diversification of placental mammal	33.9
-	-	Eocene	Appearance of several modern mammal families; diversification of primitive whales	55.8
-	-	Paleocene	Appearance of the first large mammals	65.5
Mesozoic	Cretaceous	-	Emergence of monotreme, marsupial, and placental mammals; possible first appearance of four clade (superorders) of placental mammals (Afrotheria, Xenarthra, Laurasiatheria, Supraprimates)	145.5
-	Jurassic	-	Spread of mammals, which remain small in size	199.6
-	Triassic	-	Evolution of cynodont to become smaller and more mammal-like; appearance of the first mammals	251.0
Paleozoic	Permian	-	Evolution and spread of synapsids (**pelycosaur** and therapsids)	299.0
-	Carboniferous	-	Appearance of **amniote**, the first fully terrestrial vertebrate	359.0

Mammalian Ancestors

Ancestors of mammals evolved close to 300 million years ago. They were **amniotes** called **synapsids**. **Figure** below shows how modern mammals evolved from synapsids. The stages of evolution from synapsids to mammals are described below.

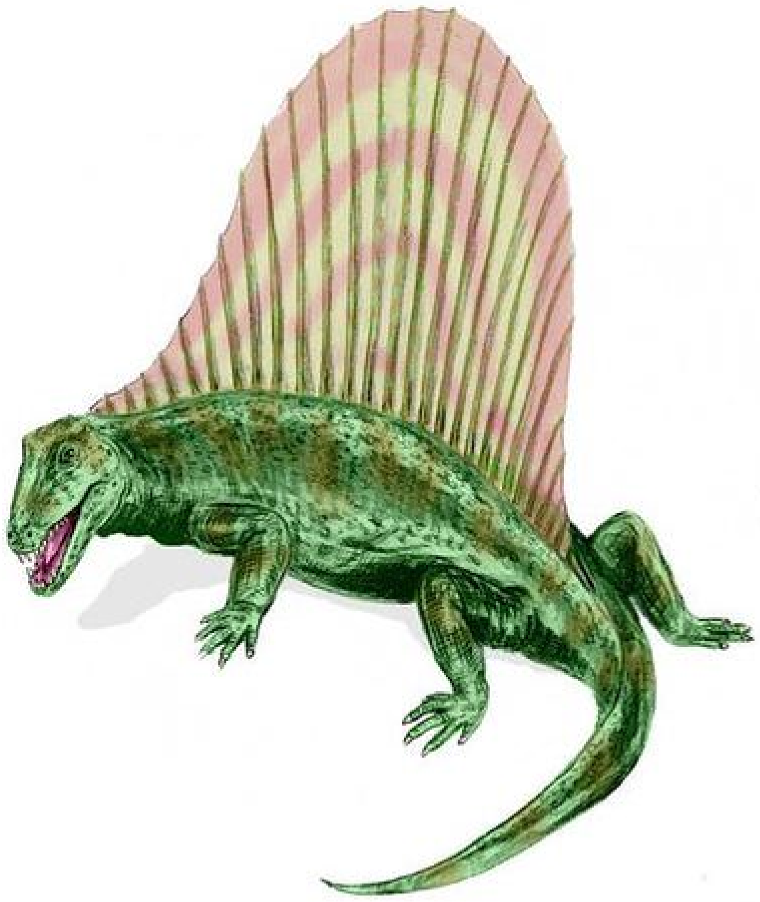


[Figure 2]

Phylogeny of Mammalian Evolution. This diagram represents the evolution of mammals.

Pelycosaurs

Synapsids called **pelycosaurs** became the most common land vertebrates during the first half of the Permian Period. A pelycosaur genus called *Dimetrodon* is shown in **Figure** below. *Dimetrodon* had sprawling legs and walked like a lizard. It also had a fairly small brain. However, it had started to develop some of the traits of mammals. For example, it had teeth of different types.



[Figure 3]

Pelycosaur Synapsid: *Dimetrodon*. *Dimetrodon* was a pelycosaur. It lived about 275 million years ago.

Therapsids

Some pelycosaurs gave rise to a group of animal called **therapsids**. The earliest therapsids lived about 260 million years ago. At first, the therapsids looked a lot like *Dimetrodon*. But after a while, they could easily be mistaken for mammals. They evolved a number of mammalian traits, such as legs positioned under the body instead of along the sides. Therapsids became the most common and diverse land vertebrates during the second half of the Permian Period.

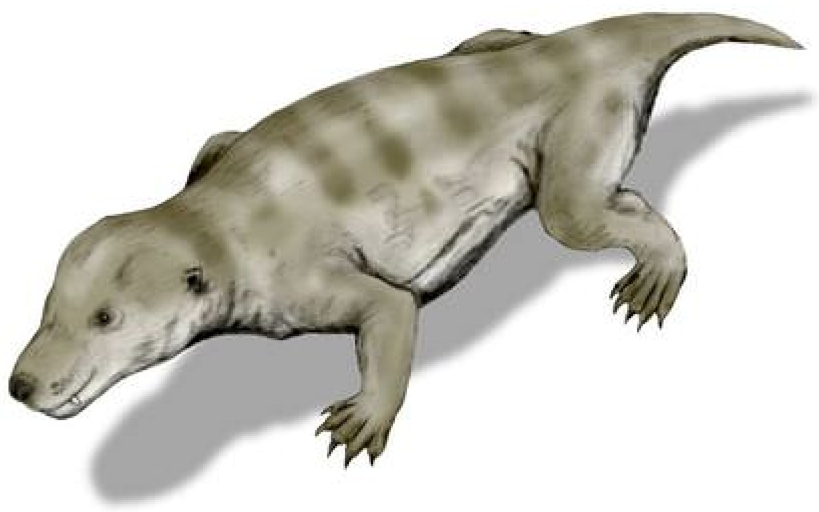
The Permian Period ended about 250 million years ago with a mass extinction. Most therapsids went extinct. Their niches were taken over by **sauropsida**. These were the amniotes that evolved into dinosaur, reptile, and bird. Not all therapsids went extinct, however. The few that remained no longer had to compete with many other therapsids. Some of them eventually evolved into mammals.

Cynodonts

The surviving therapsids were small animals. Some of the most successful were the **cynodonts** (see **Figure** below). They flourished worldwide during the first half of the Triassic Period. Some of them ate insects and were **nocturnal**, or active at night. Being nocturnal may have helped save them from extinction. Why? A nocturnal niche was one of the few niches that dinosaurs did not take over in the Triassic Period.

Cynodonts became more mammal-like as they continued to evolve. Some of their mammalian traits may have been adaptation to their nocturnal niche. For example:

- The ability to regulate body temperature might have been selected for because it would allow nocturnal animals to remain active in the cool of the night.
- A good sense of hearing might have been selected for because it would be more useful than good vision when hunting in the dark.



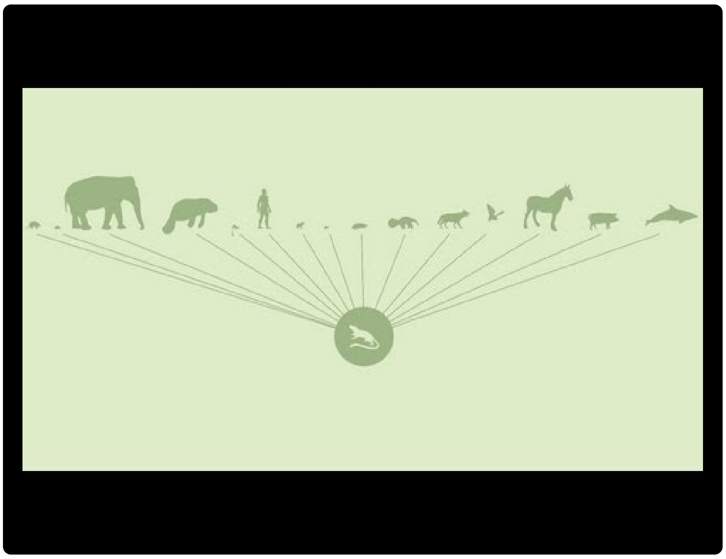
[Figure 4]

Probable Mammalian Ancestor: Cynodont. Cynodonts were mammal-like therapsids. They may have been ancestral to mammals. They were about the size of a rat.

By the end of the Triassic Period, cynodonts had become even smaller in size. They also had evolved many mammalian traits. For example, they had

- Four different types of teeth
- A relatively large brain
- Three tiny bone in the middle ear
- A diaphragm for breathing
- **endothermy**
- **lactation**
- Hair

Cynodonts probably gave rise to mammals about 200 million years ago. However, they are not considered to be mammals themselves. In fact, competition with early mammals may have led to their extinction. They went extinct sometime during the Jurassic or Cretaceous Period.



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Summary

- Amniotes called synapsids were the ancestors of mammals.
- Synapsids named pelycosaurs had some of the traits of mammals by 275 million years ago.
- Some synapsids evolved into therapsids, which became widespread during the Permian Period.
- The few therapsids that survived the Triassic takeover were small, arboreal insect eaters. They were also nocturnal. Being active at night may explain why they survived and

evolved still more mammalian traits.

Review

1. What were the synapsids? When were they most widespread?
2. Identify the therapsids. How were they related to mammals?
3. Describe cynodonts. What is their place in the evolution of mammals?
4. Describe mammalian traits found in cynodonts.

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12.32 Mammal Evolution

FlexBooks 2.0 > Biology For High School Diploma > Mammal Evolution

Last Modified: Jan 18, 2022

[Figure 1]

Could you argue that the duckbilled platypus has some characteristics of other species?

Like a bird or a fish? You could. This might suggest that an ancestor of this species may have been one of the early mammal to evolve.

Evolution of Early Mammals

The earliest mammals evolved from **cynodont**. But the evolution of mammals didn't end there. Mammals continued to evolve. monotreme mammals probably split off from other mammals first. They were followed by marsupial. placental mammal probably evolved last.

Evolution of Monotremes

The first monotremes may have evolved about 150 million years ago. Early monotreme fossil have been found in Australia. An example is a genus called ***Steropodon***, shown in **Figure** below. It may have been the ancestor of the platypus. Early monotremes retained some of the traits of their therapsid ancestors. For example, they laid egg and had a cloaca. These traits are still found in modern monotremes.

[Figure 2]

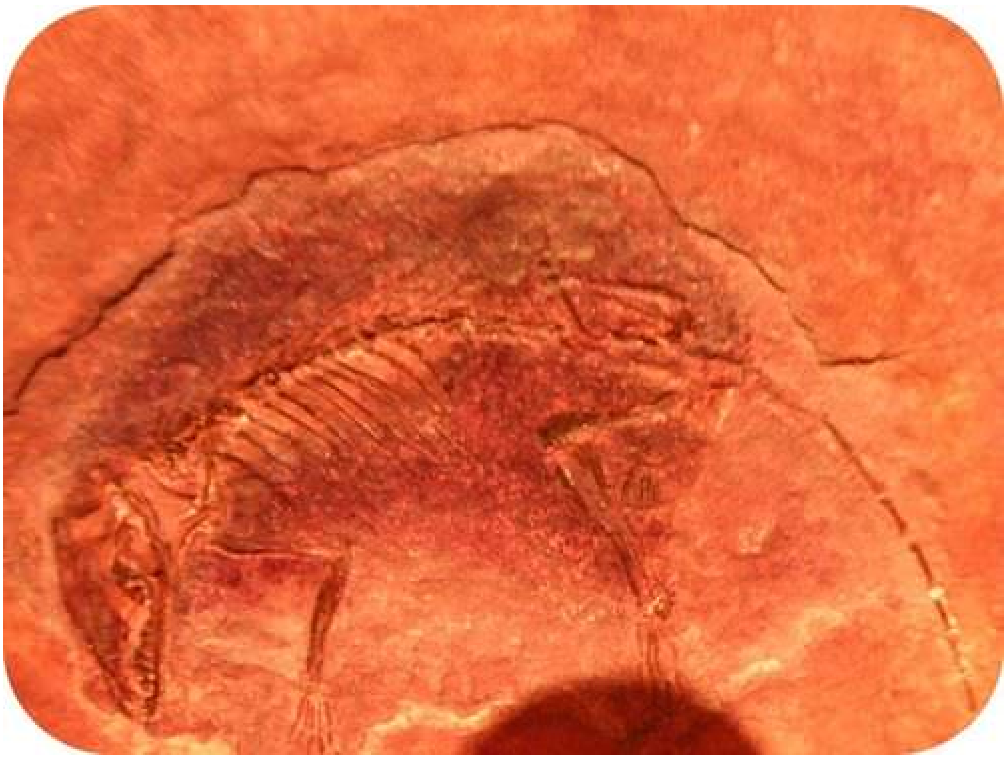
Probable Monotreme Ancestor: Steropodon. Like the platypus, Steropodon probably had a bill.

Evolution of Marsupials

The first marsupials may have evolved about 130 million years ago. One of the earliest was the extinct genus ***Sinodelphys***. *Sinodelphys* was about 15 centimeters (6 inches) long. Its limb structure suggests that it was a climbing animal. It could escape from predator by climbing into trees. It probably lived on a diet of insects and worms.

Evolution of Placental Mammals

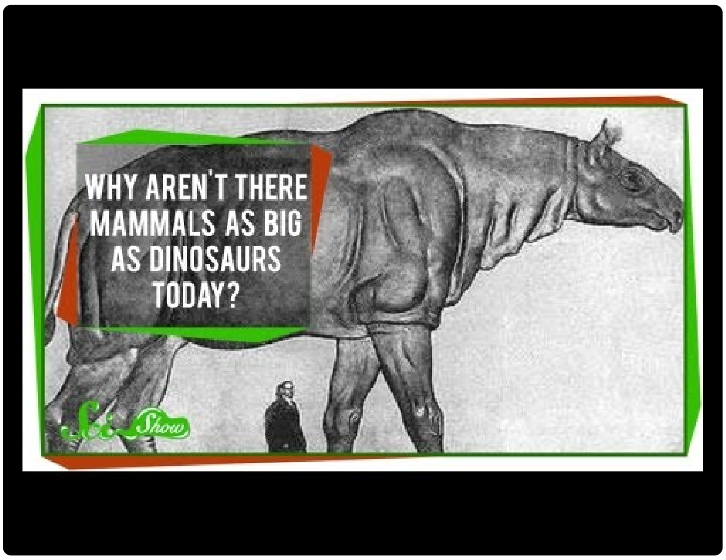
The earliest placental mammals may have evolved about 110 million years ago. The ancestor of placental mammals may be the extinct genus ***Eomaia***. Fossils of *Eomaia* have been found in what is now China. It was only about 10 centimeters (4 inches) long. It was a tree climber and probably ate insects and worms. *Eomaia* had several traits of placental mammals. **Figure** below shows how *Eomaia* may have looked.



[Figure 3]

Probable Ancestor of Placental Mammals: Eomaia. Eomaia lived a little over 100 million years ago.

The placental mammal descendants of *Eomaia* were generally more successful than marsupials and monotremes. On most continents, placental mammals became the dominant mammals, while marsupials and monotremes died out. Marsupials remained the most common and diverse mammals in Australia. The reason for their success there is not yet resolved.



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Evolution of Modern Mammals

The Cretaceous Period ended with another mass extinction. This occurred about 65 million years ago. All of the dinosaur went extinct at that time. Did the extinction of the dinosaurs allow mammals to take over?

Traditional View

Scientists have long assumed that the extinction of the dinosaurs opened up many niches for mammals to exploit. Presumably, this led to an explosion of new species of mammals early in Cenozoic Era. Few mammalian fossils from the early Cenozoic have been found to support this theory. Even so, it was still widely accepted until recently.

View from the Mammalian Supertree

In 2007, an international team of scientists compared the DNA of almost all known species of living mammals. They used the data to create a **supertree** of mammalian evolution. The supertree shows that placental mammals started to diversify as early as 95 million years ago.

What explains the diversification of mammals long before the dinosaurs went extinct? What else was happening at that time? One change was a drop in Earth's temperature. This may have favored **endothermic** mammals over **ectothermic** dinosaurs. Flowering plants were also spreading at that time. They may have provided new and plentiful foods for small mammals or their insect prey.

The supertree also shows that another major diversification of mammals occurred about 50 million years ago. Again, worldwide climate change may have been one reason. This time

Earth's temperature rose. The warmer temperature led to a greater diversity of plants. This would have meant more food for mammals or their prey.

Summary

- Monotremes evolved about 150 million years ago. Like modern monotremes, they had a cloaca and laid eggs.
- Marsupials evolved about 130 million years ago. They were very small and ate insects and worms.
- Placental mammals evolved about 110 million years ago. They were also small and climbed trees.
- Placental mammals became the dominant land mammals. Most marsupials and monotremes died out, except in Australia.
- The mammalian supertree shows that placental mammals started to diversify as early as 95 million years ago.

Review

1. Outline the evolution of monotreme, marsupial, and placental mammals.
2. Describe *Sinodelphys*.
3. Describe *Eomaia*.
4. What is the mammalian supertree?
5. Explain why the extinction of most therapsids may have allowed mammals to evolve.
6. What explains the diversification of mammals long before the dinosaurs went extinct?

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12.33 Mammal Classification

FlexBooks 2.0 > Biology For High School Diploma > Mammal Classification

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[Figure 1]

How would you classify this mammal?

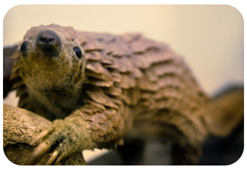
Obviously it is a camel, but is there more to it than that? There are 17 orders of placental mammal. But then these mammal need to be further classified into families, genera, and finally species.

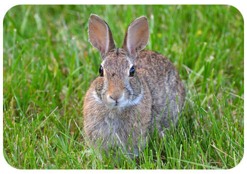
Classification of Placental Mammals

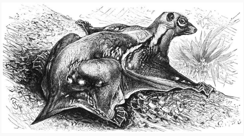
Traditional classifications of mammals are based on similarities in structure and function. Increasingly, mammals are being classified on the basis of molecular similarities. DNA analyses has recently shown that the traditional orders include mammals that may not be closely related.

Traditional Classification

The most widely accepted traditional classification of mammals divides living placental mammals into 17 orders. These orders are shown in **Table** below. This classification of mammals was widely accepted for more than 50 years. Placental mammals are still commonly placed in these orders. However, this classification is not very useful for studies of mammalian evolution. That's because it groups together some mammals that do not seem to be closely related by descent from a recent common ancestor.

Order	Example	Sample Trait
Insectivora	mole  [Figure 2]	small sharp teeth
Edentata	anteater  [Figure 3]	few or no teeth
Pholidota	pangolin  [Figure 4]	large plate-like scales
Chiroptera	bat  [Figure 5]	digits support membranous wing
Carnivora	coyote  [Figure 6]	long pointed canine teeth
Rodentia	mouse	incisor teeth grow continuously

	 [Figure 7]	
Lagomorpha	rabbit  [Figure 8]	chisel-like incisor teeth
Perissodactyla	horse  [Figure 9]	odd-toed hooves
Artiodactyla	deer  [Figure 10]	even-toed hooves
Cetacea	whale  [Figure 11]	paddle-like forelimbs
Primates	monkey  [Figure 12]	five digits on hands and feet

Proboscidea	elephant  [Figure 13]	tusks
Hyracoidea	hyrax  [Figure 14]	rubbery pads on feet
Dermoptera	colugo  [Figure 15]	membrane of skin between legs for gliding
Pinnipedia	seal  [Figure 16]	feet with fins
Sirenia	manatee  [Figure 17]	paddle-like tail
Tubulidentata	aardvark	teeth without enamel

	 [Figure 18]	

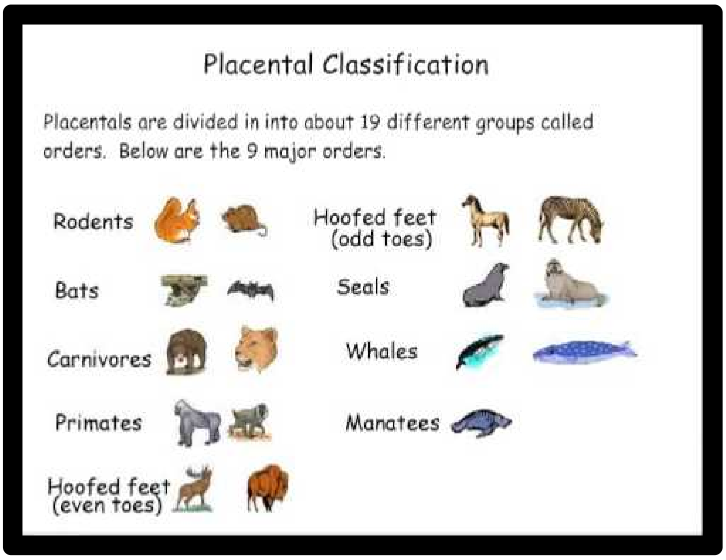
Phylogenetic Classification

The mammalian **supertree** classifies placental mammals **phylogenetically**. It uses the analysis of DNA sequences to group together mammals that are evolutionarily closely related, sharing a recent common ancestor. These groups are not necessarily the same as the traditional groups based on structure and function.

The supertree classification places placental mammals in four **superorders**. The four superorders and some of the mammals in them are:

- Afrotheria—aardvarks, elephants, manatees.
- Xenarthra—anteaters, sloths, armadillos.
- Laurasiatheria—bats, whales, hoofed mammals, carnivore.
- Supraprimates—primates, rabbits, rodent.

All four superorders appear to have become distinct from one another between 85 and 105 million years ago. The exact relationships among the superorders are still not clear. Revisions in this classification of mammals may occur as new data become available.



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Summary

- Mammals used to be classified on the basis of similarities in structure and function into 17 different orders.
- Recently, DNA analyses have shown that the traditional orders include mammals that are not closely related.
- Phylogenetic classification, based on DNA data, groups placental mammals in four superorders. The superorders appear to have become distinct from each other 85–105 million years ago.

Review

1. Compare traditional and phylogenetic classifications of placental mammals. Explain which type of classification is more useful for understanding how mammals evolved.
2. Assume that a new species of placental mammal has been discovered. Scientists have examined it closely and studied its DNA. It has wings similar to a bat that it uses for gliding. Its DNA is most similar to the DNA of rodents such as mice. How would you classify the new mammal? Explain your answer.

12.34 REFERENCES

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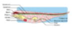	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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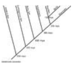
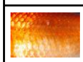
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** stux **Source:** https://pixabay.com/photos/scale-fish-scales-goldfish-365085/ **License:** Pixabay License

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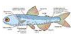	**Credit:** Zachary Wilson and Mariana Ruiz Villarreal (LadyofHats) **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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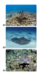	**Credit:** (a) Papahānaumokuākea Marine National Monument; (b) Barry Peters; (c) Linda Snook / MBNMS **Source:** (a) https://www.flickr.com/photos/93641120@N05/37437664176; (b) https://commons.wikimedia.org/wiki/File:Southern_stingrays_at_stingray_city.jpg; (c) https://commons.wikimedia.org/wiki/File:Hydrolagus_colliei.jpg **License:** (a) Public Domain; (b) CC-BY 2.0; (c) Public Domain
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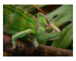	**Credit:** William Warby **Source:** http://www.flickr.com/photos/wwarby/3895166303/ **License:** CC BY 4.0
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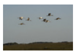	**Credit:** Everglades National Park **Source:** https://www.flickr.com/photos/evergladesnps/9101545690/ **License:** Public Domain
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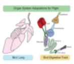	**Credit:** Zachary Wilson and Mariana Ruiz Villarreal (LadyofHats);User:Bourrichon/Wikimedia Commons **Source:** CK-12 Foundation;http://commons.wikimedia.org/wiki/File:Brains-fr.svg **License:** CC BY-NC 3.0
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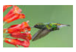
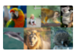
	**Credit:** Mike Baird **Source:** http://www.flickr.com/photos/mikebaird/7236676284/ **License:** CC BY 2.0
	**Credit:** (a) D Coetzee; (b) csinfo; (c) D Coetzee; (d) Bernard Spragg; (e) Bernard Spragg; (f) Giulio; (g) Dan Woodrow **Source:** (a) https://www.flickr.com/photos/29507259@N02/3572948635; (b) https://pixabay.com/photos/baby-children-s-cute-adorable-3770940/; (c) https://www.flickr.com/photos/29507259@N02/10528673364; (d) https://www.flickr.com/photos/88123769@N02/9080276709; (e) https://www.flickr.com/photos/88123769@N02/8107505945; (f) https://www.flickr.com/photos/132327312@N07/16842380400; (g) https://www.flickr.com/photos/67507304@N06/16654295638 **License:** (a) CC0; (b) Pixabay; (c) CC0; (d) CC0; (e) CC0; (f) Public Domain; (g) Public Domain
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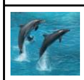	**Credit:** Flickr:talkrhubarb **Source:** http://www.flickr.com/photos/talkrhubarb/223175100/ **License:** CC BY 2.0
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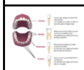
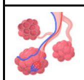
	**Credit:** 3D rendered mouth: Image copyright Zoltan Pataki, 2014; Composite created by CK-12 Foundation **Source:** http://www.shutterstock.com **License:** 3D rendered mouth: Used under license of Shutterstock.com
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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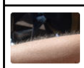	**Credit:** Flickr:Evert **Source:** http://commons.wikimedia.org/wiki/File:Goose_bumps.jpg **License:** CC BY 2.0
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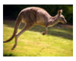
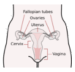
	**Credit:** Charlie Marshall **Source:** http://www.flickr.com/photos/100915417@N07/9667430048/ **License:** CC BY 4.0
	**Credit:** Centers for Disease Control and Prevention, User:Mysid/Wikimedia Commons, modified by Raymond Chou/CK-12 Foundation **Source:** http://commons.wikimedia.org/wiki/File:Scheme_female_reproductive_system-en.svg **License:** Public Domain
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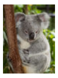	**Credit:** Brian Gratwicke **Source:** https://www.flickr.com/photos/briangratwicke/5337546645/ **License:** CC BY 2.0
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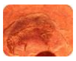	**Credit:** Flickr:emf1947 **Source:** http://www.flickr.com/photos/emf1947/6827785264/ **License:** CC BY 2.0
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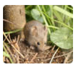
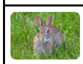
	**Credit:** Jans Canon **Source:** https://www.flickr.com/photos/43158397@N02/5484017960/ **License:** CC BY 2.0
	**Credit:** Yuri Levchenko **Source:** http://www.flickr.com/photos/i8ipod/9028050858/ **License:** CC BY 2.0
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CHAPTER 13

Human Biology

Chapter Outline

13.1 Human Body

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Last Modified: May 20, 2021

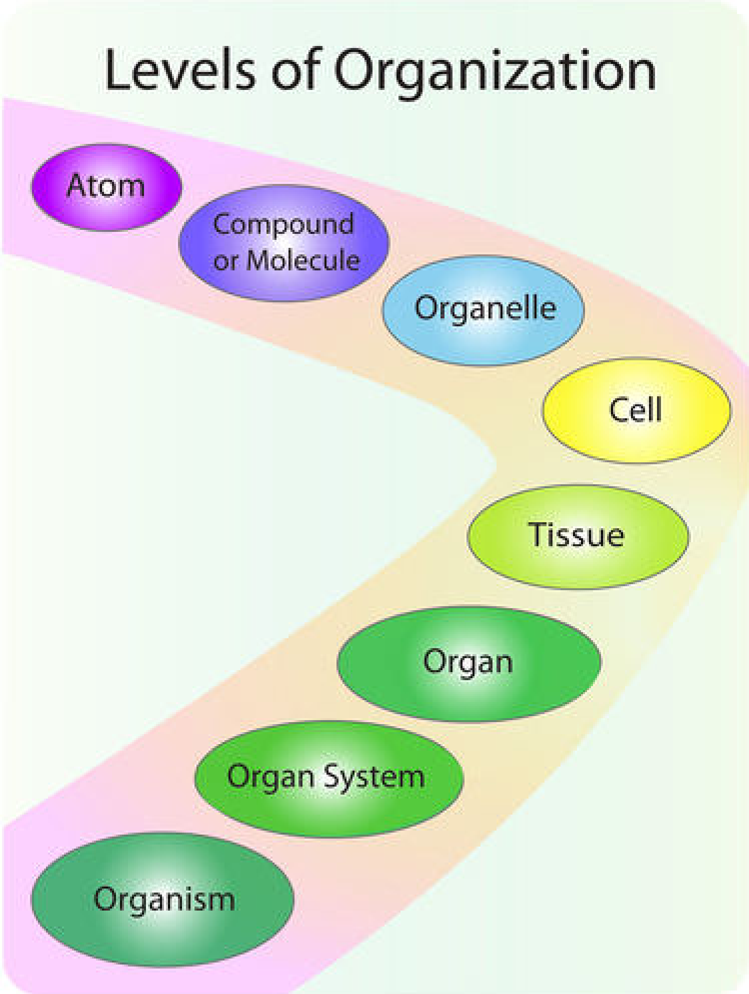
[Figure 1]

How is the human body similar to a well-tuned machine?

Many people have compared the human body to a machine. Think about some common machines, such as drills and washing machines. Each machine consists of many parts, and each part does a specific job, yet all the parts work together to perform an overall function. The human body is like a machine in all these ways. In fact, it may be the most fantastic machine on Earth.

Organization of Your Body: Cells, Tissues, Organs

The human machine is organized at different levels, starting with the **cell** and ending with the entire organism (see **Figure** below). At each higher level of organization, there is a greater degree of complexity.

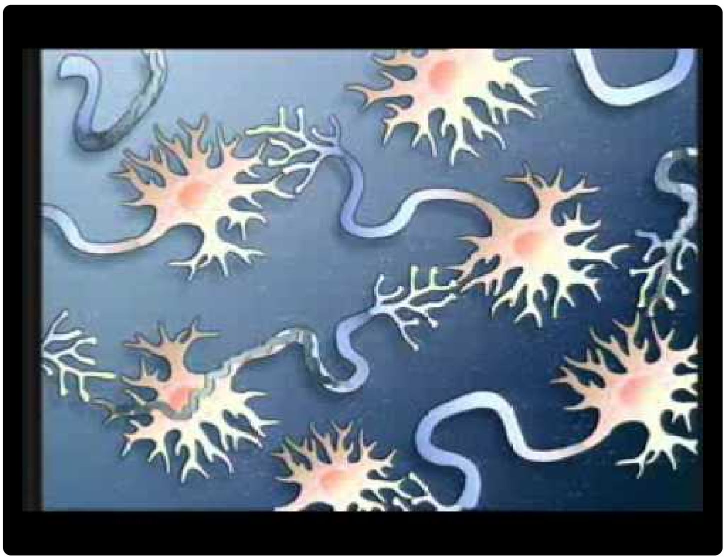


[Figure 2]

The human organism has several levels of organization.

Cells

The most basic parts of the human machine are cells—an amazing 100 trillion of them by the time the average person reaches adulthood! **Cells** are the basic units of structure and function in the human body, as they are in all living things. Each cell carries out basic life processes that allow the body to survive. Many human cells are specialized in form and function, as shown in **Figure** below. Each type of cell in the figure plays a specific role. For example, nerve cells have long projections that help them carry electrical messages to other cells. Muscle cells have many mitochondrion that provide the energy they need to move the body.



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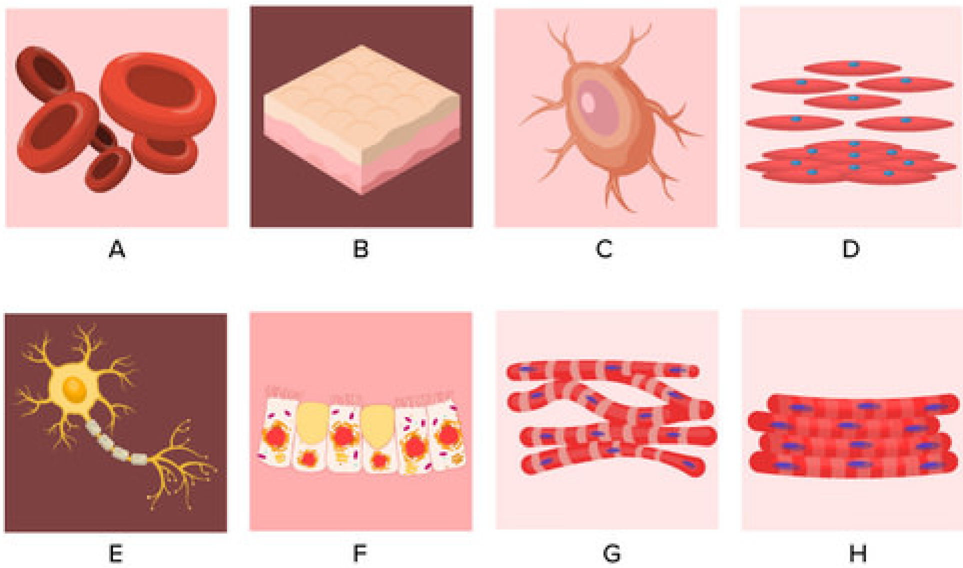
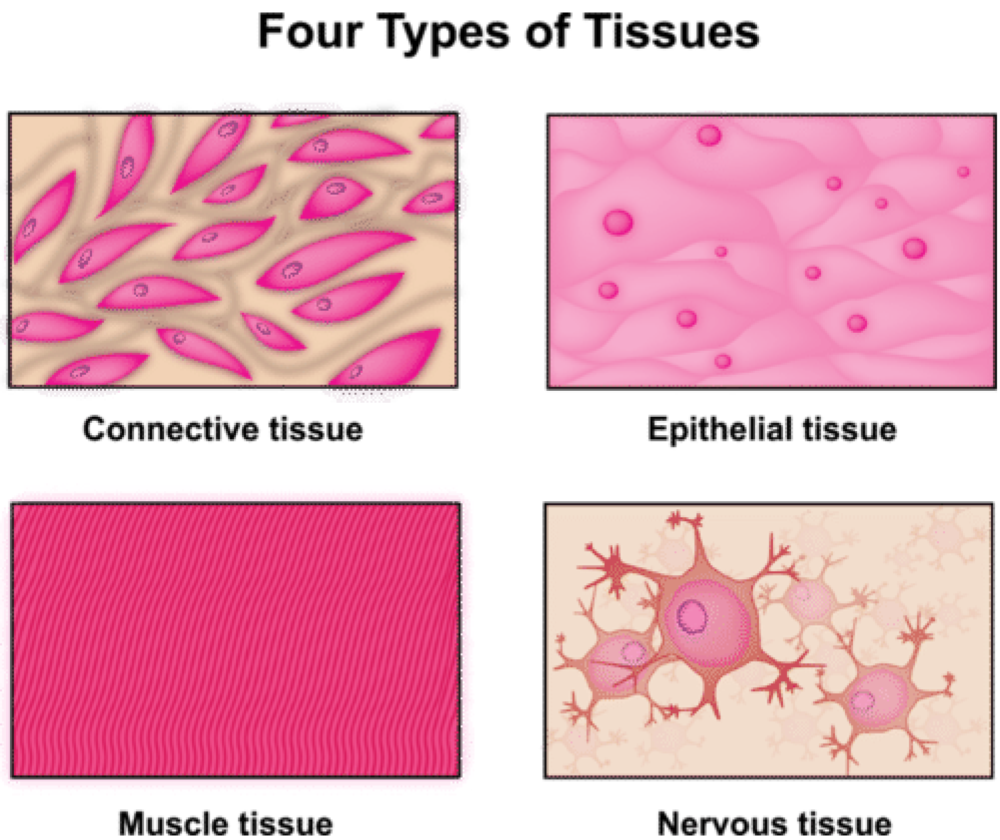


[Figure 3]

Different types of cells in the human body are specialized for specific jobs. Do you know the functions of any of the cell types shown here? (a) blood cells, (b) surface skin cells, (c) bone cell, (d) smooth muscle cells, (e) neuron, (f) columnar epithelial and goblet cells, (g) cardiac muscle cells, (h) skeletal muscle cells.

Tissues

After the cell, the **tissue** is the next level of organization in the human body. A **tissue** is a group of connected cells that have a similar function. There are four basic types of human tissues: epithelial, muscle, nervous, and **connective tissue**. These four tissue types, which are shown in **Figure** below, make up all the **organ** of the human body.



[Figure 4]

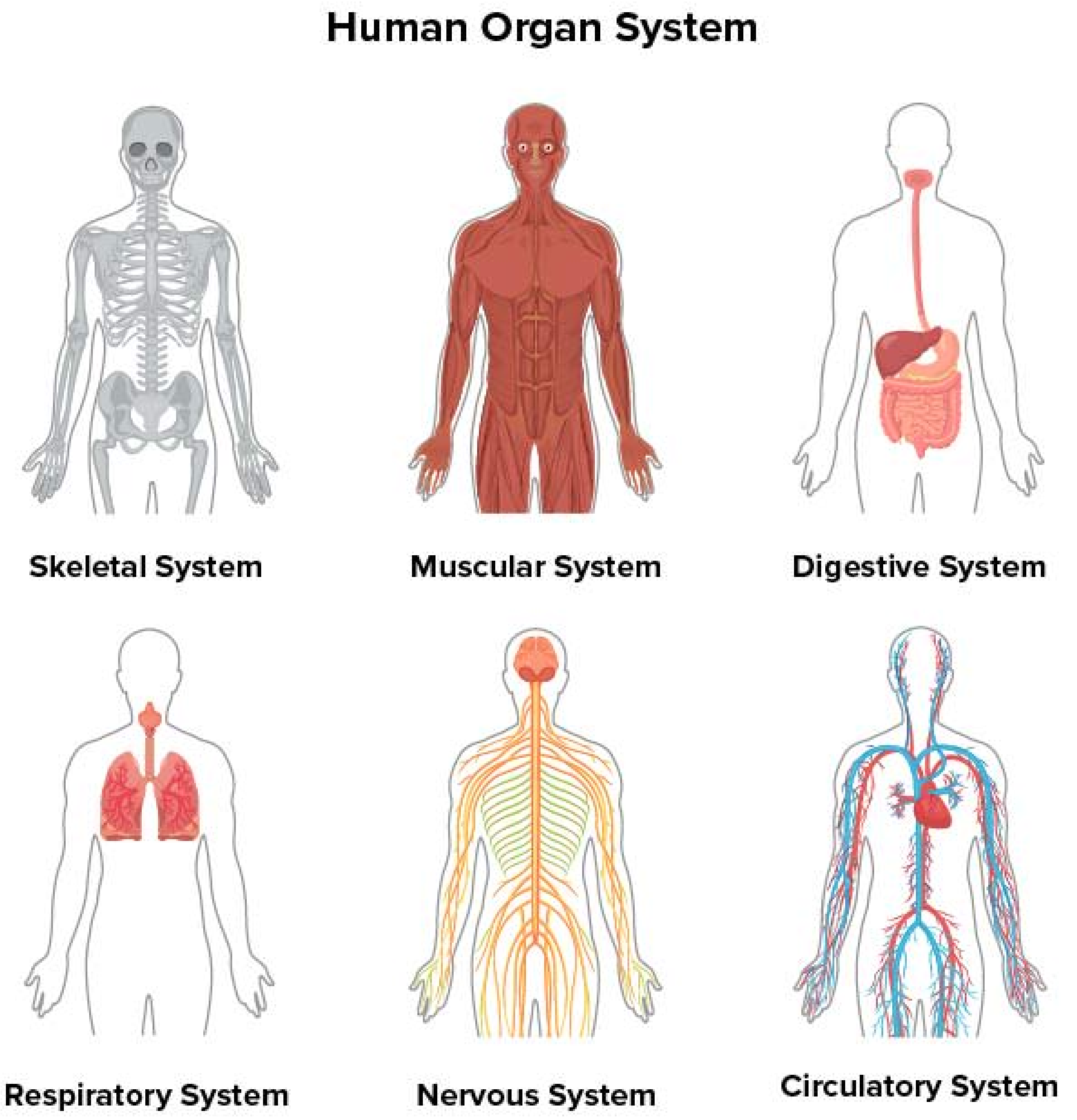
The human body consists of these four tissue types.

- **Connective tissue** is made up of cells that form the body's structure. Examples include bone and cartilage.
- **epithelial tissue** is made up of cells that line inner and outer body surfaces, such as the skin and the lining of the digestive tract. Epithelial tissue protects the body and its internal organs, secretes substances such as hormone, and absorbs substances such as nutrient.
- **muscle tissue** is made up of cells that have the unique ability to contract, or become shorter. Muscles attached to bones enable the body to move.
- **nervous tissue** is made up of **neuron**, or nerve cells, that carry electrical messages. Nervous tissue makes up the brain and the nerves that connect the brain to all parts of the body.

Organs and Organ Systems

After tissues, organs are the next level of organization of the human body. An **organ** is a structure that consists of two or more types of tissues that work together to do the same job. Examples of human organs include the brain, heart, lung, skin, and kidney. Human organs are organized into **organ system**, many of which are shown in **Figure** below. An **organ**

system is a group of organs that work together to carry out a complex overall function. Each organ of the system does part of the larger job.



[Figure 5]

Many of the organ systems that make up the human body are represented here. What is the overall function of each organ system?

Your body's 12 organ systems are shown below (**Table** below). Your organ systems do not work alone in your body. They must all be able to work together. For example, one of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

Organ System	Major Tissues and Organs	Function
Cardiovascular	Heart; blood vessel; blood	Transports oxygen, hormones, and nutrients to the body cells. Moves wastes and carbon dioxide away from cells.
Lymphatic	lymph node; **lymph vessel**	Defend against infection and disease, moves lymph between tissues and the blood stream.
Digestive	esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, mineral, vitamin, and water.
Endocrine	pituitary gland, hypothalamus; adrenal glands; ovary; testis	Produces **hormones** that communicate between cells.
Integumentary	Skin, hair, nails	Provides protection from injury and water loss, physical defense against infection by microorganisms, and temperature control.
Muscular	Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendon	Involved in movement and heat production.
Nervous	Brain, spinal cord; nerves	Collects, transfers, and processes information.
Reproductive	Female: uterus; vagina; fallopian tube; ovaries Male: penis; testes; seminal vesicle	Produces gamete (sex cells) and sex hormone.
Respiratory	trachea, larynx, pharynx, lungs	Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs).
Skeletal	Bones, cartilage; ligament	Supports and protects soft tissues of body; produces blood cells; stores minerals.
Urinary	Kidneys; urinary bladder	Removes extra water, salts, and waste products from blood and body; controls pH; controls water and salt balance.
Immune	bone marrow; spleen; white blood cell	Defends against diseases.

Further Reading

Carcinogens and Cancer

Air Pollution and Illness

Bioterrorism

Summary

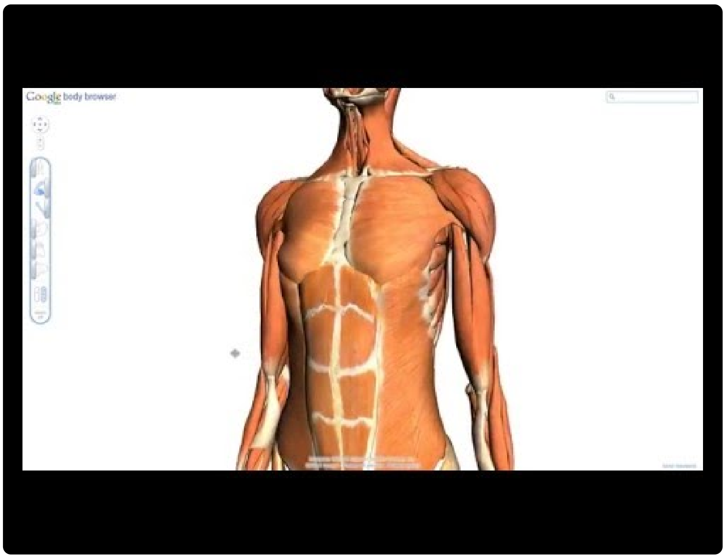
- The human body is organized at different levels, starting with the cell.
- Cells are organized into tissues, and tissues form organs.
- Organs are organized into organ systems such as the skeletal and muscular systems.

Review

1. What are the levels of organization of the human body?
2. Which type of tissue covers the surface of the body?
3. What are the functions of the skeletal system?
4. Which organ system supports the body and allows it to move?

5. Explain how form and function are related in human cells. Include examples.
6. Compare and contrast epithelial and muscle tissues.

Resources



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13.2 Homeostasis

FlexBooks 2.0 > Biology For High School Diploma > Homeostasis

Last Modified: Aug 01, 2018

[Figure 1]

What happens if stability is disrupted?

Remove one stone and the whole arch collapses. The same is true for the human body. All the systems work together to maintain stability or homeostasis. Disrupt one system, and the whole body may be affected.

Homeostasis

All of the organ and organ system of the human body work together like a well-oiled machine. This is because they are closely regulated by the nervous and endocrine systems. The **nervous system** controls virtually all body activities, and the **endocrine system** secretes **hormone** that regulate these activities. Functioning together, the organ systems supply body cell with all the substances they need and eliminate their wastes. They also keep temperature, pH, and other conditions at just the right levels to support life processes.

Maintaining Homeostasis

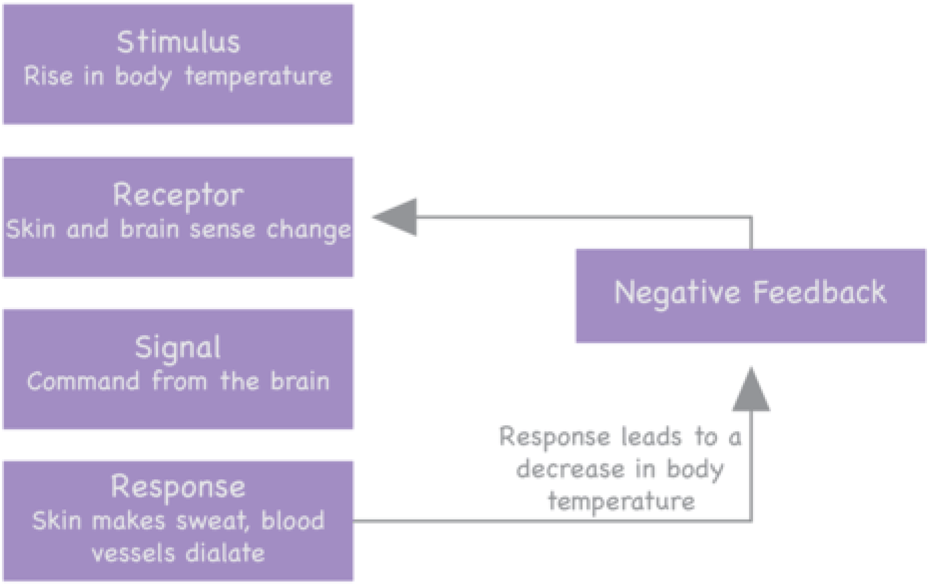
The process in which organ systems work to maintain a stable internal environment is called **homeostasis**. Keeping a stable internal environment requires constant adjustments. Here are just three of the many ways that human organ systems help the body maintain homeostasis:

- respiratory system: A high concentration of carbon dioxide in the blood triggers faster breathing. The lung exhale more frequently, which removes carbon dioxide from the body more quickly.
- excretory system: A low level of water in the blood triggers retention of water by the kidney. The kidneys produce more concentrated urine, so less water is lost from the body.
- Endocrine system: A high concentration of sugar in the blood triggers secretion of insulin by an endocrine gland called the pancreas. Insulin is a hormone that helps cells absorb sugar from the blood.

So how does your body maintain homeostasis? The regulation of your internal environment is done primarily through **negative feedback**. **Negative feedback** is a response to a stimulus that keeps a variable close to a set value (**Figure** below). Essentially, it "shuts off" or "turns on" a system when it varies from a set value.

For example, your body has an internal thermostat. During a winter day, in your house a thermostat senses the temperature in a room and responds by turning on or off the heater. Your body acts in much the same way. When body temperature rises, receptors in the skin and the brain sense the temperature change. The temperature change triggers a command from the brain. This command can cause several responses. If you are too hot, the skin makes sweat and blood vessel near the skin surface dilate. This response helps decrease body temperature.

Another example of negative feedback has to do with blood glucose levels. When glucose (sugar) levels in the blood are too high, the pancreas secretes insulin to stimulate the absorption of glucose and the conversion of glucose into glycogen, which is stored in the liver. As blood glucose levels decrease, less insulin is produced. When glucose levels are too low, another **hormone** called glucagon is produced, which causes the liver to convert glycogen back to glucose.



[Figure 2]

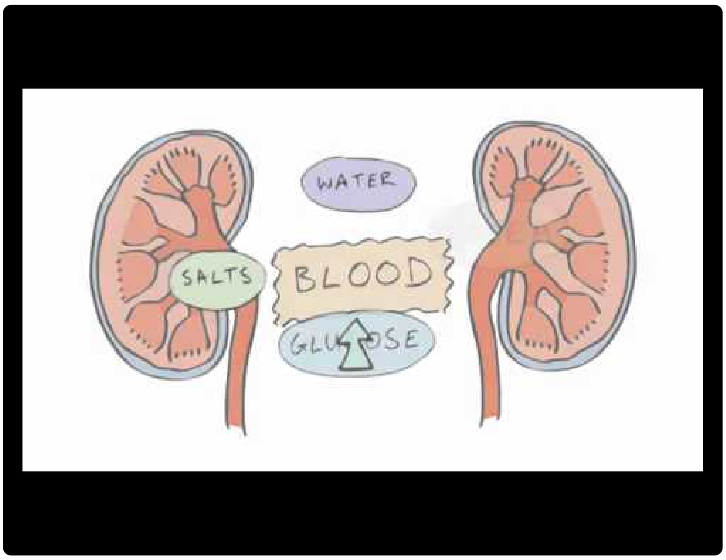
Feedback Regulation. If a raise in body temperature (stimulus) is detected (receptor), a signal will cause the brain to maintain homeostasis (response). Once the body temperature returns to normal, negative feedback will cause the response to end. This sequence of stimulus-receptor-signal-response is used throughout the body to maintain homeostasis.

Positive Feedback

Some processes in the body are regulated by **positive feedback**. **Positive feedback** is when a response to an event increases the likelihood of the event to continue. An example of positive feedback is milk production in nursing mothers. As the baby drinks her mother's milk, the hormone prolactin, a chemical signal, is released. The more the baby suckles, the more prolactin is released, which causes more milk to be produced. Other examples of positive feedback include contractions during childbirth. When constrictions in the uterus push a baby into the birth canal, additional contractions occur.

Failure of Homeostasis

Many homeostatic mechanisms such as these work continuously to maintain stable conditions in the human body. Sometimes, however, the mechanisms fail. When they do, cells may not get everything they need, or toxic wastes may accumulate in the body. If homeostasis is not restored, the imbalance may lead to disease or even death.



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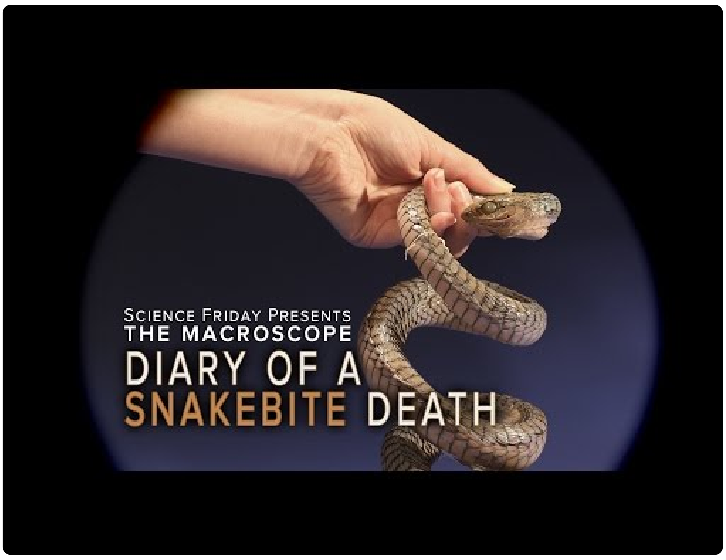
Science Friday: Diary of A Snakebite Death

What does it feel like to be bitten by a venomous snake? In this video by science Friday, learn about how Dr. Karl P. Schmidt wrote about the effects of snake bite venom while he was dying.



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Summary

- All of the organ systems of the body work together to maintain homeostasis of the organism.

- If homeostasis fails, death or disease may result.

Review

1. What is homeostasis?
2. Describe how one of the human organ systems helps maintain homeostasis.
3. A house has several systems, such as the electrical system, plumbing system, and heating and cooling system. In what ways are the systems of a house similar to human body systems?

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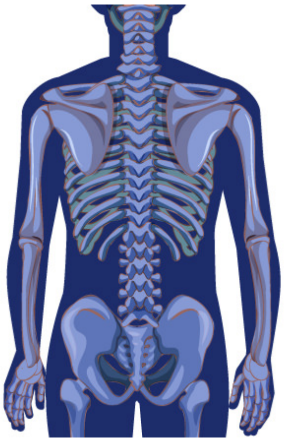
13.3 Skeletal System

FlexBooks 2.0 > Biology For High School Diploma > Skeletal System

Last Modified: Nov 16, 2019



[Figure 1]

The skeletal system consists of all the bones of the body. How important are your bones?

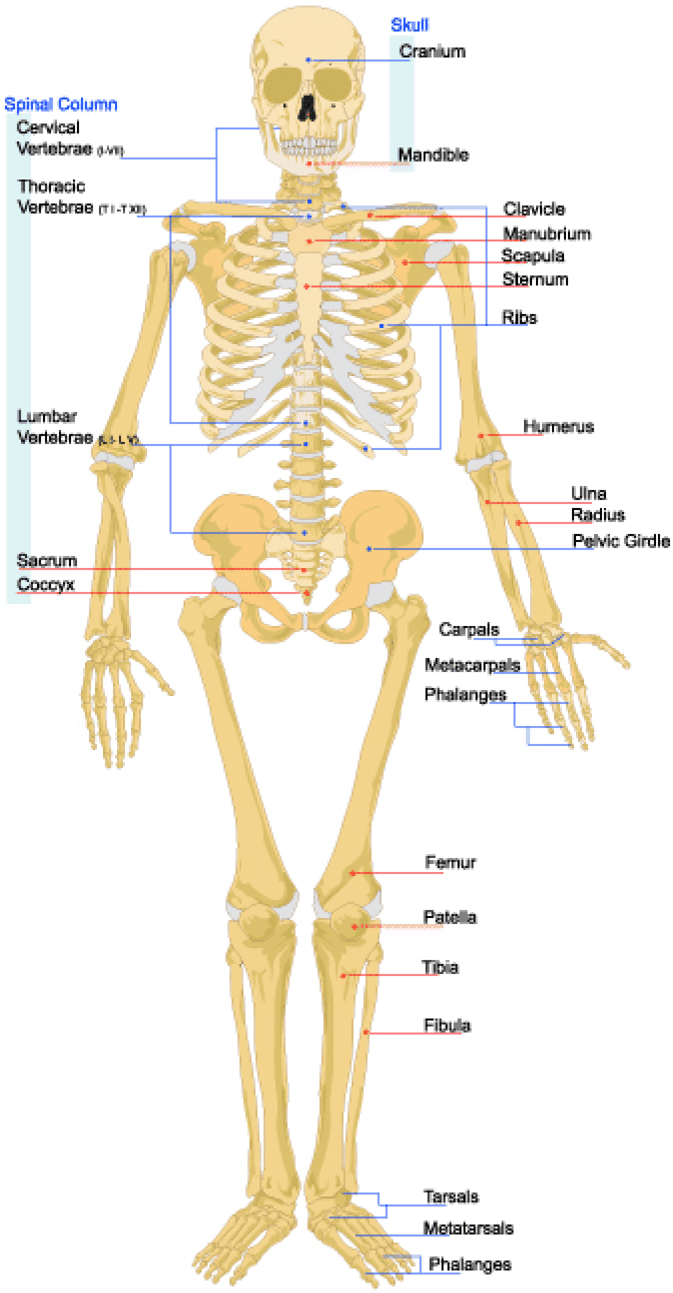
Try to imagine what you would look like without them. You would be a soft, wobbly pile of skin, muscles, and internal organ, so you might look something like a very large slug. Not that you would be able to see yourself—folds of skin would droop down over your eyes and block your vision because of your lack of skull bone. You could push the skin out of the way, if you could only move your arms, but you need bones for that as well!

The Skeleton

The human skeleton is an internal framework that, in adults, consists of 206 **bones**, most of which are shown in **Figure** below.

In addition to bones, the skeleton also consists of **cartilage** and **ligament**:

- **Cartilage** is a type of dense connective tissue, made of tough protein fibers, that provides a smooth surface for the movement of bones at joint.
- A **ligament** is a band of fibrous connective tissue that holds bones together and keeps them in place.



[Figure 2]

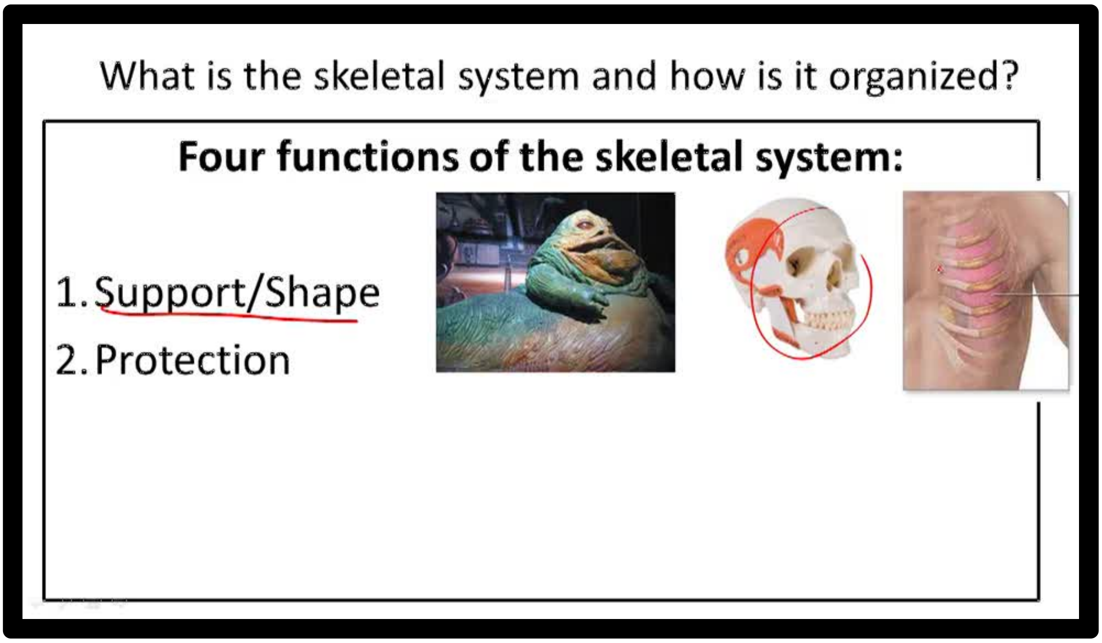
The human skeleton consists of bones, cartilage, and ligaments.

The skeleton supports the body and gives it shape. It has several other functions as well, including:

1. protecting internal organs
2. providing attachment surfaces for muscles
3. producing blood cell
4. storing mineral

5. maintaining **mineral homeostasis**.

Maintaining **mineral homeostasis** is a very important function of the skeleton, because just the right levels of calcium and other minerals are needed in the blood for normal functioning of the body. When mineral levels in the blood are too high, bones absorb some of the minerals and store them as mineral salts, which is why bones are so hard. When blood levels of minerals are too low, bones release some of the minerals back into the blood, thus restoring homeostasis.



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Science Friday: Jump in Jerboas

Jerboas are adorable creatures that are capable of jumping up to three feet. In this video by science Friday, Dr. Kim Cooper reveals how the extremely springy leg bones of jerboas make this possible, and the implications it might have for human bone growth.

https://flexbooks.ck12.org/flx/render/embeddedobject/193679

Further Reading

Bones

Bone Growth

Joints

Skeletal Diseases

Summary

- The adult human skeleton includes 206 bones and other tissues.
- The skeleton supports the body, protects internal organs, produces blood cells, and maintains mineral homeostasis.

Review

1. What is cartilage? What is its role in the skeletal system?
2. List three functions of the human skeleton.
3. Explain how bones maintain mineral homeostasis in the body.

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13.4 Bones

FlexBooks 2.0 > Biology For High School Diploma > Bones

Last Modified: Jul 04, 2019

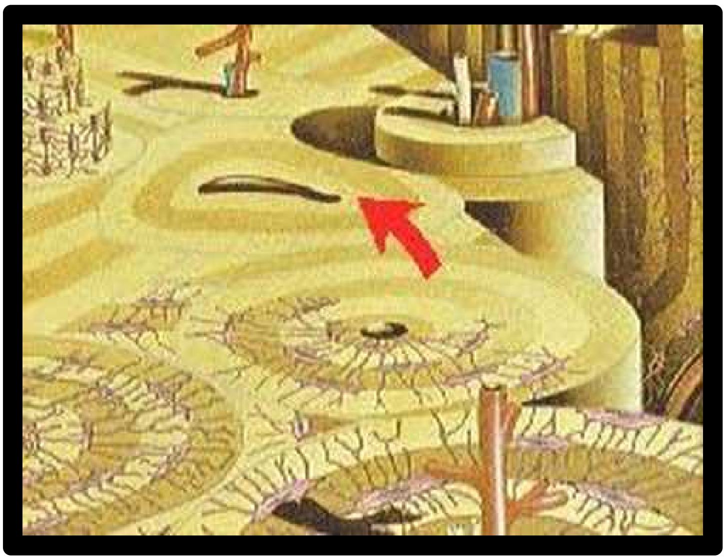
[Figure 1]

Are bones living?

It's common to think of bones as not living. But bones are very much living. In fact, you are constantly making new bone tissue. That means that you are also constantly getting rid of bone. Bone is full of blood and nerve and all sorts of cell and protein, making it an extremely complex living tissue.

Structure of Bones

Many people think of bones as being dead, dry, and brittle. These adjectives correctly describe the bones of a preserved skeleton, but the bones in a living human being are very much alive. As shown in **Figure** below, the basic structure of bones is **bone matrix**, which makes up the underlying rigid framework of bones, composed of both **compact bone** and **spongy bone**. The bone matrix consists of tough protein fibers, mainly **collagen**, that become hard and rigid due to mineralization with calcium crystals. Bone matrix is crisscrossed by blood vessel and nerves and also contains specialized bone cells that are actively involved in metabolic processes.



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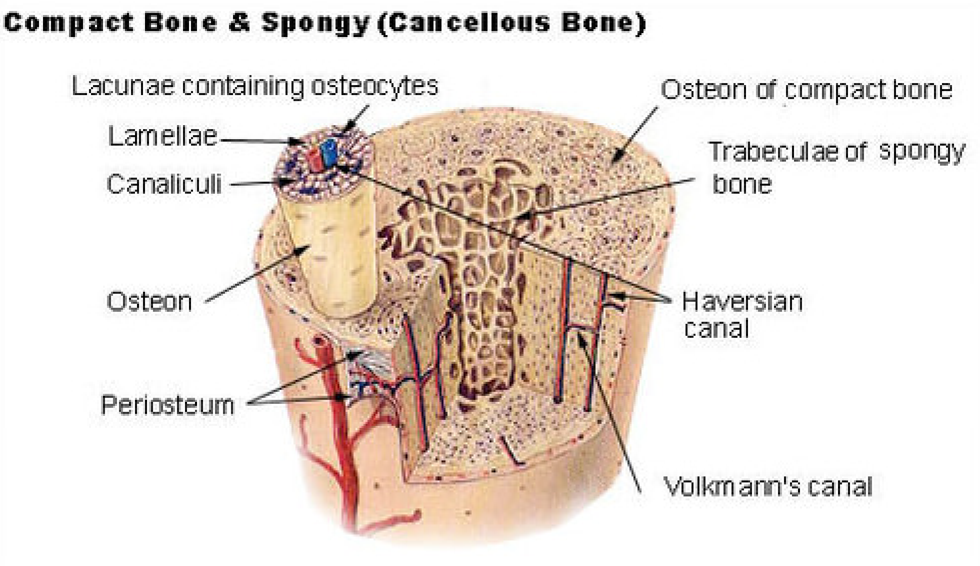


[Figure 2]

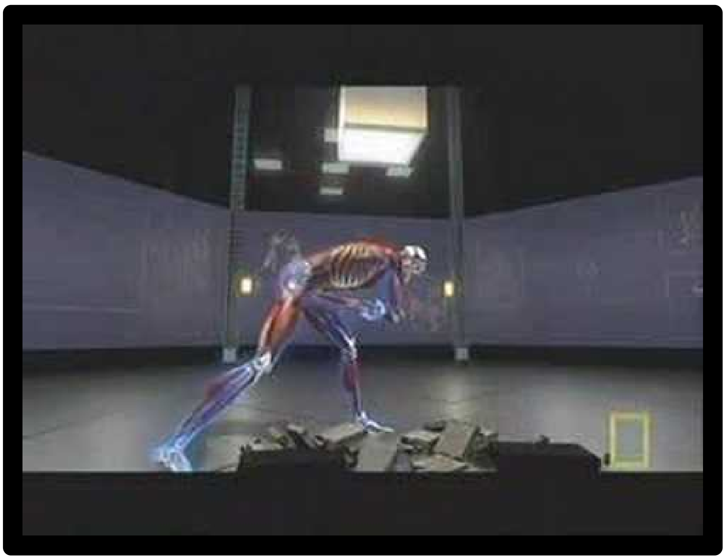
Bone matrix provides bones with their basic structure. Notice the spongy bone in the middle, and the compact bone towards the outer region. The osteon is the functional unit of compact bone.

Bone Cells

There are three types of specialized cells in human bones: osteoblasts, osteocytes, and osteoclasts. These cells are responsible for bone growth and mineral homeostasis.

- **Osteoblasts** make new bone cells and secrete collagen that mineralizes to become bone matrix. They are responsible for bone growth and the uptake of mineral from the blood.
- **Osteocytes** regulate mineral homeostasis. They direct the uptake of minerals from the blood and the release of minerals back into the blood as needed.
- **Osteoclasts** dissolve minerals in bone matrix and release them back into the blood.

Bones are far from static, or unchanging. Instead, they are dynamic, living tissues that are constantly being reshaped. Under the direction of osteocytes, osteoblasts continuously build up bone, while osteoclasts continuously break it down.



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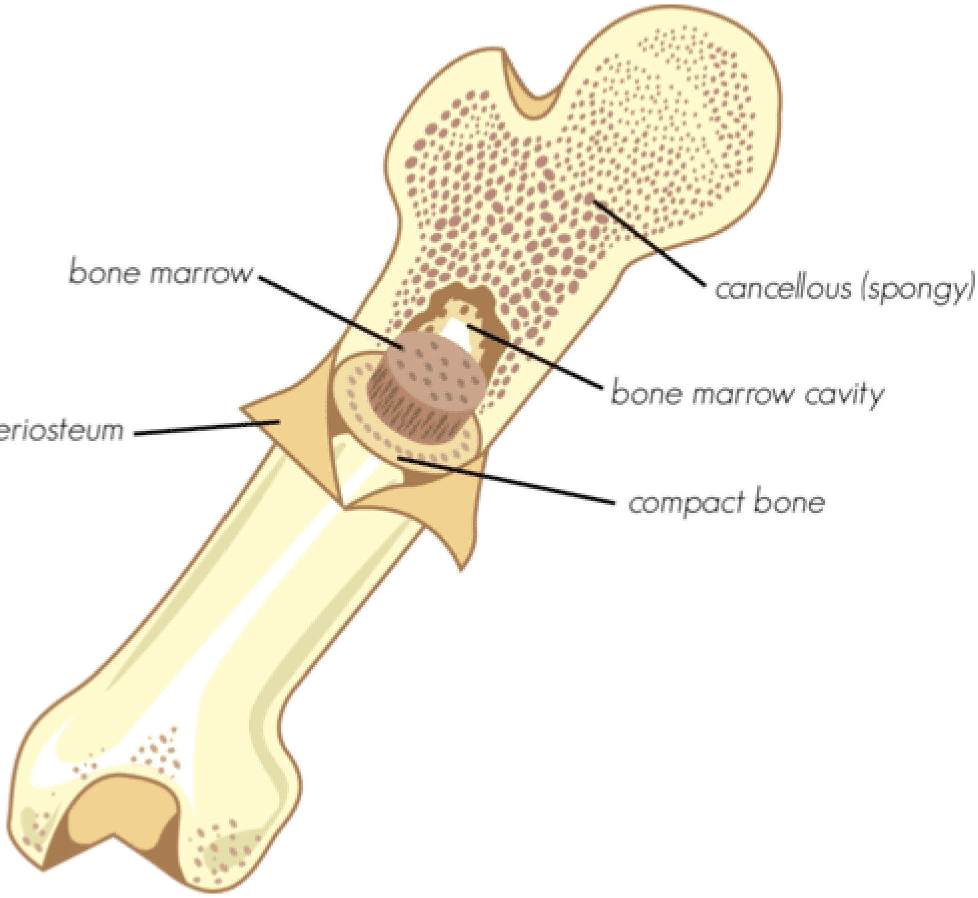
Bone Tissues

Bones consist of different types of tissue, including compact bone, spongy bone, **bone marrow**, and **periosteum**. All of these tissue types are shown in **Figure** below.

- **Compact bone** makes up the dense outer layer of bone. Its functional unit is the **osteon**. Compact bone is very hard and strong.
- **Spongy bone** is found inside bones and is lighter and less dense than compact bone. This is because spongy bone is porous.
- **Bone marrow** is a soft connective tissue that produces blood cells. It is found inside the pores of spongy bone.
- **Periosteum** is a tough, fibrous membrane that covers and protects the outer surfaces of bone.



[Figure 3]

This bone contains different types of bone tissue. How does each type of tissue contribute to the functions of bone?

Summary

- Under the direction of osteocytes, osteoblasts continuously build up bone, while osteoclasts continuously break down bone. These processes help maintain mineral homeostasis.
- Bone tissues include compact bone, spongy bone, bone marrow, and periosteum.

Review

1. Describe bone matrix.
2. Identify the three types of specialized bone cells and what they do.
3. Compare and contrast the structure and function of compact bone and spongy bone.
4. What is bone marrow? Where is it found?

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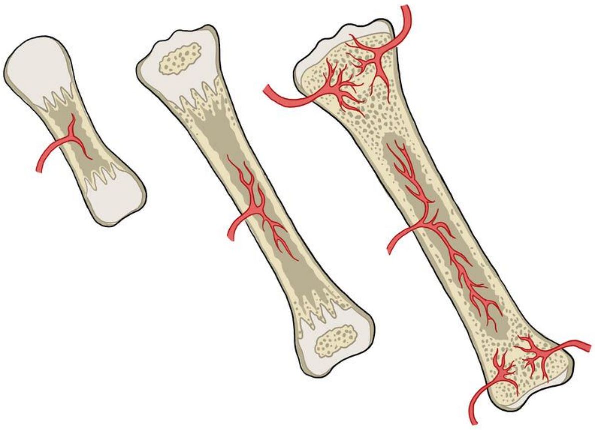
13.5 Bone Growth

FlexBooks 2.0 > Biology For High School Diploma > Bone Growth

Last Modified: Jul 04, 2019



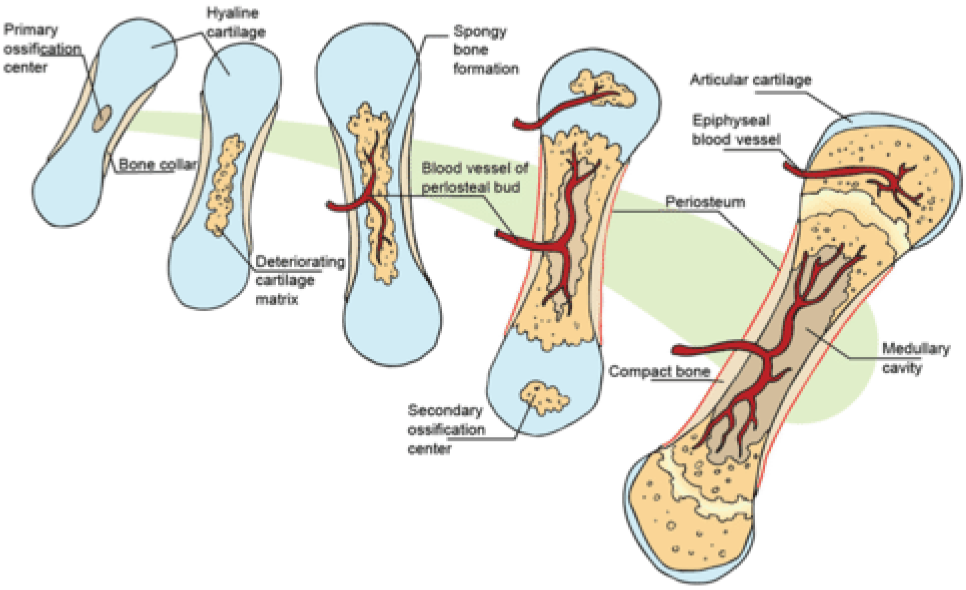
[Figure 1]

How do bones grow?

bone are hard structures. So how do they grow? Well, bones are a living tissue. They have a blood supply. You are consistently making new bone. In fact, the human skeleton is replaced every 7-10 years. But how do bones grow? From their ends, where they have **cartilage**.

Growth and Development of Bones

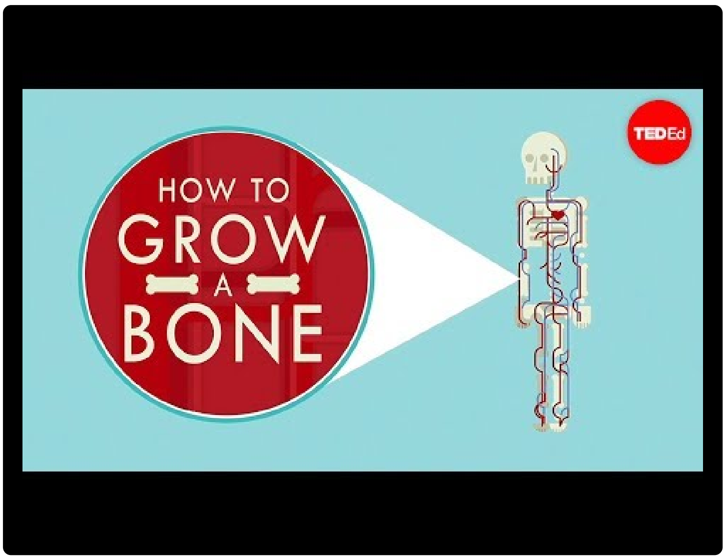
Early in the development of a human fetus, the skeleton is made entirely of **cartilage**. The relatively soft cartilage gradually turns into hard bone through **ossification**. This is a process in which mineral deposits replace cartilage. As shown in **Figure** below, ossification of long bones, which are found in the arms and legs, begins at the center of the bones and continues toward the ends. By birth, several areas of cartilage remain in the skeleton, including **growth plates** at the ends of the long bones. This cartilage grows as the long bones grow, so the bones can keep increasing in length during childhood.



[Figure 2]

Long bones ossify and get longer as they grow and develop. These bones grow from their ends, known as the epiphysis, and the presence of a growth plate, or epiphyseal line, signifies that the bone is still growing.

In the late teens or early twenties, a person reaches skeletal maturity. By then, all of the cartilage has been replaced by bone, so no further growth in bone length is possible. However, bones can still increase in thickness. This may occur in response to increased muscle activity, such as weight training.



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Summary

- Bones become increasingly ossified and grow larger during fetal development, childhood, and adolescence.
- When skeletal maturity is reached at about age 20, no additional growth in bone length can occur.

Review

1. Define ossification.
2. A newborn baby has a soft spot on the top of its head. Over the next few months, the soft spot gradually hardens. What explains this?
3. Jana is 17 years old and 172 cm tall. She plays basketball and hopes to grow at least 4 cm more before she turns 18 and goes to college. Jana recently injured her leg, and her doctor took an X-ray of it. Based on the X-ray, the doctor determined that Jana had reached skeletal maturity. How much taller is Jana likely to grow? Explain your answer.

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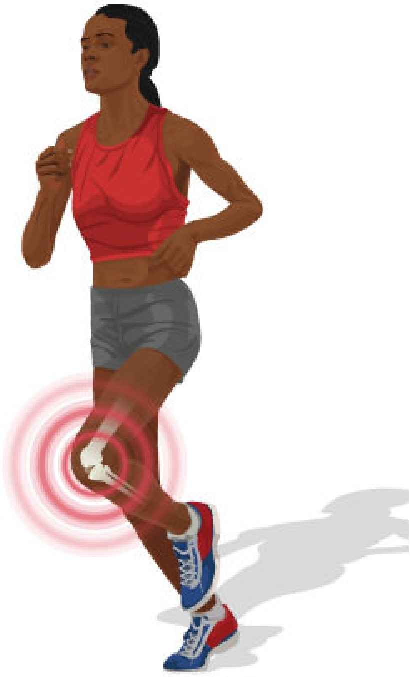
13.6 Joints

FlexBooks 2.0 > Biology For High School Diploma > Joints

Last Modified: May 21, 2021



[Figure 1]

What allows running?

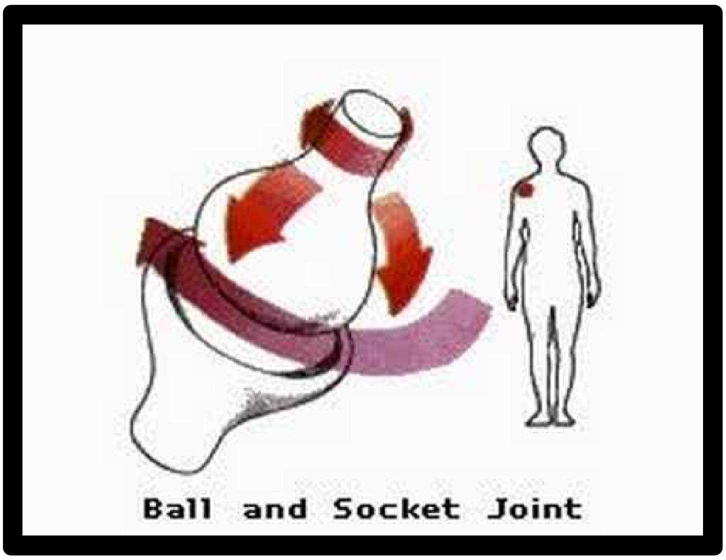
Running. A means of terrestrial locomotion allowing humans and other animal to move rapidly on foot. The knees, which connect one part of the leg to the other, have to allow the legs to move. The knee is a joint, the part of the skeletal system that connects bone.

Joints

A **joint** is a place where two or more bones of the skeleton meet. With the help of muscles, joints work like mechanical levers, allowing the body to move with relatively little force. The surfaces of bones at joints are covered with a smooth layer of **cartilage** that reduces friction at the points of contact between the bones.

Types of Joints

There are three main types of joints: immovable, partly movable, and movable.



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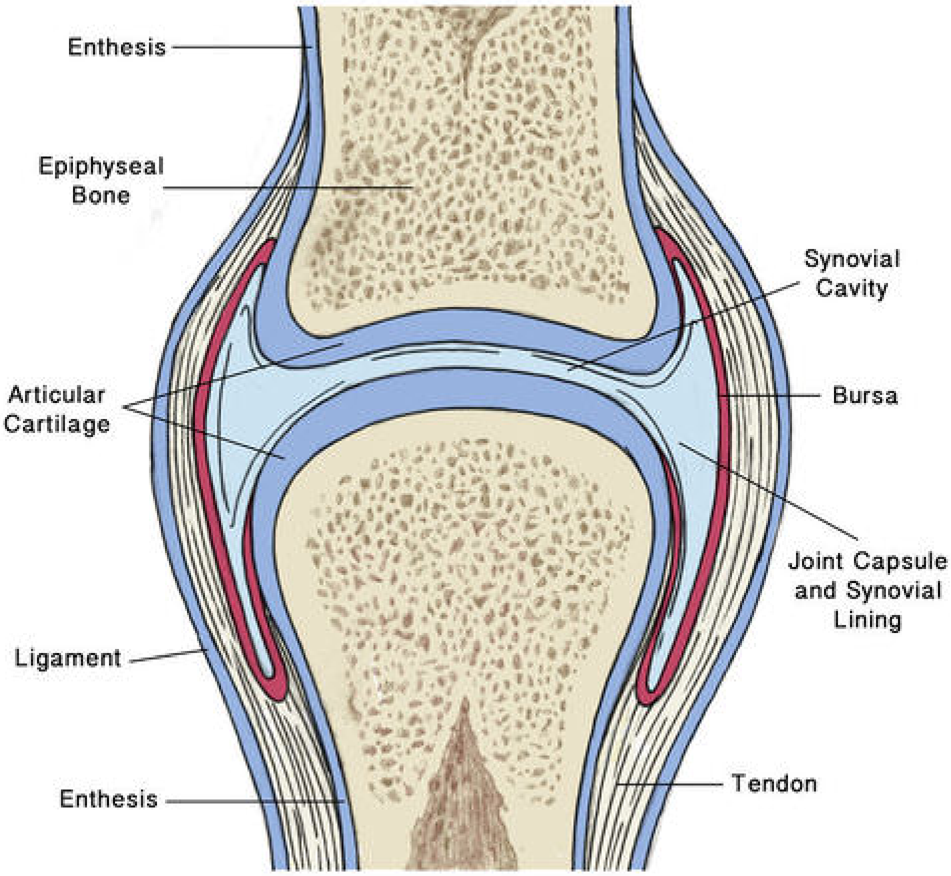
- **immovable joint** allow no movement because the bones at these joints are held securely together by dense **collagen**. The bones of the skull are connected by immovable joints.
- **partly movable joint** allow only very limited movement. Bones at these joints are held in place by cartilage. The ribs and sternum are connected by partly movable joints.
- **movable joint** allow the most movement. Bones at these joints are connected by **ligament**. Movable joints are the most common type of joints in the body, so they are described in more detail next.

Movable Joints

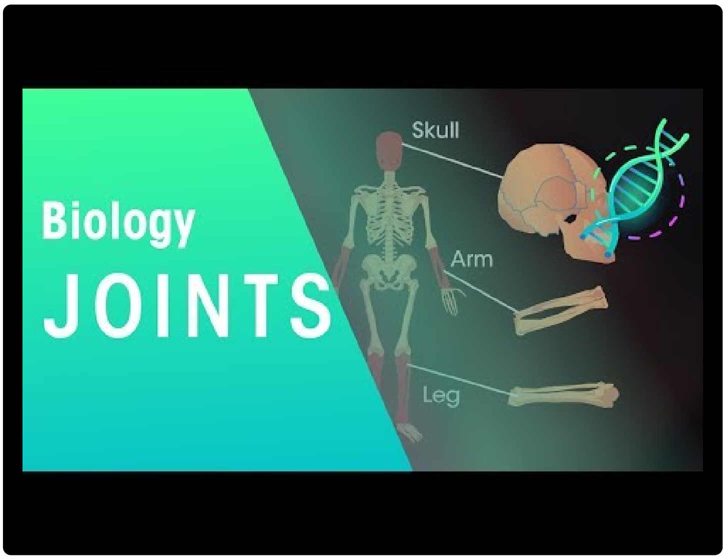
Movable joints are also known as **synovial joint**. This is because the space between the bones is filled with a thick fluid, called **synovial fluid**, that cushions the joint (see **Figure** below).



[Figure 2]

A movable, or synovial, joint is protected and cushioned by cartilage and synovial fluid.

There are a variety of types of movable joints, which are illustrated in **Figure** below. The joints are classified by how they move. For example, a **ball-and-socket joint**, such as the shoulder, has the greatest range of motion, allowing movement in several directions. Other movable joints, including **hinge joint** such as the knee, allow less movement.



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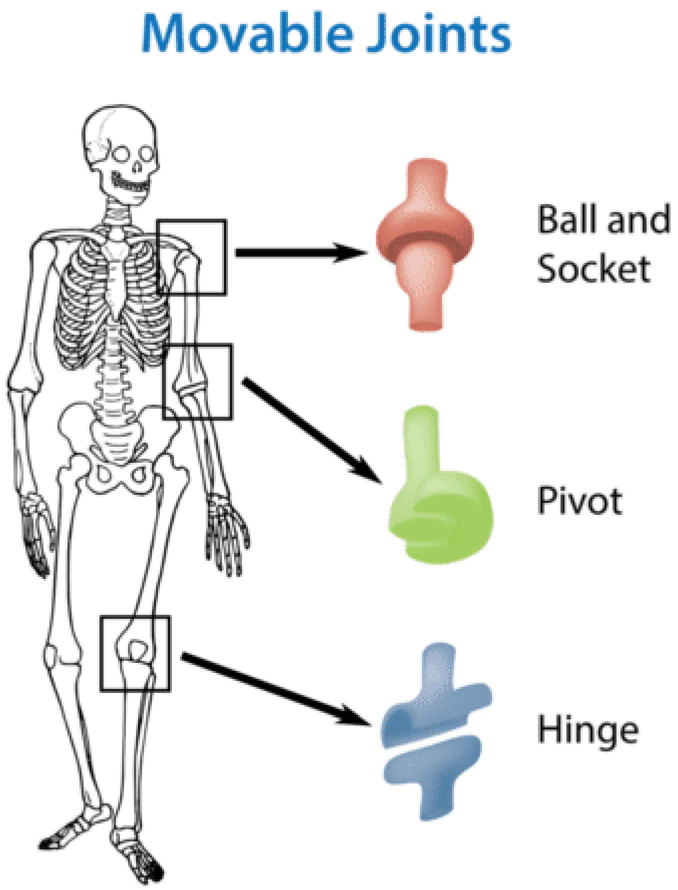


[Figure 3]

Types of Movable Joints in the Human Skeleton. Movable joints can move in a variety of ways. Try moving each of the joints indicated in the diagram. Can you tell how their movements differ? Other joints in the human skeleton that are not depicted here include saddle, ellipsoid, and plane joints.

Summary

- Joints are places where two or more bones of the skeleton meet.
- With the help of muscles, joints allow the body to move with relatively little force.
- Some joints can move more than others.

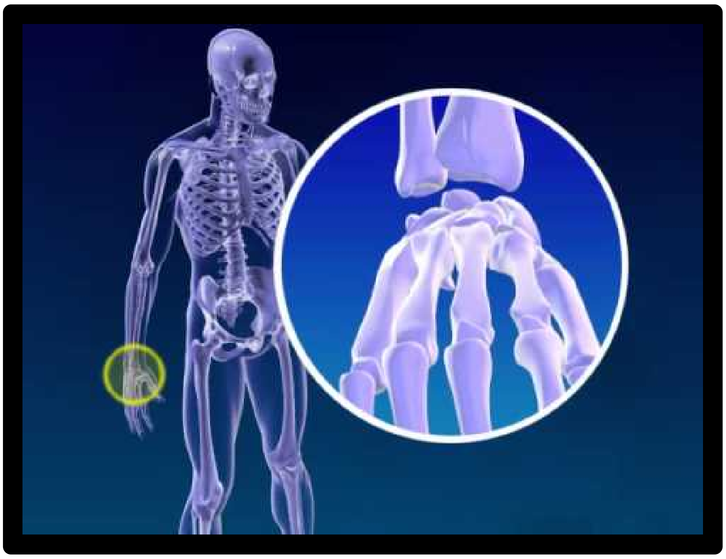
Review

1. Define immovable joint, and give an example of bones that are connected by this type of joint.
2. Describe a synovial joint.

3. Describe the movement of a pivot joint, such as the elbow.

Explore More

Use this resource to answer the questions that follow.



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1. Describe the motion of the following joints:

   a. shoulder

   b. knee

   c. neck

   d. wrist

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13.7 Skeletal Diseases

FlexBooks 2.0 > Biology For High School Diploma > Skeletal Diseases

Last Modified: Mar 28, 2022

[Figure 1]

Do you think this would hurt? Why?

That would probably hurt. And hurt a lot. Broken bone, or **fracture**, may be one of the more common problems of the skeletal system. And this one would probably need surgery to fix. But, in addition to broken bones, there are other problems and diseases of the skeletal system.

Skeletal System Problems

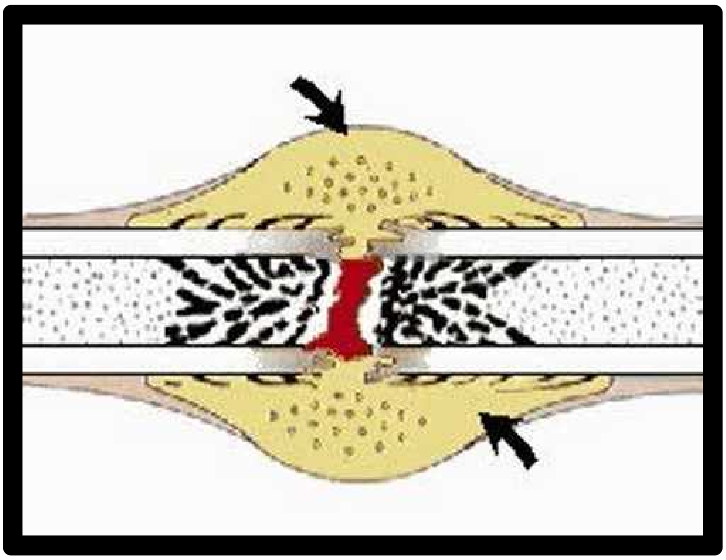
Despite their hardness and strength, bones can suffer from injury and disease. Bone problems include fractures, **osteoarthritis**, and **rickets**.

- **Fractures** are breaks in bone, usually caused by excessive stress on bone. Fractures heal when osteoblasts form new bone. Soon after a fracture, the body begins to repair the break. The area becomes swollen and sore. Within a few days, bone cell travel to the break site and begin to rebuild the bone. It takes about two to three months before compact and spongy bone form at the break site. Sometimes the body needs extra help in repairing a broken bone. In such a case, a surgeon will piece a broken bone together with metal pins. Moving the broken pieces together will help keep the bone from moving and give the body a chance to repair the break.

- **Osteoarthritis** is a condition in which cartilage breaks down in joint due to wear and tear, causing joint stiffness and pain.
- **Osteoporosis** is a disease in which bones lose mass and become more fragile than they should be. Osteoporosis also makes bones more likely to break. Two of the easiest ways to prevent osteoporosis are eating a healthy diet that has the right amount of calcium and vitamin D and to do some sort of weight-bearing exercise every day. Foods that are a good source of calcium include milk, yogurt, and cheese. Non-dairy sources of calcium include Chinese cabbage, kale, and broccoli. Many fruit juices, fruit drinks, tofu, and cereals have calcium added to them. It is recommended that teenagers get 1300 mg of calcium every day. For example, one cup (8 fl. oz.) of milk provides about 300 mg of calcium, or about 30% of the daily requirement.
- **Rickets** is a softening of the bones in children. The most common cause is a vitamin D deficiency. Vitamin D is needed by the body to absorb calcium from foods and to form bones. However, a lack of calcium in one's diet may also cause rickets. Rickets can lead to fractures and bowing of the leg bones, which is illustrated in the **Figure** below.

[Figure 2]

The bones of a child with rickets are so soft that the weight of the body causes them to bend.



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science Friday: **Jump In Jerboas**

It's a potato on toothpicks! No, it's a hopping noodle! A fuzzy rodent T-rex! Any way you look at them, jerboas are about as cute as they come. These adorable critters bounce about on long, springy legs - appendage that just might help us better understand and perhaps manipulate the growth of human bones.

https://flexbooks.ck12.org/flx/render/embeddedobject/193679

Summary

- Skeletal system problems include fractures, osteoarthritis, and rickets.

Review

1. Osteoporosis is a disease in which osteoclasts are more active than osteoblasts. How is this likely to affect the bones? Why would a person with osteoporosis have a greater-than-normal risk of bone fractures?

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13.8 Muscles

FlexBooks 2.0 > Biology For High School Diploma > Muscles

Last Modified: Mar 18, 2021

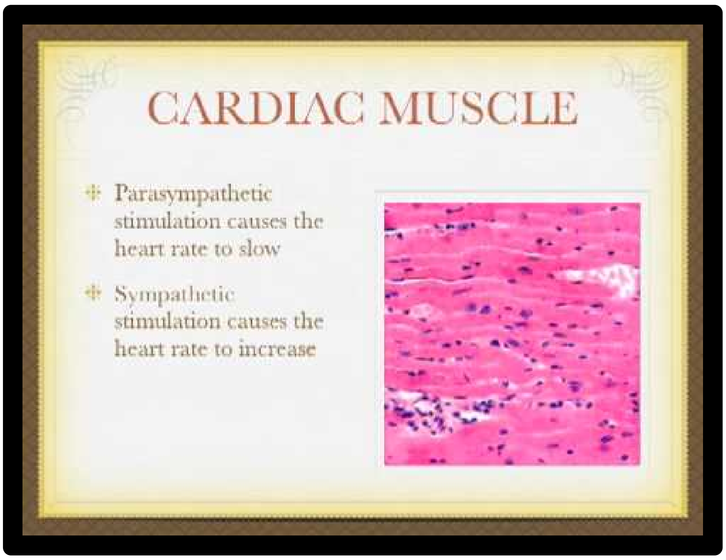
[Figure 1]

What exactly are muscles?

Does the word "muscle" make you think of the biceps of a weightlifter, like the man in pictured above? Muscles such as biceps that move the body are easy to feel and see, but they aren't the only muscles in the human body. Many muscles are deep within the body. They form the walls of internal organ such as the heart and stomach. You can flex your biceps like a body builder, but you cannot control the muscles inside you. It's a good thing that they work on their own without any conscious effort on your part, because movement of these muscles is essential for survival.

What Are Muscles?

The **muscular system** consists of all the muscles of the body. Muscles are composed mainly of muscle cell, which are also called **muscle fiber**. Each muscle fiber is a very long, thin cell that can do something no other cell can do. It can contract, or shorten. Muscle contractions are responsible for virtually all the movements of the body, both inside and out. There are three types of muscle tissue in the human body: cardiac, smooth, and **skeletal muscle** tissue. They are shown in **Figure** below and described below.



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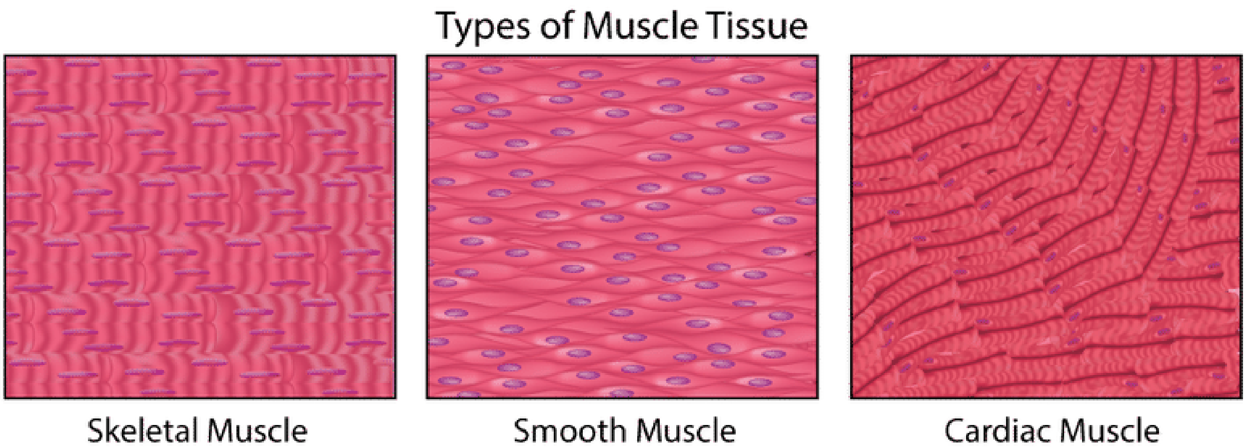

[Figure 2]

Types of Muscle Tissue. Both skeletal and cardiac muscles appear striated, or striped, because their cells are arranged in bundles. Smooth muscles are not striated because their cells are arranged in sheets instead of bundles.

Smooth Muscle

Muscle tissue in the walls of internal organs such as the stomach and intestines is **smooth muscle**. When smooth muscle contracts, it helps the organs carry out their functions. For example, when smooth muscle in the stomach contracts, it squeezes the food inside the stomach, which helps break the food into smaller pieces. Contractions of smooth muscle are involuntary. This means they are not under conscious control.

Skeletal Muscle

Muscle tissue that is attached to bone is **skeletal muscle**. Whether you are blinking your eyes or running a marathon, you are using skeletal muscle. Contractions of skeletal muscle are voluntary, or under conscious control. When skeletal muscle contracts, bones move. Skeletal muscle is the most common type of muscle in the human body.

Cardiac Muscle

cardiac muscle is found only in the walls of the heart. When cardiac muscle contracts, the heart beats and pumps blood. Cardiac muscle contains a great many mitochondrion, which produce ATP for energy. This helps the heart resist fatigue. Contractions of cardiac muscle are involuntary, like those of smooth muscle. Cardiac muscle, like skeletal muscle, is arranged in bundles, so it appears **striated**, or striped.

Further Reading

Skeletal Muscles

Muscle Contraction

Summary

- There are three types of human muscle tissue: smooth muscle (in internal organs), skeletal muscle, and cardiac muscle (only in the heart).

Review

1. Compare and contrast the three types of muscle tissue.
2. What can muscle cells do that other cells cannot?
3. Why are skeletal and cardiac muscles striated?
4. Where is smooth muscle tissue found?
5. What is the function of skeletal muscle? Give an example.

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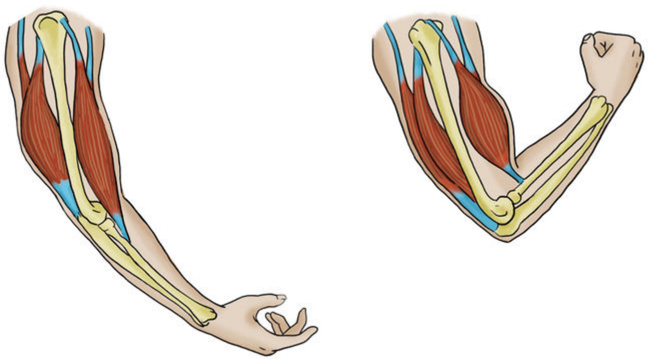
13.9 Skeletal Muscles

FlexBooks 2.0 > Biology For High School Diploma > Skeletal Muscles

Last Modified: Jul 04, 2019



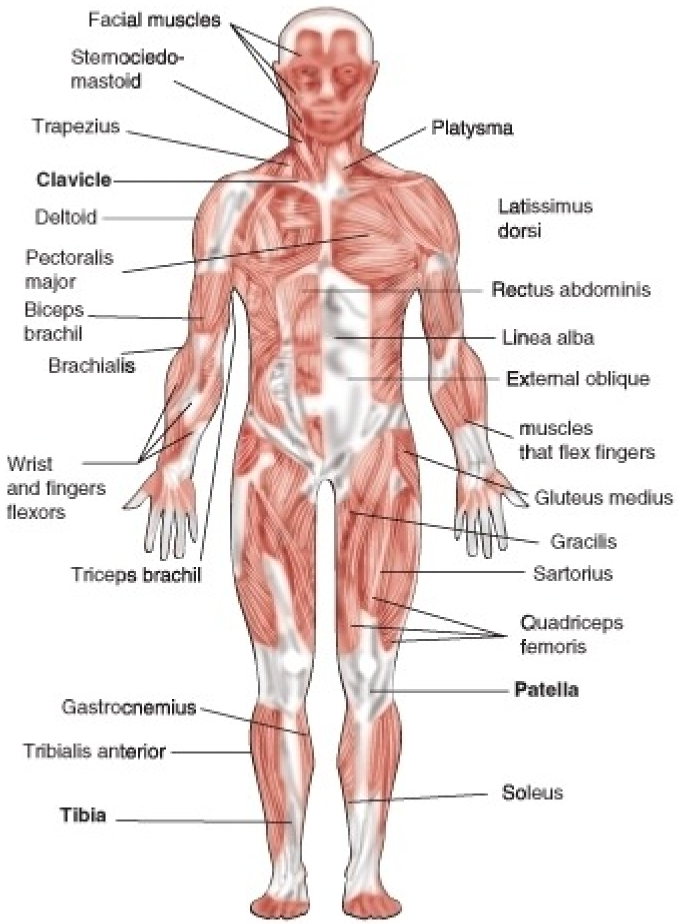
[Figure 1]

How do your bones move?

By the contraction and extension of your skeletal muscles. Notice how the muscles are attached to the bone. The muscles pull on the bones, causing movement.

Skeletal Muscles

There are well over 600 skeletal muscles in the human body, some of which are identified in **Figure** below. Skeletal muscles vary considerably in size, from tiny muscles inside the middle ear to very large muscles in the upper leg.



[Figure 2]

Skeletal Muscles. Skeletal muscles enable the body to move.

Structure of Skeletal Muscles

Each skeletal muscle consists of hundreds or even thousands of skeletal **muscle fiber**. The fibers are bundled together and wrapped in connective tissue, as shown **Figure** below. The connective tissue supports and protects the delicate muscle cell and allows them to withstand the forces of contraction. It also provides pathways for nerve and blood vessel to reach the muscles. Skeletal muscles work hard to move body parts. They need a rich blood supply to provide them with nutrient and oxygen and to carry away their wastes.

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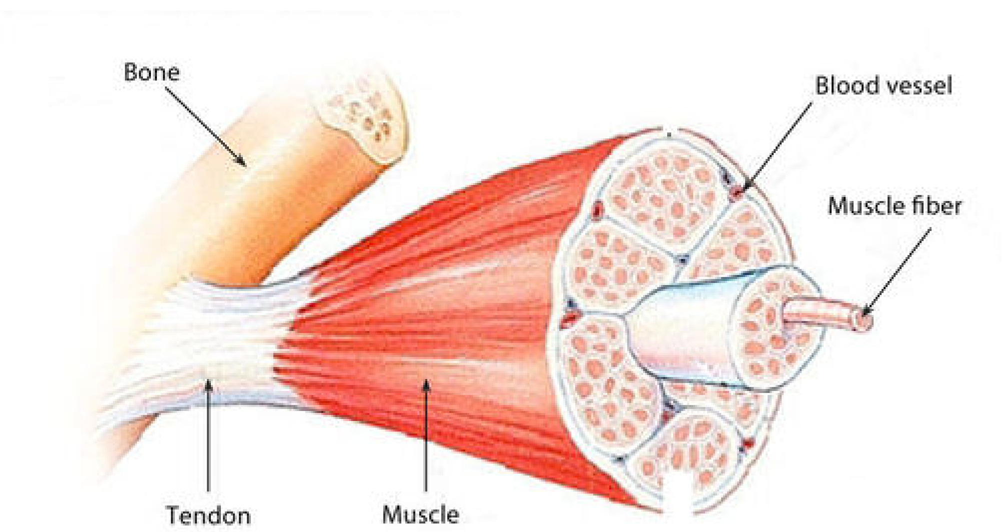

[Figure 3]

Skeletal Muscle Structure. A skeletal muscle contains bundles of muscle fibers inside a "coat" of connective tissue.

Skeletal Muscles and Bones

Skeletal muscles are attached to the skeleton by tough connective tissues called **tendon** (see **Figure** above). Many skeletal muscles are attached to the ends of bones that meet at a **joint**. The muscles span the joint and connect the bones. When the muscles contract, they pull on the bones, causing them to move.

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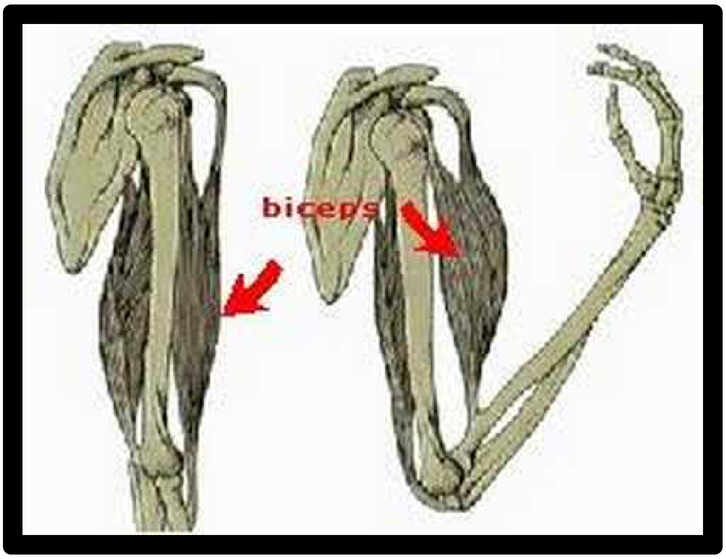
Muscles can only contract. They cannot actively extend, or lengthen. Therefore, to move bones in opposite directions, pairs of muscles must work in opposition. For example, the biceps and triceps muscles of the upper arm work in opposition to bend and extend the arm at the elbow (see **Figure** below). What other body movements do you think require opposing muscle pairs?



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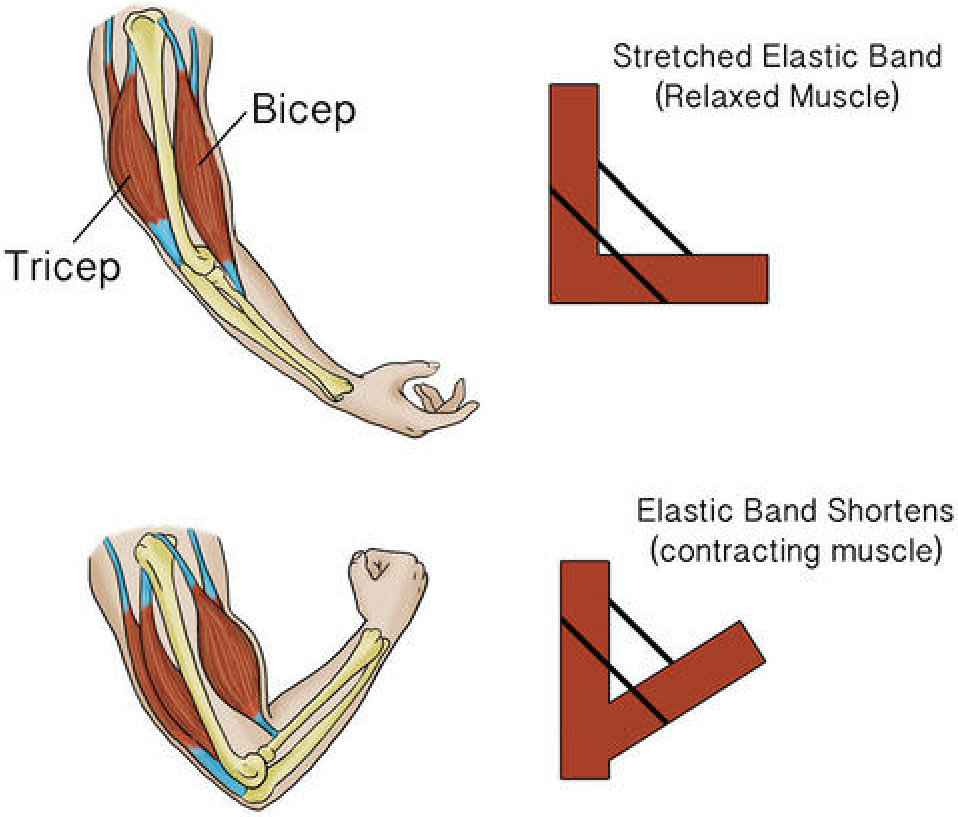

[Figure 4]

Triceps and biceps muscles in the upper arm are opposing muscles.

Use It or Lose It

In exercises such as weight lifting, skeletal muscle contracts against a resisting force (see **Figure** below). Using skeletal muscle in this way increases its size and strength. In exercises such as running, the cardiac muscle contracts faster and the heart pumps more blood. Using cardiac muscle in this way increases its strength and efficiency. Continued exercise is necessary to maintain bigger, stronger muscles. If you don't use a muscle, it will get smaller and weaker—so use it or lose it.

[Figure 5]

This exercise pits human muscles against a force. What force is it?

Summary

- Skeletal muscles are attached to the skeleton and cause bones to move when they contract.

Review

1. What is a muscle fiber?
2. What is the function of skeletal muscle?
3. How are skeletal muscles attached to bones?
4. Explain why many skeletal muscles must work in opposing pairs.

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13.10 Muscle Contraction

FlexBooks 2.0 > Biology For High School Diploma > Muscle Contraction

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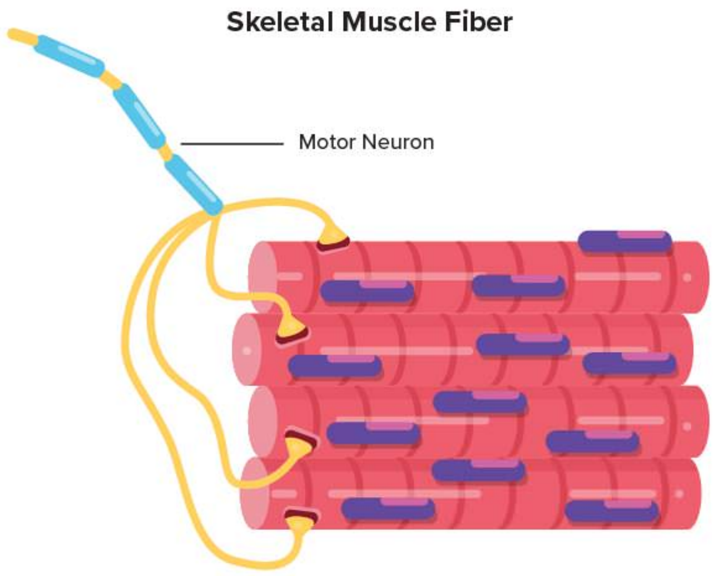


[Figure 1]

What makes a muscle contract?

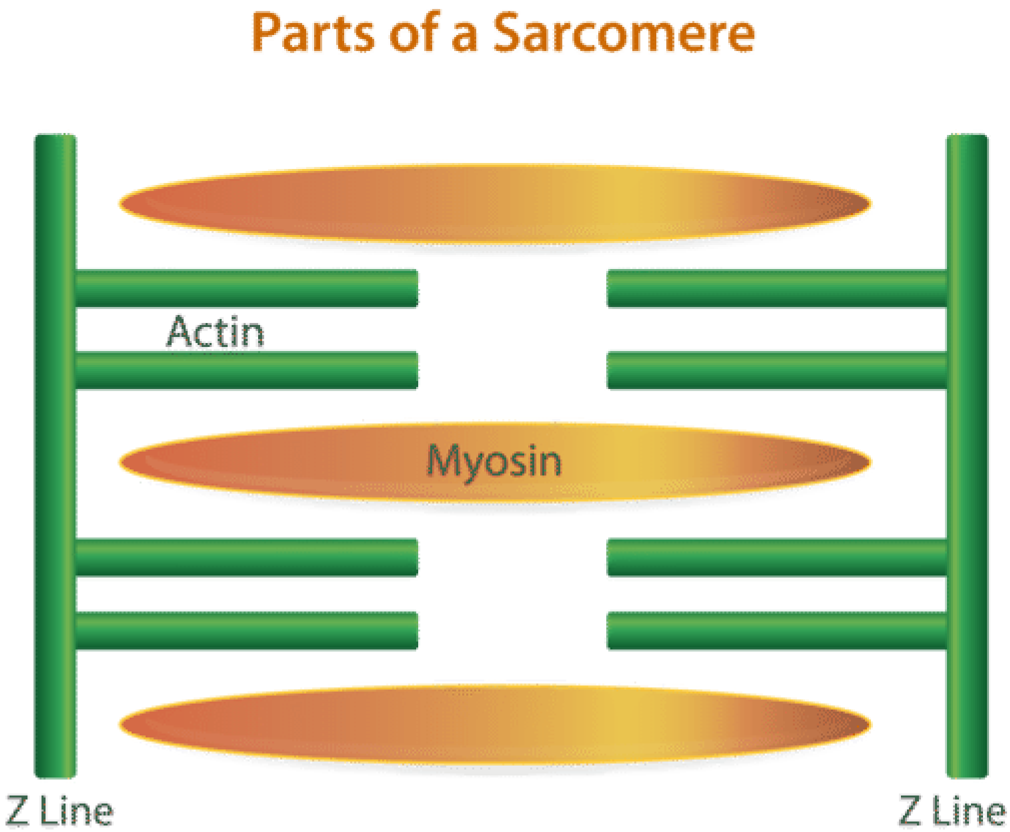
It starts with a signal from the nervous system. So it starts with a signal from your brain. The signal goes through your nervous system to your muscle. Your muscle contracts, and your bone move. And all this happens incredibly fast.

Muscle Contraction

Muscle contraction occurs when muscle fiber get shorter. Literally, the muscle fibers get smaller in size. To understand how this happens, you need to know more about the structure of muscle fibers.

Structure of Muscle Fibers

Each muscle fiber contains hundreds of organelle called **myofibrils**. Each myofibril is made up of two types of protein filaments: **actin** filaments, which are thinner, and **myosin** filaments, which are thicker. Actin filaments are anchored to structures called **Z lines** (see **Figure** below). The region between two Z lines is called a **sarcomere**. Within a sarcomere, myosin filaments overlap the actin filaments. The myosin filaments have tiny structures called **cross bridge** that can attach to actin filaments.

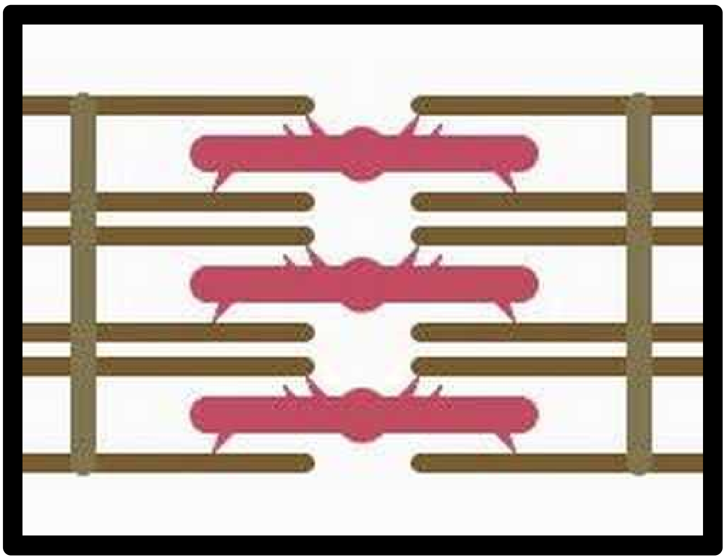


[Figure 2]

Sarcomere. A sarcomere contains actin and myosin filaments between two Z lines.

Sliding Filament Theory

The most widely accepted theory explaining how muscle fibers contract is called the **sliding filament theory**. According to this theory, myosin filaments use energy from ATP to "walk" along the actin filaments with their cross bridges. This pulls the actin filaments closer together. The movement of the actin filaments also pulls the Z lines closer together, thus shortening the sarcomere.



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When all of the sarcomeres in a muscle fiber shorten, the fiber contracts. A muscle fiber either contracts fully or it doesn't contract at all. The number of fibers that contract determines the strength of the muscular force. When more fibers contract at the same time, the force is greater.

Muscles and Nerves

Muscles cannot contract on their own. They need a stimulus from a nerve cell to "tell" them to contract. Let's say you decide to raise your hand in class. Your brain sends electrical messages to nerve cells, called **motor neuron**, in your arm and shoulder. The motor neurons, in turn, stimulate muscle fibers in your arm and shoulder to contract, causing your arm to rise. Involuntary contractions of cardiac and smooth muscle are also controlled by nerves.

Summary

- According to the sliding filament theory, a muscle fiber contracts when myosin filaments pull actin filaments closer together and thus shorten sarcomeres within a fiber.
- When all the sarcomeres in a muscle fiber shorten, the fiber contracts.

Review

1. What is a sarcomere and Z-line?
2. What are the two protein filaments of a myofibril?
3. Explain how muscles contract according to the sliding filament theory.
4. A serious neck injury may leave a person paralyzed from the neck down. Explain why.

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13.11 Skin

FlexBooks 2.0 > Biology For High School Diploma > Skin

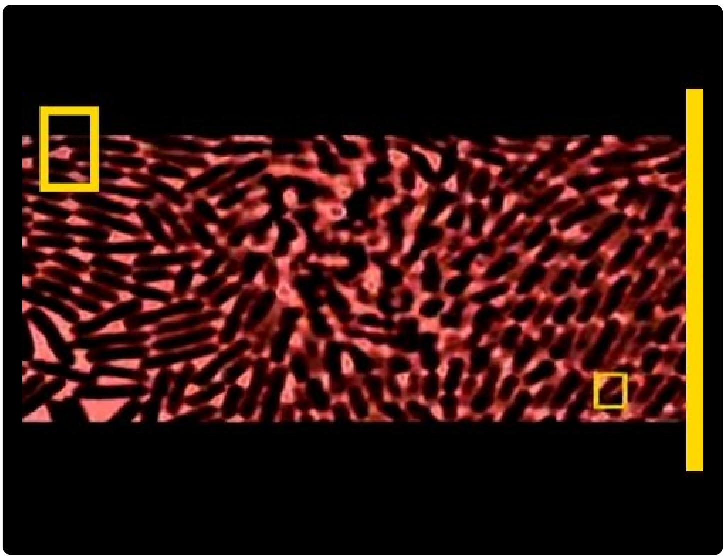
Last Modified: Jul 20, 2020

What is integumentary?

Because the organ of the **integumentary system** are external to the body, you may think of them as little more than "accessories," like clothing or jewelry. But the organs of the integumentary system serve important biological functions. They provide a protective covering for the body and help the body maintain homeostasis.

The Skin

The skin is the major organ of the **integumentary system**, which also includes the nails and hair. In fact, the skin is the body's largest organ, and a remarkable one at that. Consider these skin facts. The average square inch (6.5 cm^2) of skin has 20 blood vessel, 650 **sweat gland**, and more than a thousand nerve endings. It also has an incredible 60,000 pigment-producing cell. All of these structures are packed into a stack of cells that is just 2 mm thick, or about as thick as the cover of a book.



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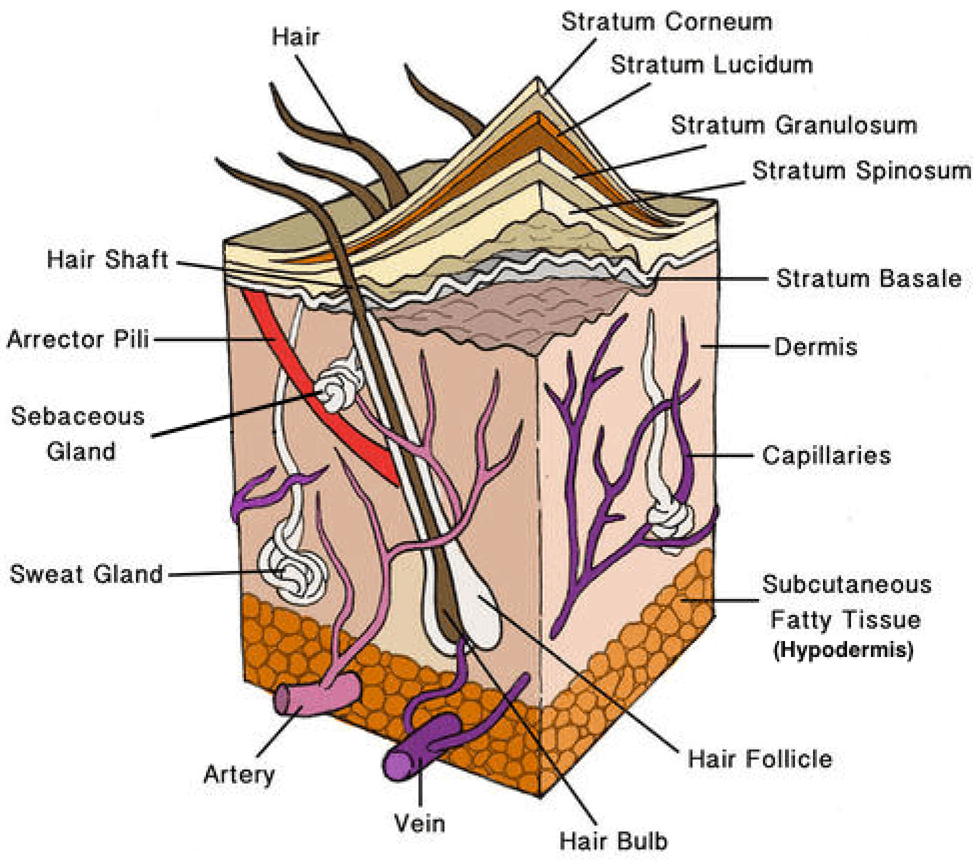
Although the skin is thin, it consists of two distinct layers, called the **epidermis** and the **dermis**. These layers are shown in **Figure** below.

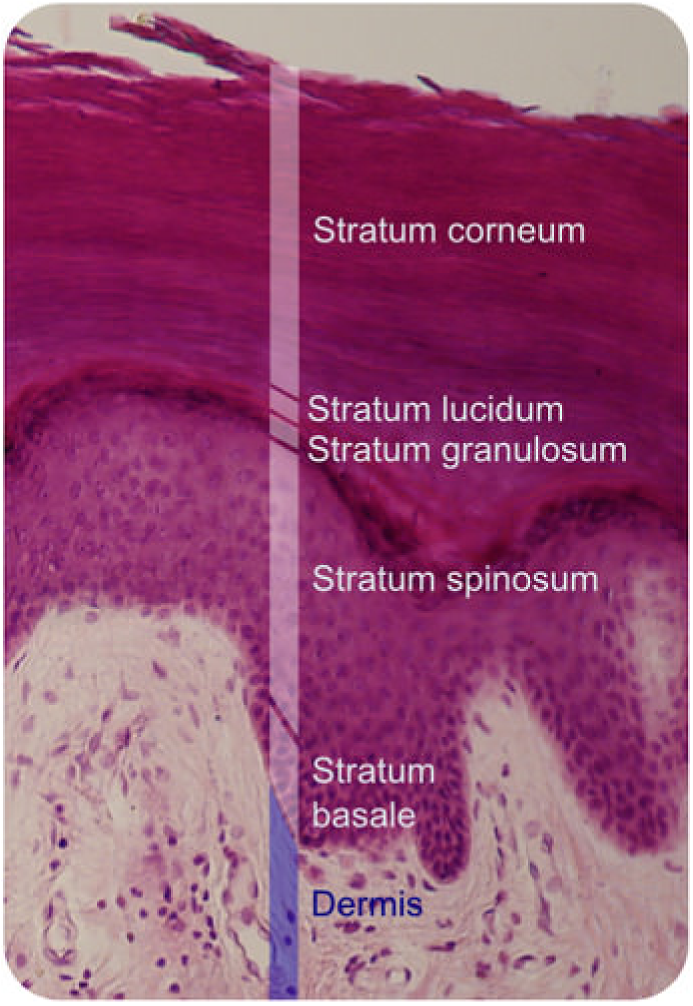


[Figure 1]

Layers of Human Skin. The outer layer of the skin is the epidermis, and the inner layer is the dermis. Most skin structures originate in the dermis.

Epidermis

The **epidermis** is the outer layer of skin, consisting of epithelial cells and little else (see **Figure** below). For example, there are no nerve endings or blood vessels in the epidermis. The innermost cells of the epidermis are continuously dividing through mitosis to form new cells. The newly formed cells move up through the epidermis toward the skin surface, while producing a tough, fibrous protein called **keratin**. The cells become filled with keratin and die by the time they reach the surface, where they form a protective, waterproof layer called the **stratum corneum**. The dead cells are gradually shed from the surface of the skin and replaced by other cells.



[Figure 2]

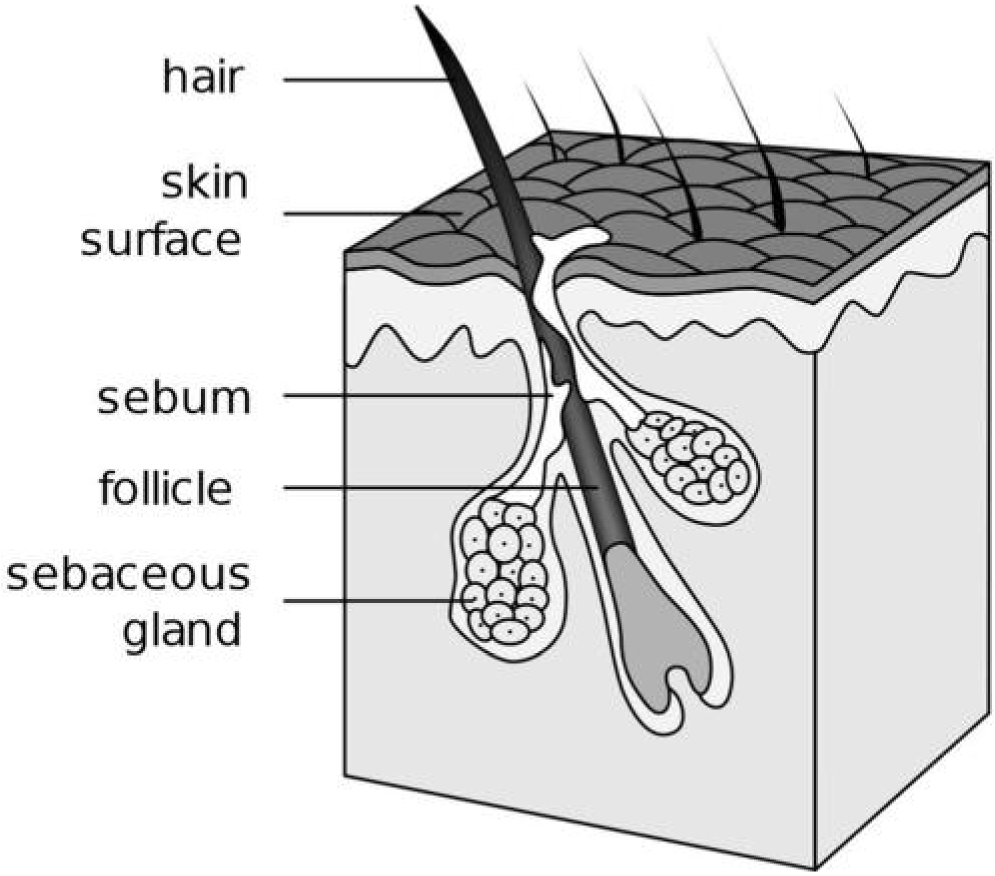
Cell Layers of the Epidermis. The epidermis consists mainly of epithelial cells.

The epidermis also contains **melanocyte**, which are cells that produce **melanin**. **Melanin** is the brownish pigment that gives skin much of its color. Everyone has about the same number of melanocytes, but the melanocytes of people with darker skin produce more melanin. The amount of melanin produced is determined by heredity and exposure to UV light, which increases melanin output. Exposure to UV light also stimulates the skin to produce **vitamin D**. Because melanin blocks UV light from penetrating the skin, people with darker skin may be at greater risk of vitamin D deficiency.

Dermis

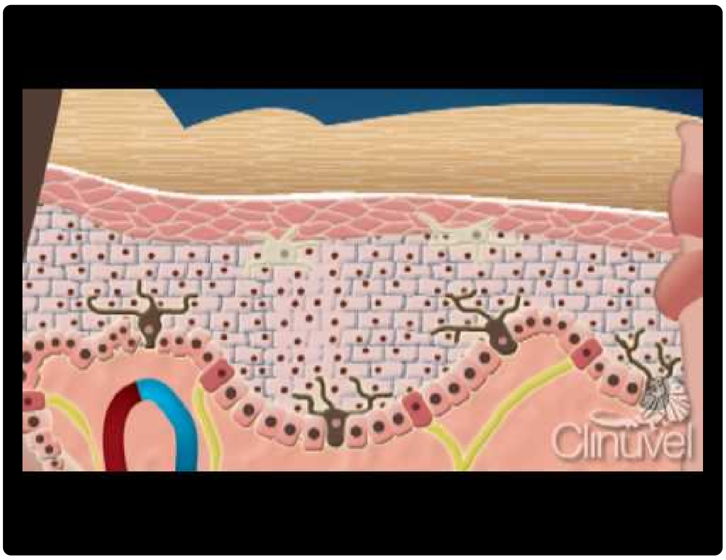
The **dermis** is the lower layer of the skin, located directly beneath the epidermis (see **Figure** below). It is made of tough connective tissue and attached to the epidermis by collagen fibers. The dermis contains blood vessels and nerve endings. Because of the nerve endings, skin can feel touch, pressure, heat, cold, and pain. The dermis also contains **hair follicle** and two types of glands.

- **Hair follicles** are the structures where hairs originate. Hairs grow out of follicle, pass through the epidermis, and exit at the surface of the skin.
- **sebaceous gland** produce an oily substance called **sebum**. Sebum is secreted into hair follicles and makes its way to the skin surface. It waterproofs the hair and skin and helps prevent them from drying out. Sebum also has antibacterial properties, so it inhibits the growth of microorganisms on the skin.
- **Sweat glands** produce the salty fluid called sweat, which contains excess water, salts, and other waste products. The glands have ducts that pass through the epidermis and open to the surface through pores in the skin.



[Figure 3]

Structures of the Dermis. The dermis contains most of the structures found in skin.



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Functions of the Skin

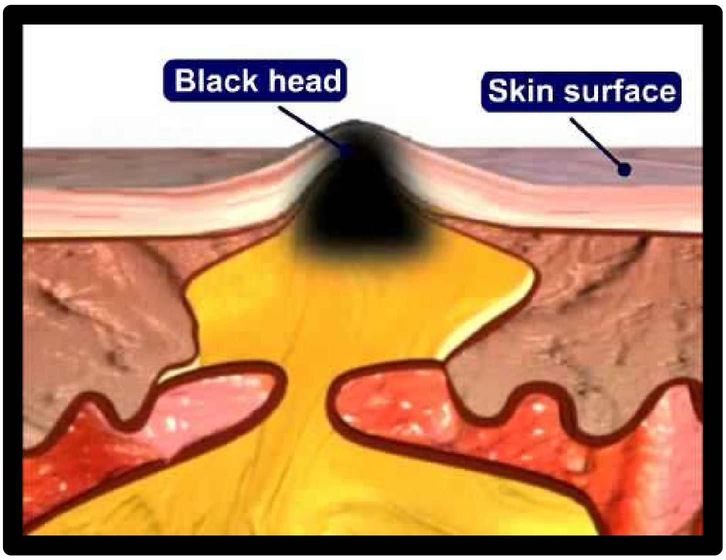
The skin has multiple roles in the body. Many of these roles are related to homeostasis. The skin's main functions are preventing water loss from the body and serving as a barrier to the entry of microorganisms. In addition, melanin in the skin blocks UV light and protects deeper layers from its damaging effects.

The skin also helps regulate body temperature. When the body is too warm, sweat is released by the sweat glands and spreads over the skin surface. As the sweat evaporates, it cools the body. Blood vessels in the skin also dilate, or widen, when the body is too warm. This allows more blood to flow through the skin, bringing body heat to the surface, where it radiates into the environment. When the body is too cool, sweat glands stop producing sweat, and blood vessels in the skin constrict, or narrow, thus conserving body heat.

Skin Problems

In part because it is exposed to the environment, the skin is prone to injury and other problems. Two common problems of the skin are **acne** and **skin cancer** (see **Figure** below).

- **Acne** is a condition in which red bumps called pimples form on the skin due to a bacterial infection. It affects more than 85 percent of teens and may continue into adulthood. The underlying cause of acne is excessive secretion of sebum, which plugs hair follicles and makes them good breeding grounds for bacterium.



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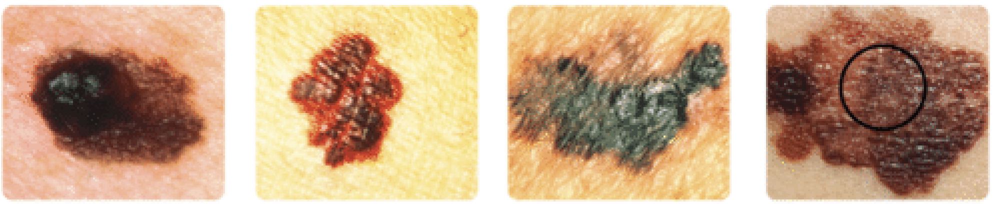
- **Skin cancer** is a disease in which skin cells grow out of control. It is caused mainly by excessive exposure to UV light. People with lighter skin are at greater risk of developing skin cancer because they have less melanin to block harmful UV radiation. The best way to prevent skin cancer is to avoid UV exposure by using sunscreen and wearing protective clothing.



[Figure 4]

ABCDs of Skin Cancer. A brown spot on the skin is likely to be a harmless mole, but it could be a sign of skin cancer. Unlike moles, skin cancers are generally asymmetrical, have irregular borders, may be very dark in color, and may have a relatively great diameter.

Further Reading

Nails and Hair

Summary

- The skin consists of two layers: the epidermis, which contains mainly epithelial cells, and the dermis, which contains most of skin's other structures, including blood vessels, nerve endings, hair follicles, and glands.

- Skin protects the body from injury, water loss, and microorganisms. It also plays a major role in maintaining a stable body temperature.
- Common skin problems include acne and skin cancer.

Review

1. What organs make up the integumentary system?
2. Describe how new epidermal cells form, develop, and are shed from the body.
3. What is keratin?
4. What is the function of the stratum corneum?
5. What is acne? What causes acne?
6. Assume that you get a paper cut, but it doesn't bleed. How deep is the cut? How do you know?
7. Skin cancer has been increasing over recent decades. What could explain this? (Hint: What is the main cause of skin cancer?)
8. Explain how melanin is related to skin color, vitamin D production, and skin cancer.
9. Explain how the skin helps the body maintain a stable temperature.

13.12 Nails and Hair

FlexBooks 2.0 > Biology For High School Diploma > Nails and Hair

Last Modified: Jul 04, 2019

[Figure 1]

Would you believe this is a close-up of your hair and scalp?

Well maybe not yours. But some other person's. Hair is an integral part of the integumentary system. And although many people may lose some or all of the hair on top of their head, they still have hair on their arms and legs that perform important functions.

Nails and Hair

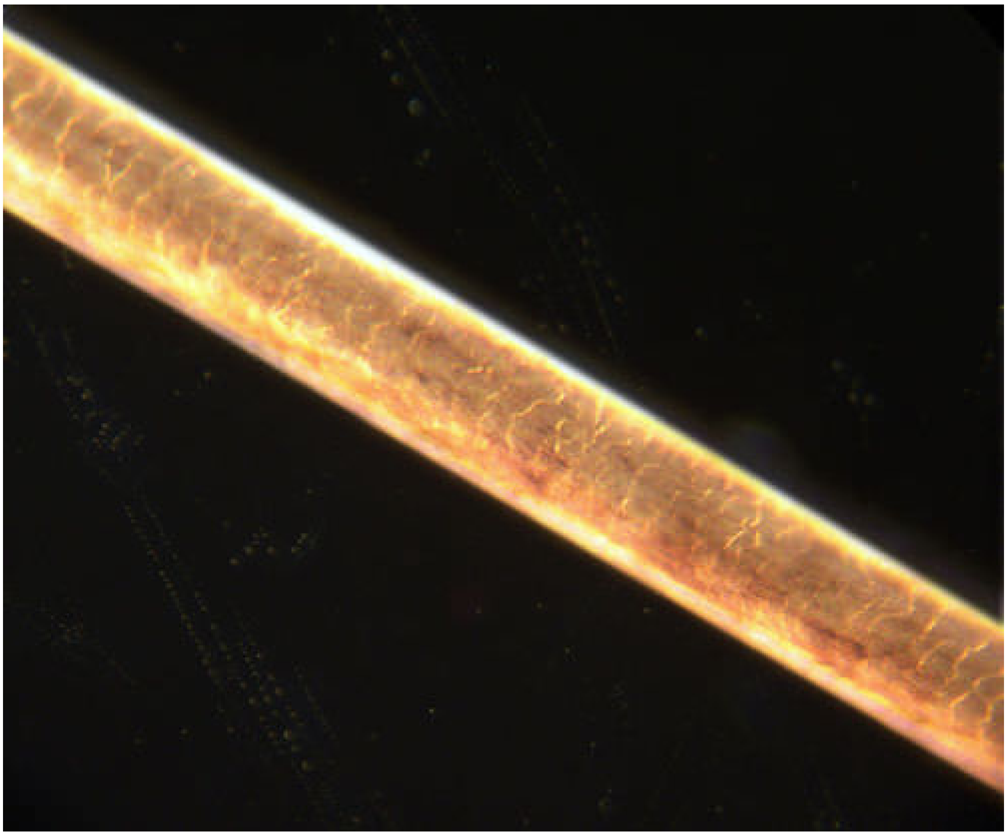
In addition to the skin, the integumentary system includes the nails and hair. Like the skin, these organ help the body maintain homeostasis.

Nails

Fingernails and toenails consist of specialized epidermal cell that are filled with **keratin**. The keratin makes them tough and hard, which is important for the functions they serve. Fingernails prevent injury by forming protective plates over the ends of the fingers. They also enhance sensation by acting as a counterforce to the sensitive fingertips when objects are handled. Nails are similar to claws in other animal. They cover the tips of fingers and toes. Fingernails and toenails both grow from nail beds. As the nail grows, more cells are added at the nail bed. Older cells get pushed away from the nail bed and the nail grows longer. There are no nerve endings in the nail. Otherwise cutting your nails would hurt a lot!

Hair

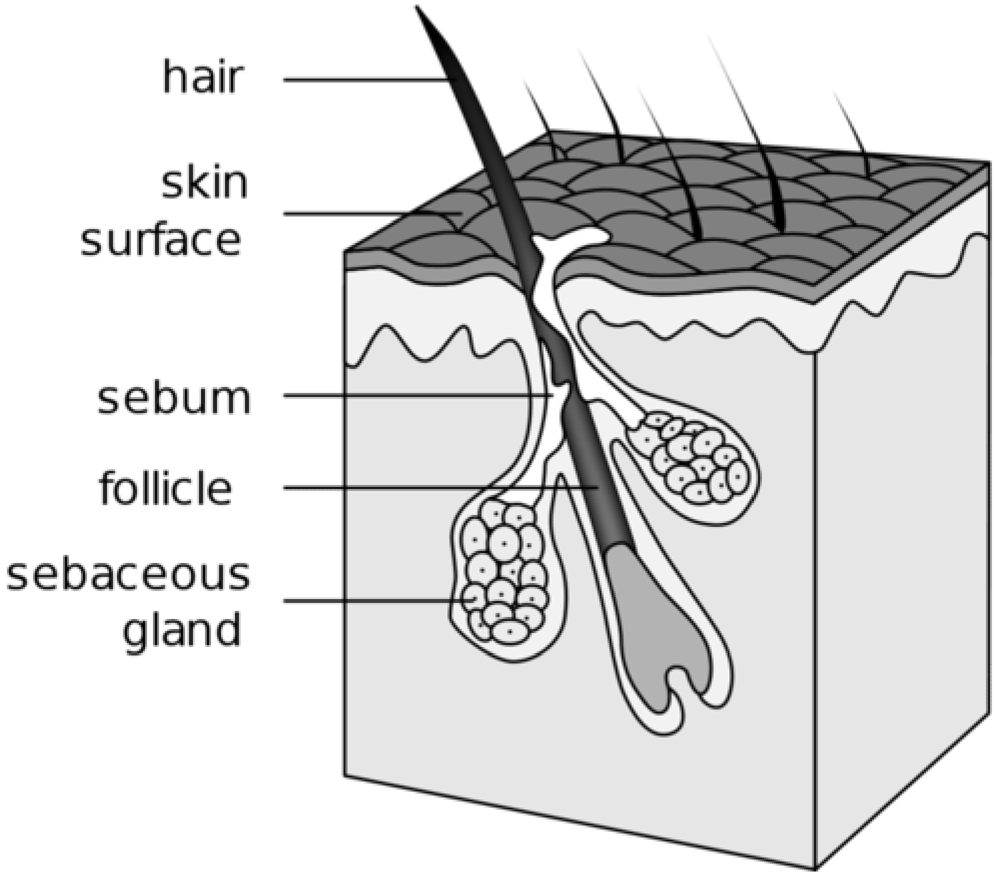
Hair is one of the defining characteristics of mammals. Its main component is keratin. A hair shaft consists of dead, keratin-filled cells that overlap each other like the shingles on a roof (see **Figure** below). Like roof shingles, the overlapping cells help shed water from the hair.



[Figure 2]

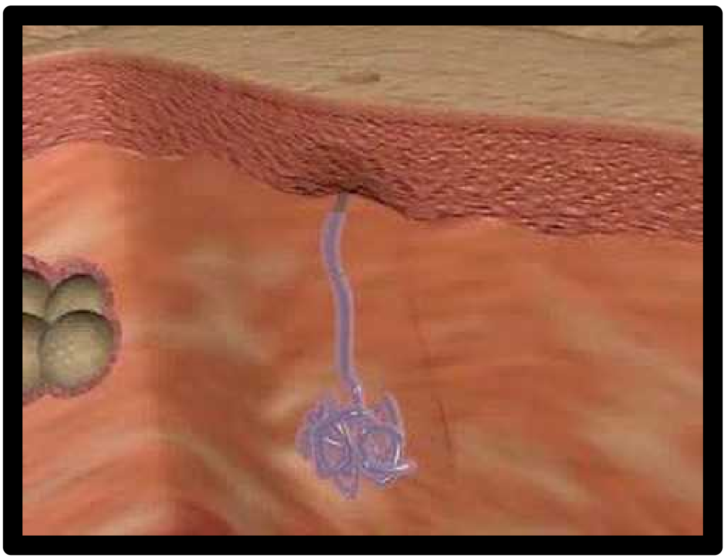
Shaft of Human Hair. This shaft of hair is magnified to show its overlapping cells.

Hair helps to insulate and protect the body. Head hair is especially important in preventing heat loss from the body. Eyelashes and eyebrows protect the eyes from water, dirt, and other irritants. Hairs in the nose trap dust particles and microorganisms in the air and prevent them from reaching the lung. Hair also provides sensory input when objects brush against it or it sways in moving air.



[Figure 3]

Hair, hair follicle, and oil glands. The oil, called sebum, helps to prevent water loss from the skin. The sebaceous gland secretes sebum, which waterproofs the skin and hair.



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Summary

- Nails and hair contain mostly keratin. They protect the body and enhance the sense of touch.

Review

1. A certain disease causes the loss of all body hair. How might homeostasis of the body be disturbed by the absence of hair? (Hint: What are the functions of hair?)

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13.13 Neuron

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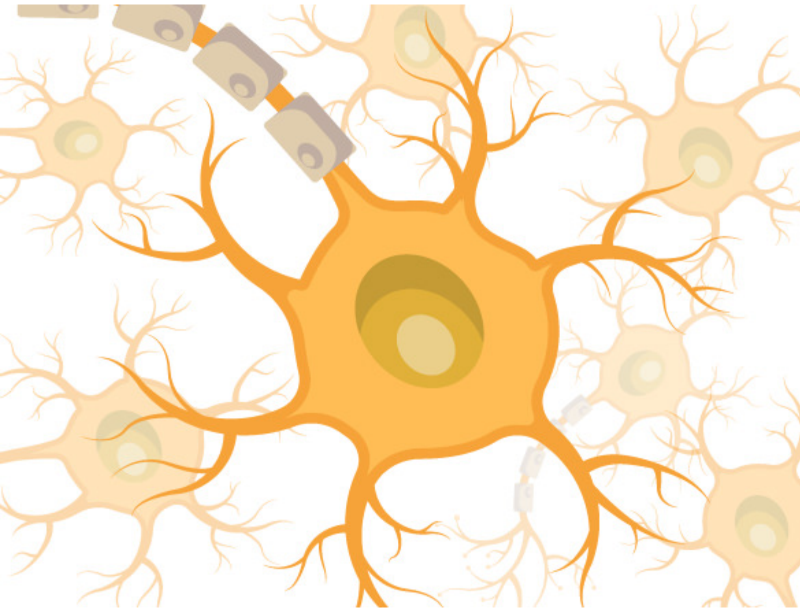


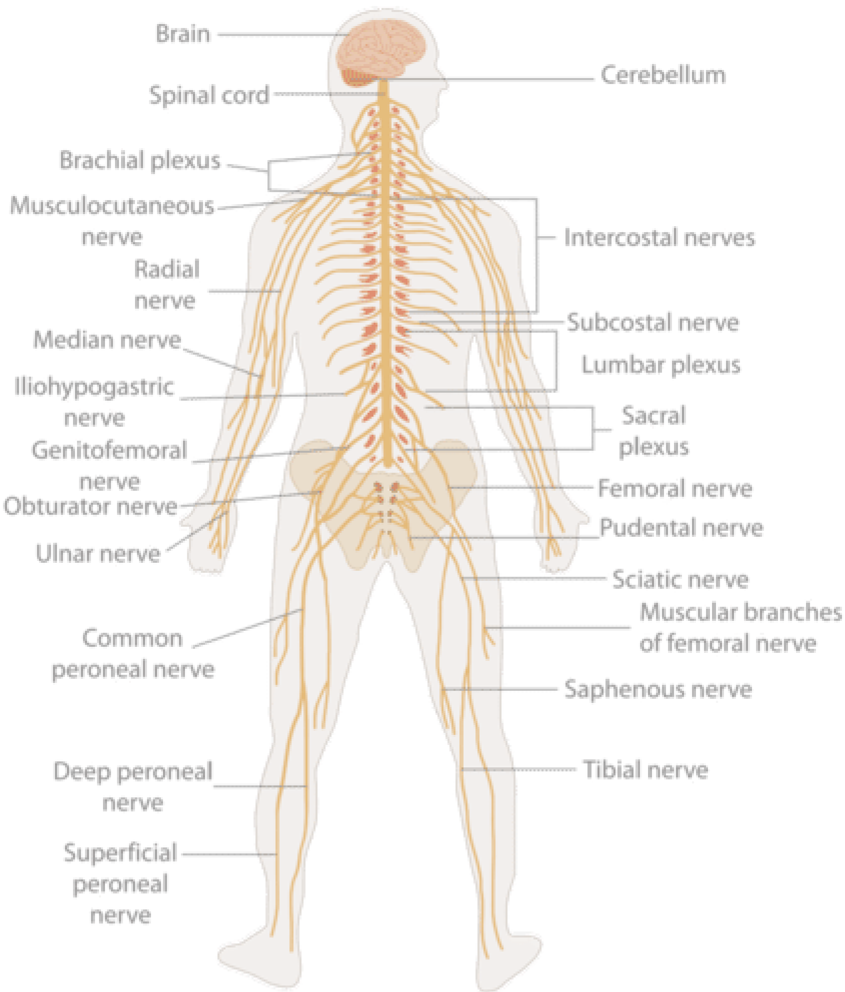
[Figure 1]

A close-up view of a spider web? Some sort of exotic bacteria? What do you think this is?

This is actually a nerve cell, the cell of the **nervous system**. This cell sends electrical "sparks" that transmit signals throughout your body.

The Nervous System

A small child darts in front of your bike as you race down the street. You see the child and immediately react. You put on the brakes, steer away from the child, and yell out a warning, all in just a split second. How do you respond so quickly? Such rapid responses are controlled by your nervous system. The **nervous system** is a complex network of nervous tissue that carries electrical messages throughout the body. It includes the brain and spinal cord, the **central nervous system**, and nerves that run throughout the body, the **peripheral nervous system** (see **Figure** below). To understand how nervous messages can travel so quickly, you need to know more about nerve cells.



[Figure 2]

The human nervous system includes the brain and spinal cord (central nervous system) and nerves that run throughout the body (peripheral nervous system).

Nerve Cells

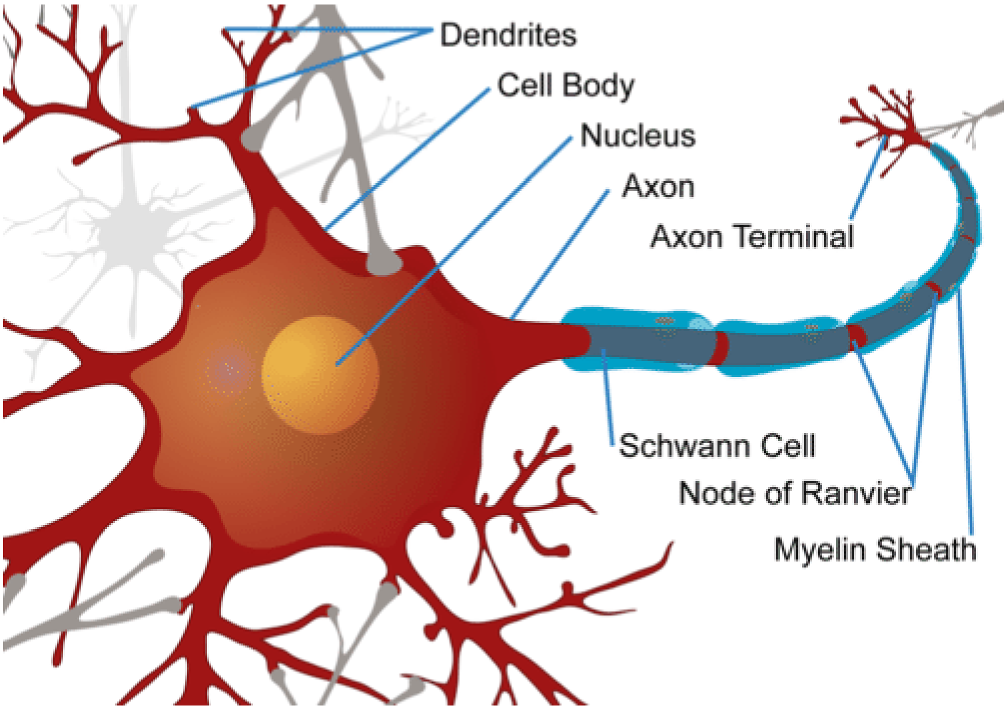
Although the nervous system is very complex, nervous tissue consists of just two basic types of nerve cells: neurons and glial cell. **Neurons** are the structural and functional units of the nervous system. They transmit electrical signals, called **nerve impulse. Glial cells** provide support for neurons. For example, they provide neurons with nutrient and other materials.

Neuron Structure

As shown in **Figure** below, a neuron consists of three basic parts: the **cell body**, **dendrite**, and **axon**.

- The **cell body** contains the nucleus and other cell organelle.
- **Dendrites** extend from the cell body and receive nerve impulses from other neurons.

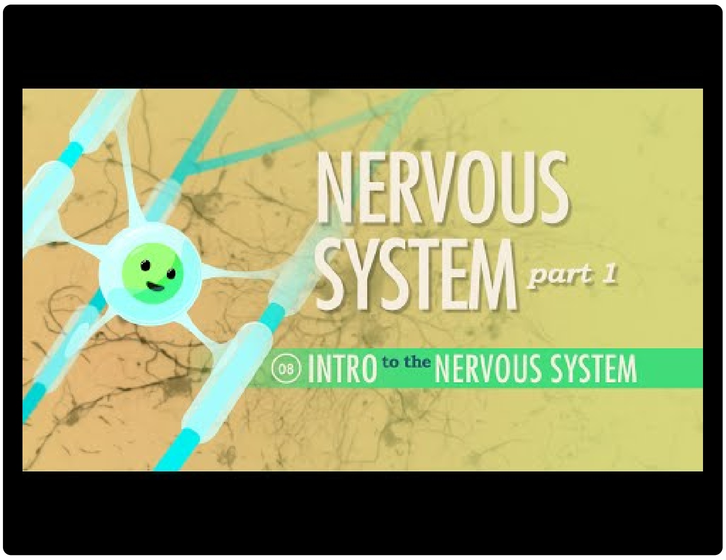
- The **axon** is a long extension of the cell body that transmits nerve impulses to other cells. The axon branches at the end, forming **axon terminal**. These are the points where the neuron communicates with other cells.



[Figure 3]

The structure of a neuron allows it to rapidly transmit nerve impulses to other cells.

The axon of many neurons has an outer layer called a **myelin sheath** (see **Figure** above). **Myelin** is a lipid produced by a type of a glial cell known as a **Schwann cell**. The myelin sheath acts like a layer of insulation, similar to the plastic that encases an electrical cord. Regularly spaced node, or gaps, in the myelin sheath allow nerve impulses to skip along the axon very rapidly.



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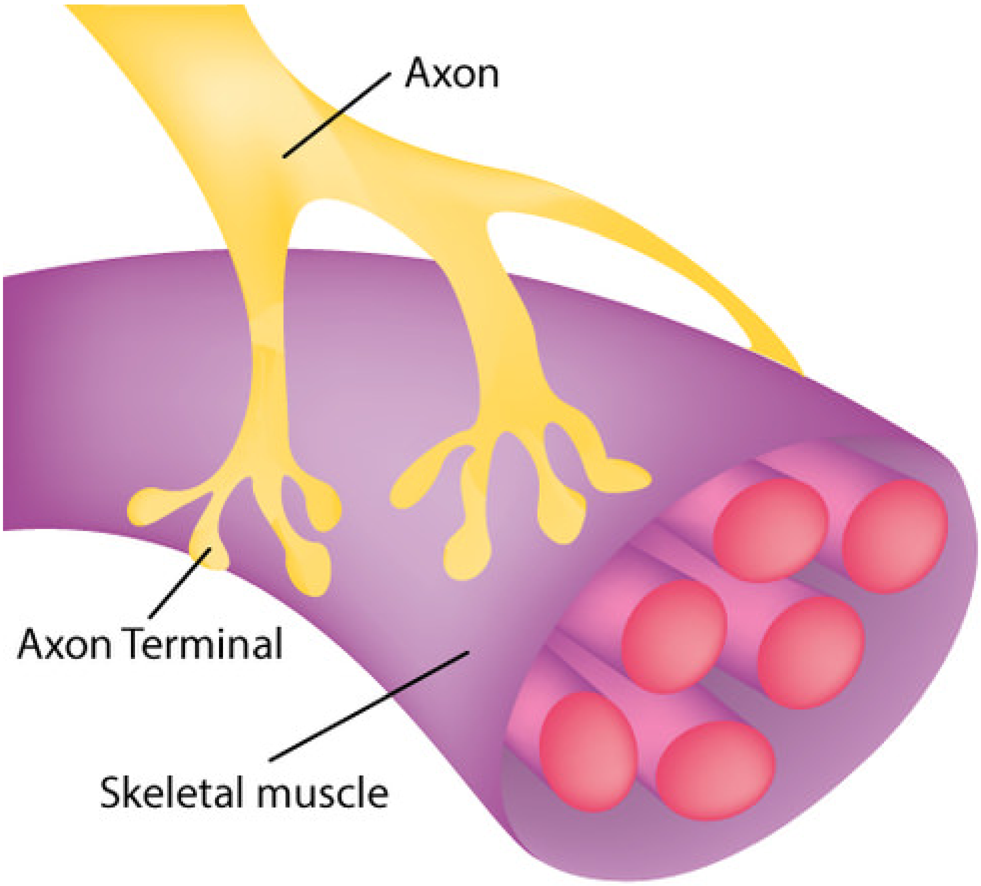
Types of Neurons

Neurons are classified based on the direction in which they carry nerve impulses.

- **sensory neuron** carry nerve impulses from tissue and organ to the spinal cord and brain.
- **motor neuron** carry nerve impulses from the brain and spinal cord to muscles and glands (see **Figure** below).
- **interneuron** carry nerve impulses back and forth between sensory and motor neurons.



[Figure 4]

This axon is part of a motor neuron. It transmits nerve impulses to a skeletal muscle, causing the muscle to contract.

Summary

- Neurons are the structural and functional units of the nervous system. They consist of a cell body, dendrites, and axon.
- Neurons transmit nerve impulses to other cells.
- Types of neurons include sensory neurons, motor neurons, and interneurons.

Review

1. What are the two main parts of the nervous system?
2. List and describe the parts of a neuron.
3. What do motor neurons do?
4. What is myelin and the myelin sheath?

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13.14 Nerve Impulse

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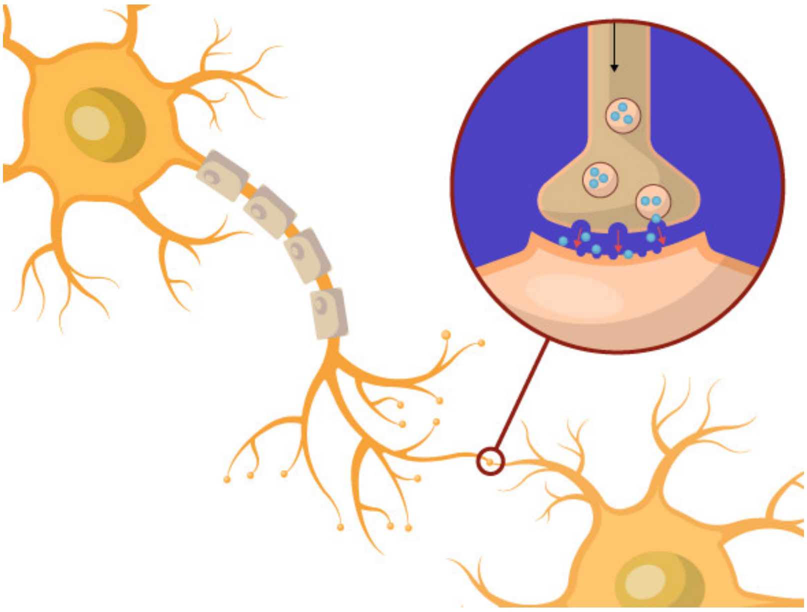


[Figure 1]

How does a nervous system signal move from one cell to the next?

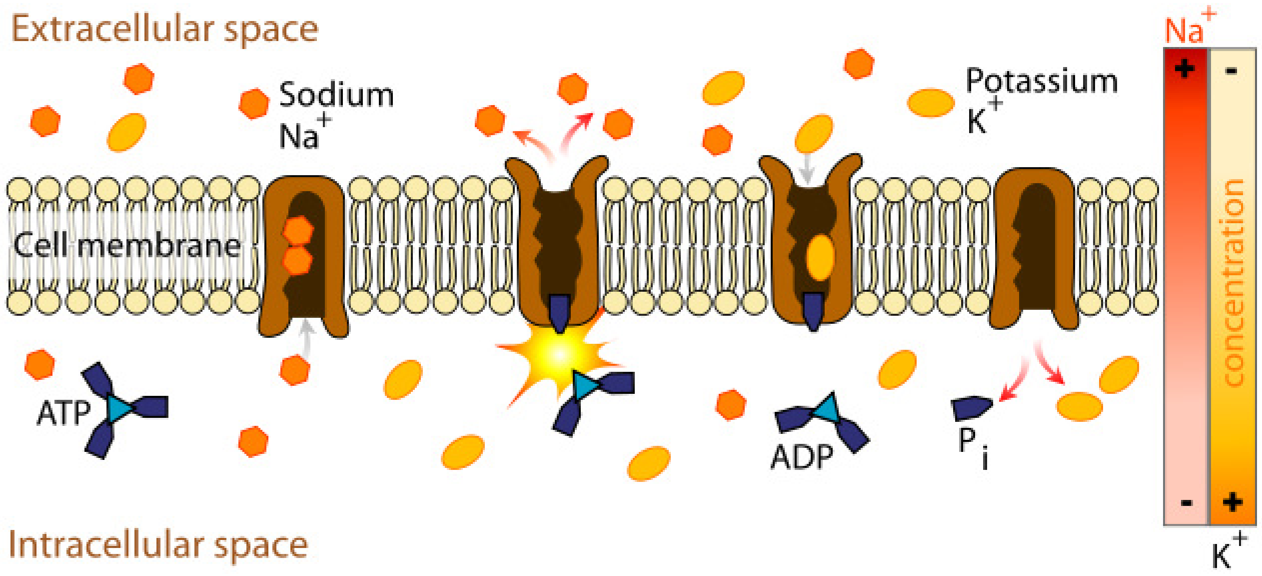
It literally jumps by way of a chemical transmitter. Notice the two cell are not connected, but separated by a small gap. The **synapse**. The space between a neuron and the next cell.

Nerve Impulses

Nerve impulses are electrical in nature. They result from a difference in electrical charge across the plasma membrane of a neuron. How does this difference in electrical charge come about? The answer involves **ion**, which are electrically charged atoms or molecules.

Resting Potential

When a neuron is not actively transmitting a nerve impulse, it is in a resting state, ready to transmit a nerve impulse. During the resting state, the **sodium-potassium pump** maintains a difference in charge across the cell membrane (see **Figure** below). It uses energy in ATP to pump positive sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. As a result, the inside of the neuron is negatively charged compared to the extracellular fluid surrounding the neuron. This is due to many more positively charged ions outside the cell compared to inside the cell. This difference in electrical charge is called the **resting potential.**

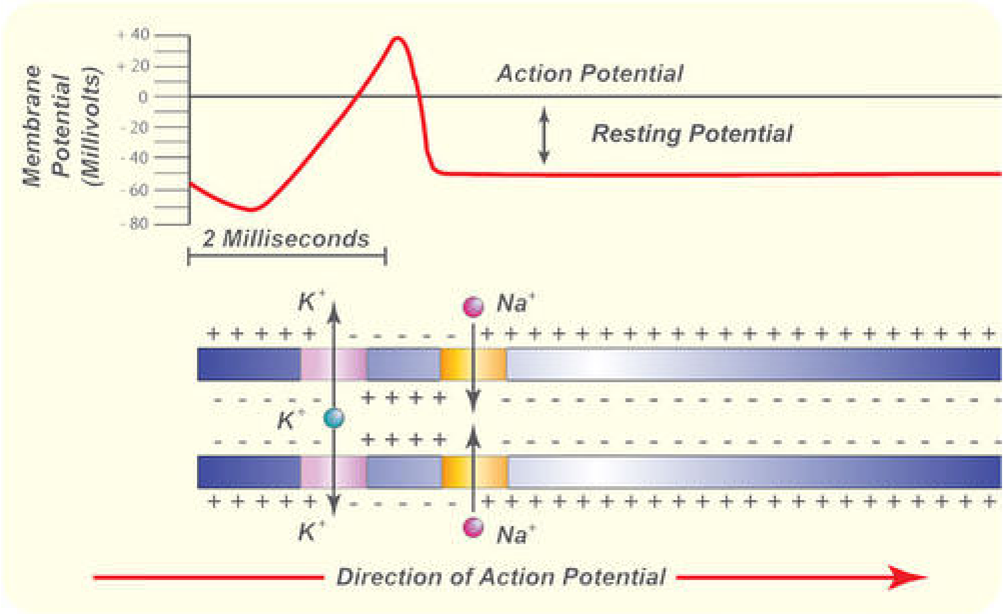


[Figure 2]

The sodium-potassium pump maintains the resting potential of a neuron.

Action Potential

A **nerve impulse** is a sudden reversal of the electrical charge across the membrane of a resting neuron. The reversal of charge is called an **action potential.** It begins when the neuron receives a chemical signal from another cell. The signal causes gates in sodium ion channel to open, allowing positive sodium ions to flow back into the cell. As a result, the inside of the cell becomes positively charged compared to the outside of the cell. This reversal of charge ripples down the axon very rapidly as an electric current (see **Figure** below).

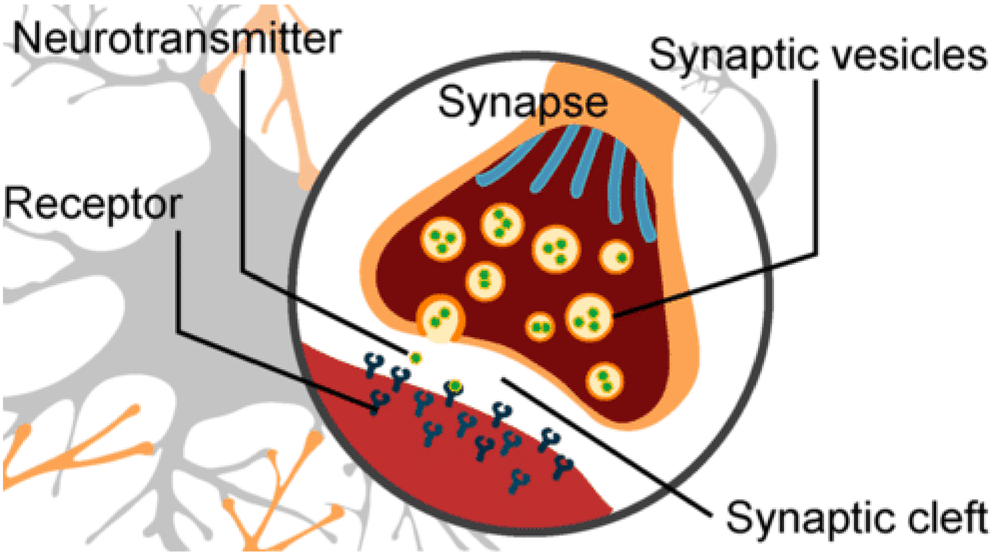


[Figure 3]

An action potential speeds along an axon in milliseconds.

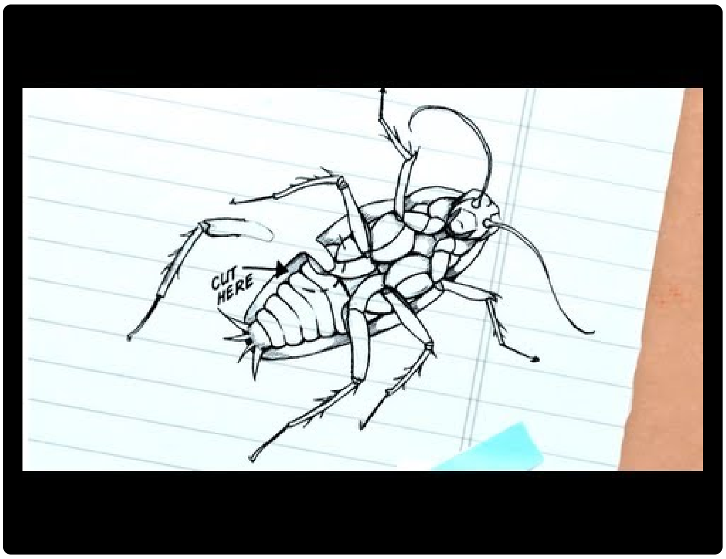
In neurons with myelin sheaths, ions flow across the membrane only at the node between sections of myelin. As a result, the action potential jumps along the axon membrane from node to node, rather than spreading smoothly along the entire membrane. This increases the speed at which it travels.

The place where an axon terminal meets another cell is called a **synapse**. The axon terminal and other cell are separated by a narrow space known as a **synaptic cleft** (see **Figure** below). When an action potential reaches the axon terminal, the axon terminal releases molecules of a chemical called a **neurotransmitter**. The neurotransmitter molecules travel across the synaptic cleft and bind to receptors on the membrane of the other cell. If the other cell is a neuron, this starts an action potential in the other cell.



[Figure 4]

At a synapse, neurotransmitters are released by the axon terminal. They bind with receptors on the other cell.



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Summary

- A nerve impulse begins when a neuron receives a chemical stimulus.
- The nerve impulse travels down the axon membrane as an electrical action potential to the axon terminal.
- The axon terminal releases neurotransmitters that carry the nerve impulse to the next cell.

Review

1. Define resting potential and action potential.
2. Explain how resting potential is maintained
3. Describe how an action potential occurs.
4. What is a synapse?

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13.15 Central Nervous System

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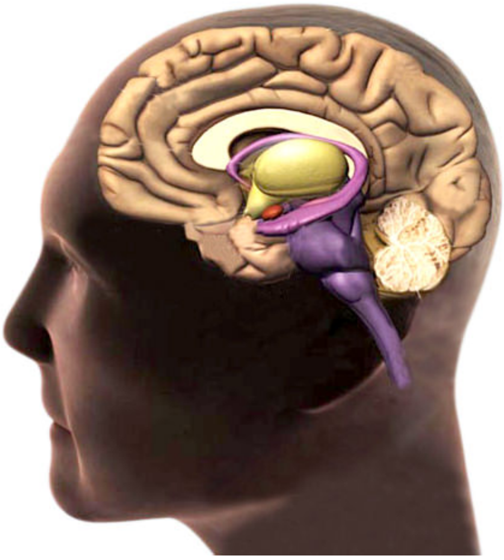


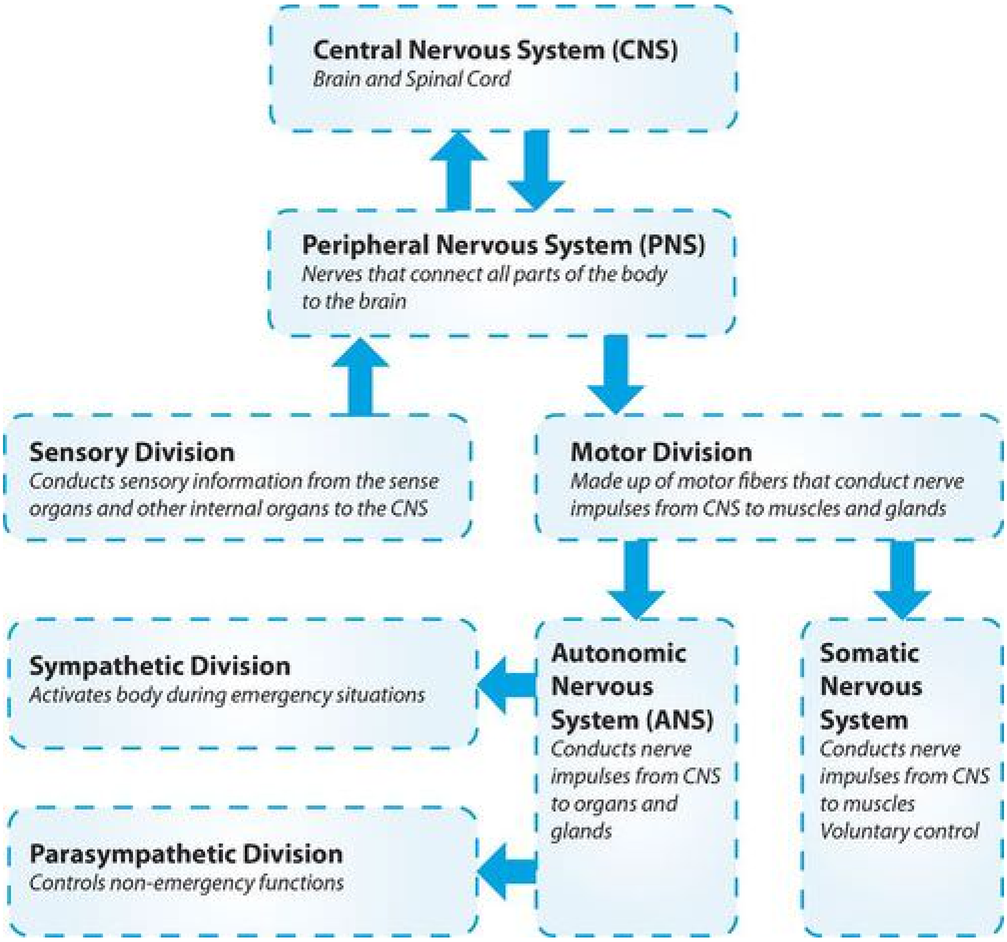
[Figure 1]

The human brain. The "control center." What does it control?

Practically everything. From breathing and heartbeat to reasoning, memory, and language. And it is the main part of the central nervous system.

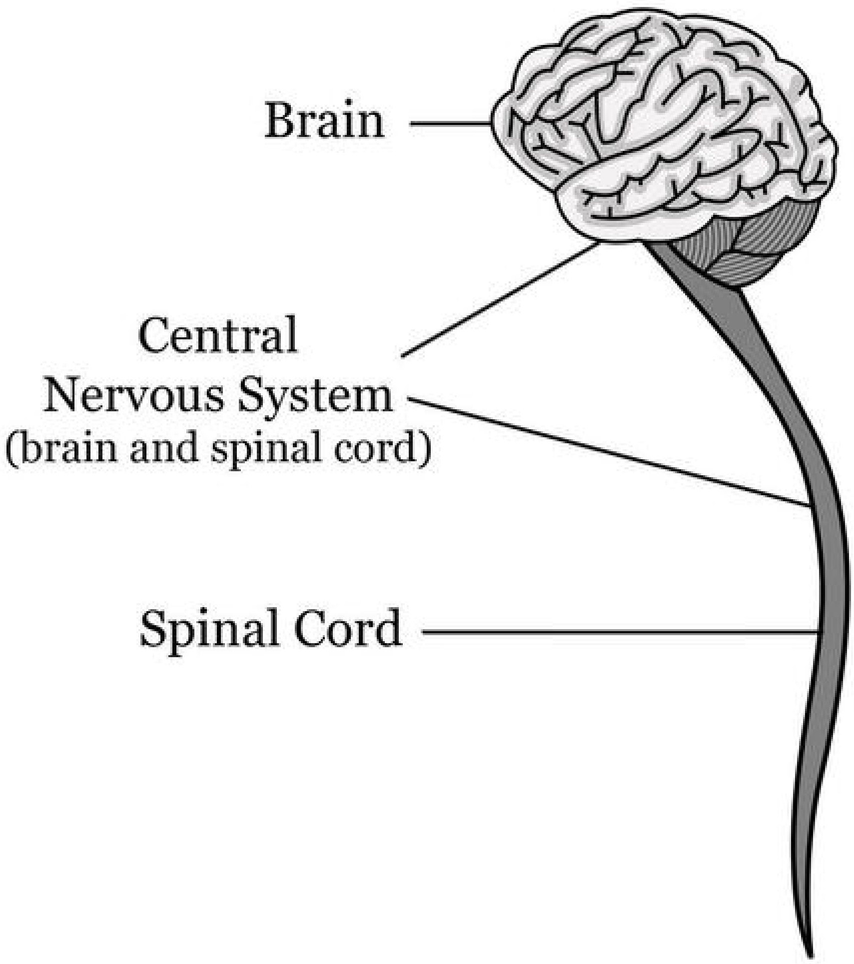
Central Nervous System

The nervous system has two main divisions: the central nervous system and the peripheral nervous system (see **Figure** below). The **central nervous system (CNS)** includes the **brain** and **spinal cord** (see **Figure** below).



[Figure 2]

The two main divisions of the human nervous system are the central nervous system and the peripheral nervous system. The peripheral nervous system has additional divisions.



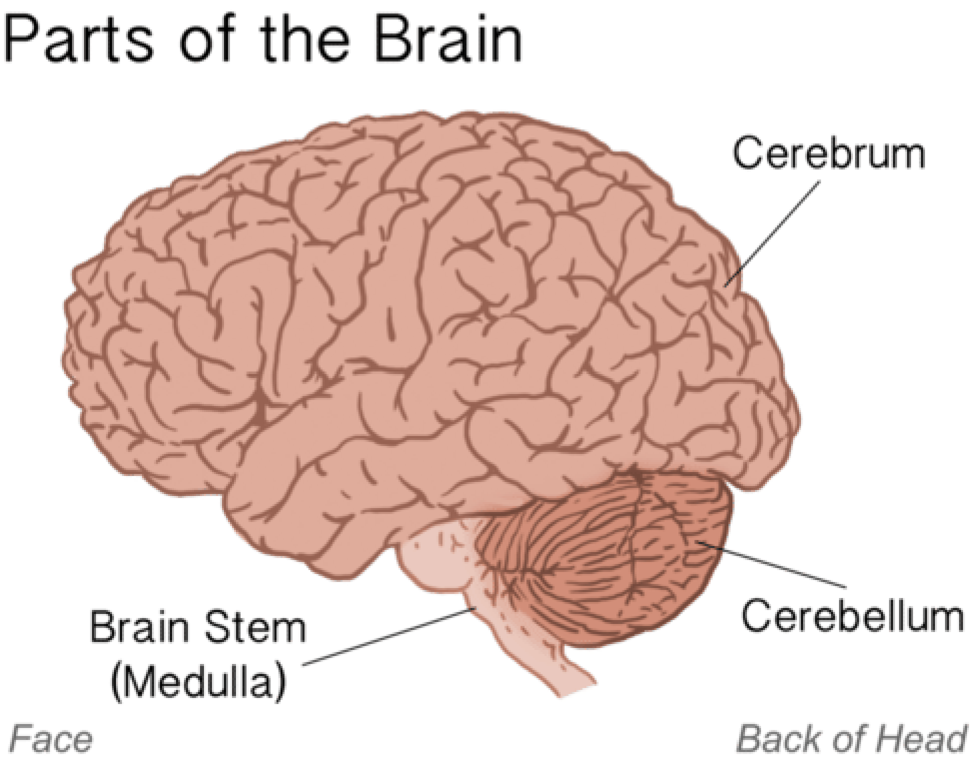
[Figure 3]

This diagram shows the components of the central nervous system.

The Brain

The **brain** is the most complex organ of the human body and the control center of the nervous system. It contains an astonishing 100 billion neurons! The brain controls such mental processes as reasoning, imagination, memory, and language. It also interprets information from the senses. In addition, it controls basic physical processes such as breathing and heartbeat.

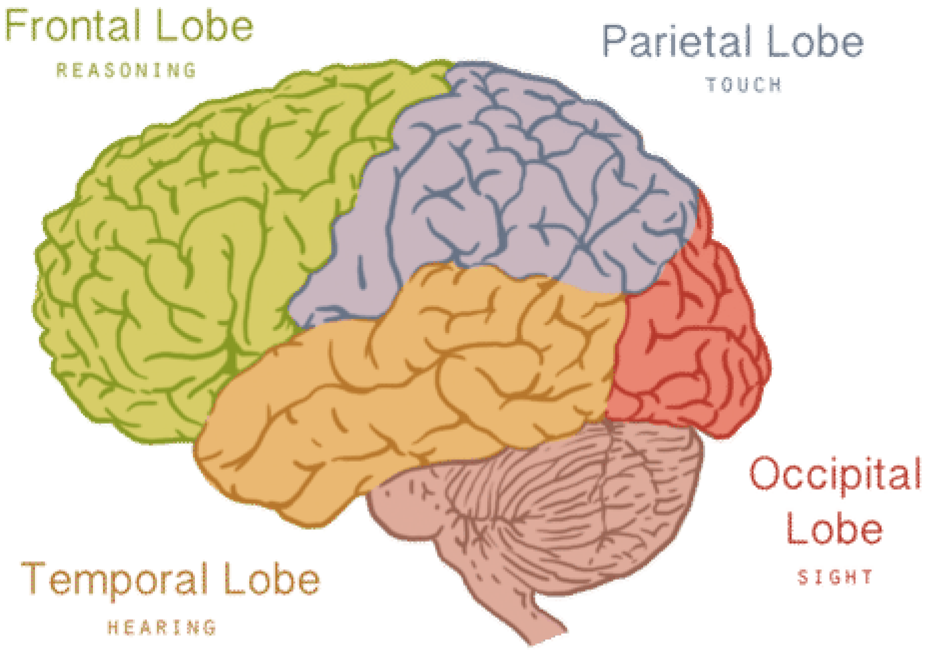
The brain has three major parts: the **cerebrum**, **cerebellum**, and **brain stem**. These parts are shown in **Figure** below and described in this section.



[Figure 4]

In this drawing, assume you are looking at the left side of the head. This is how the brain would appear if you could look underneath the skull.

- The **cerebrum** is the largest part of the brain. It controls conscious functions such as reasoning, language, sight, touch, and hearing. It is divided into two hemispheres, or halves. The hemispheres are very similar but not identical to one another. They are connected by a thick bundle of axon deep within the brain. Each hemisphere is further divided into the four lobes shown in **Figure** below.
- The **cerebellum** is just below the cerebrum. It coordinates body movement. Many nerve pathways link the cerebellum with motor neuron throughout the body.
- The **brain stem** is the lowest part of the brain. It connects the rest of the brain with the spinal cord and passes nerve impulse between the brain and spinal cord. It also controls unconscious functions such as heart rate and breathing.



[Figure 5]

Each hemisphere of the cerebrum consists of four parts, called lobes. Each lobe is associated with particular brain functions. Just one function of each lobe is listed here.

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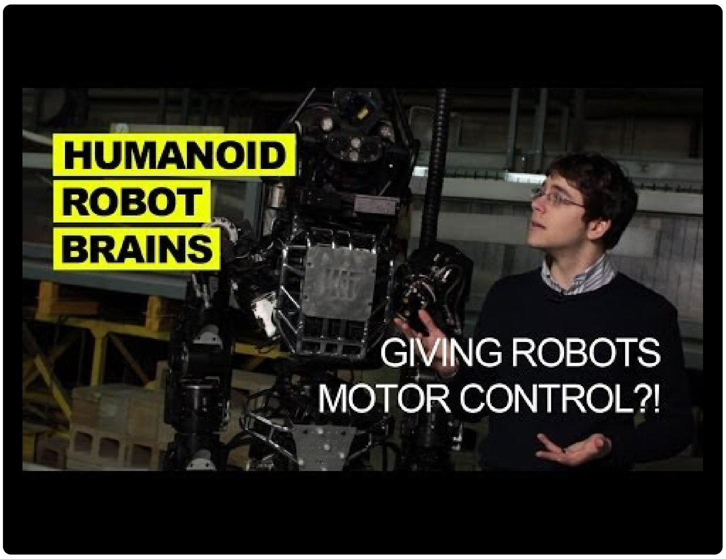
Spinal Cord

The **spinal cord** is a thin, tubular bundle of nervous tissue that extends from the brainstem and continues down the center of the back to the pelvis. It is protected by the **vertebra**, which encase it. The spinal cord serves as an information superhighway, passing messages from the body to the brain and from the brain to the body.

Humanoid Robot Brains

The smartest people in the world have spent millions of dollars on developing high-tech robots. But even though technology has come a long way, these humanoid robots are nowhere close to having the "brain" and motor control of a human. Why is that? Learn about the motor control processes in the human brain, and how cutting-edge research is trying to implement it in robots below.



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Science Friday: Face Time: How quickly do you judge a face?

How fast do you judge somebody by their face? In this video by science Friday, Dr. Jon Freeman discusses how the brain quickly creates character assessments of people and the effects these assessments may have.

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Further Reading

Drugs and the Nervous System

Nervous System Diseases

Summary

- The central nervous includes the brain and spinal cord.
- The brain is the control center of the nervous system. It controls virtually all mental and physical processes.
- The spinal cord is a long, thin bundle of nervous tissue that passes messages from the body to the brain and from the brain to the body.

Review

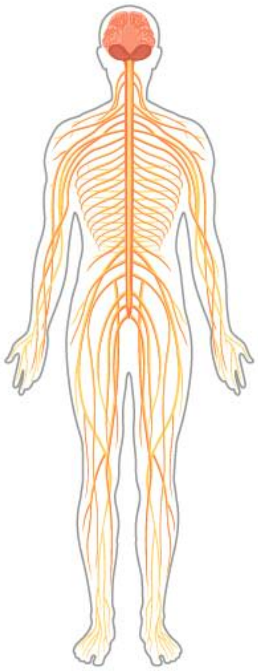
1. Name the organs of the central nervous system.
2. Which part of the brain controls conscious functions such as reasoning?
3. What are the roles of the brain stem?
4. Sam's dad was in a car accident in which his neck was broken. He survived the injury but is now paralyzed from the neck down. Explain why.

Report Content Errors

13.16 Peripheral Nervous System

FlexBooks 2.0 > Biology For High School Diploma > Peripheral Nervous System

Last Modified: Aug 01, 2018



[Figure 1]

How does the signal get to your toes?

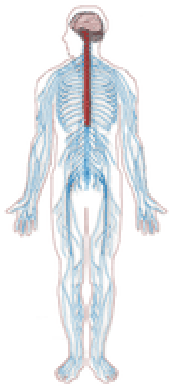
If the brain controls practically everything, how does the signal get to your toes? Or your legs? Or arms? By way of the peripheral nervous system, or all the **nerve** shown here other than the brain and spinal cord. Notice how they go everywhere.

Peripheral Nervous System

The **peripheral nervous system (PNS)** consists of all the nervous tissue that lies outside the central nervous system. It is shown in yellow in **Figure** below. It is connected to the central nervous system by nerves. A **nerve** is a cable-like bundle of axon. Some nerves are very long. The longest human nerve is the sciatic nerve. It runs from the spinal cord in the lower back down the left leg all the way to the toes of the left foot. Like the nervous system as a whole, the peripheral nervous system also has two divisions: the **sensory division** and the **motor division**.

- The **sensory division** of the PNS carries sensory information from the body to the central nervous system.

- The **motor division** of the PNS carries nerve impulse from the central nervous system to muscles and glands throughout the body. The nerve impulses stimulate muscles to contract and glands to secrete hormone. The motor division of the peripheral nervous system is further divided into the somatic and autonomic nervous systems.



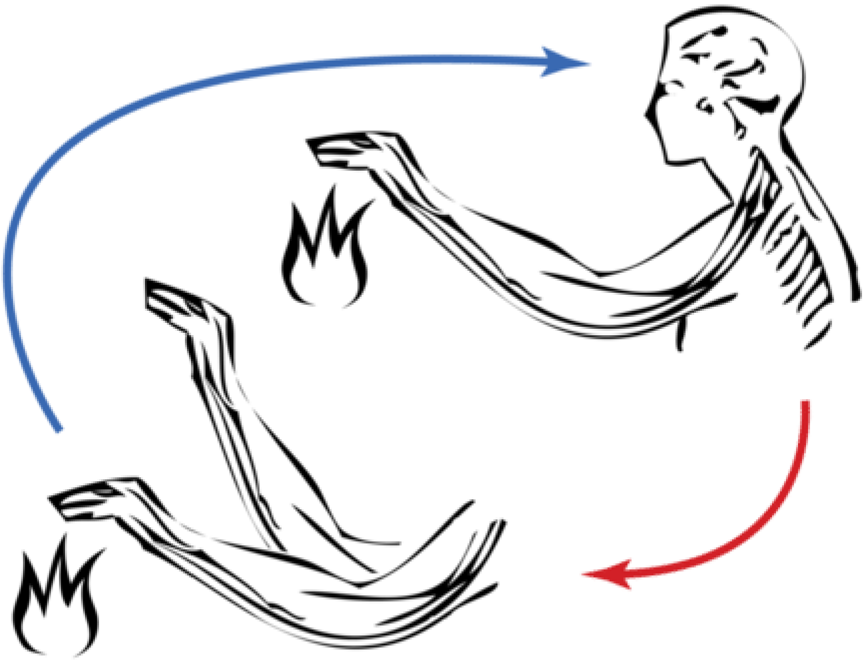
[Figure 2]

The nerves of the peripheral nervous system are shown in blue in this image. Can you identify the sciatic nerve?

Somatic Nervous System

The **somatic nervous system (SNS)** controls mainly voluntary activities that are under conscious control. It is made up of nerves that are connected to skeletal muscle. Whenever you perform a conscious movement, from signing your name to riding your bike, your somatic nervous system is responsible.

The somatic nervous system also controls some unconscious movements, called **reflex**. A **reflex** is a very rapid motor response that is not directed by the brain. In a reflex, nerve impulses travel to and from the spinal cord in a **reflex arc**, like the one in **Figure** below. In this example, the person jerks his hand away from the flame without any conscious thought. It happens unconsciously because the nerve impulses bypass the brain.



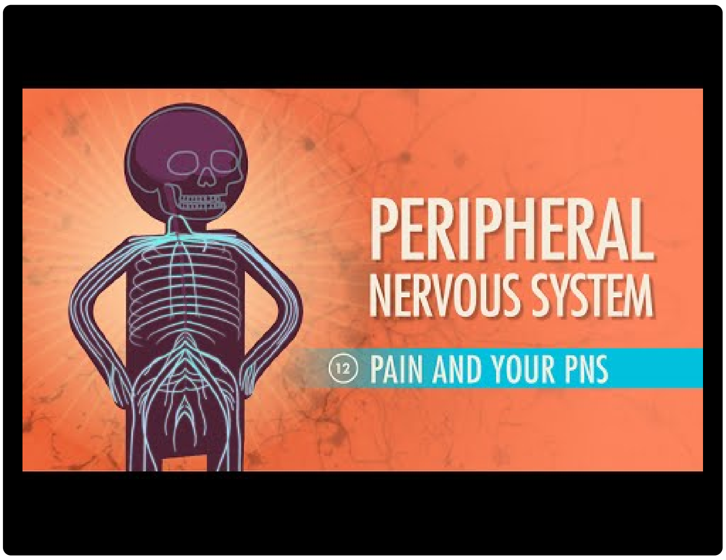
[Figure 3]

A reflex arc like this one enables involuntary actions. How might reflex responses be beneficial to the organism?

Autonomic Nervous System

All other involuntary activities not under conscious control are the responsibility of the **autonomic nervous system (ANS)**. Nerves of the ANS are connected to glands and internal organ. They control basic physical functions such as heart rate, breathing, digestion, and sweat production. The autonomic nervous system also has two subdivisions: the **sympathetic division** and the **parasympathetic division**.

- The **sympathetic division** deals with emergency situations. It prepares the body for "fight or flight." Do you get clammy palms or a racing heart when you have to play a solo or give a speech? Nerves of the sympathetic division control these responses.
- The **parasympathetic division** controls involuntary activities that are not emergencies. For example, it controls the organs of your digestive system so they can break down the food you eat.



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Science Friday: The Agony and Ecstasy of Capsaicin

Have you ever tasted something spicy? In this video by science Friday, Dr. Marco Tizzano discusses how capsaicin creates the burning sensation that some people enjoy.

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Summary

- The peripheral nervous system consists of all the nervous tissue that lies outside the central nervous system. It is connected to the central nervous system by nerves.

- The peripheral nervous system has several divisions and subdivisions that transmit nerve impulses between the central nervous system and the rest of the body.

Review

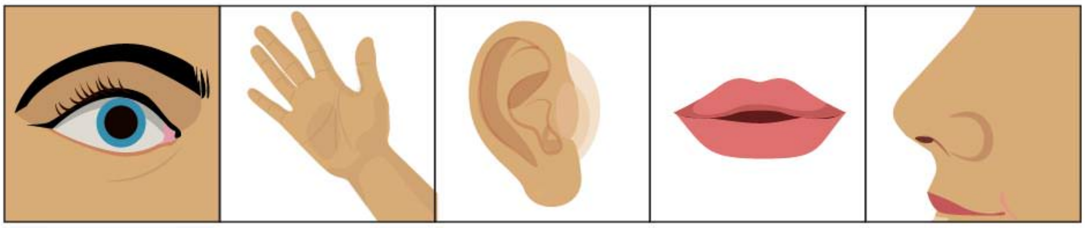
1. Identify the two major divisions of the peripheral nervous system.
2. What is the role of the sensory division?
3. Compare and contrast the somatic and autonomic nervous systems.
4. What are the two divisions of the autonomic nervous system?
5. What is the role of the sympathetic division?

Report Content Errors

13.17 Senses

FlexBooks 2.0 > Biology For High School Diploma > Senses

Last Modified: Feb 26, 2022



[Figure 1]

Name the five senses.

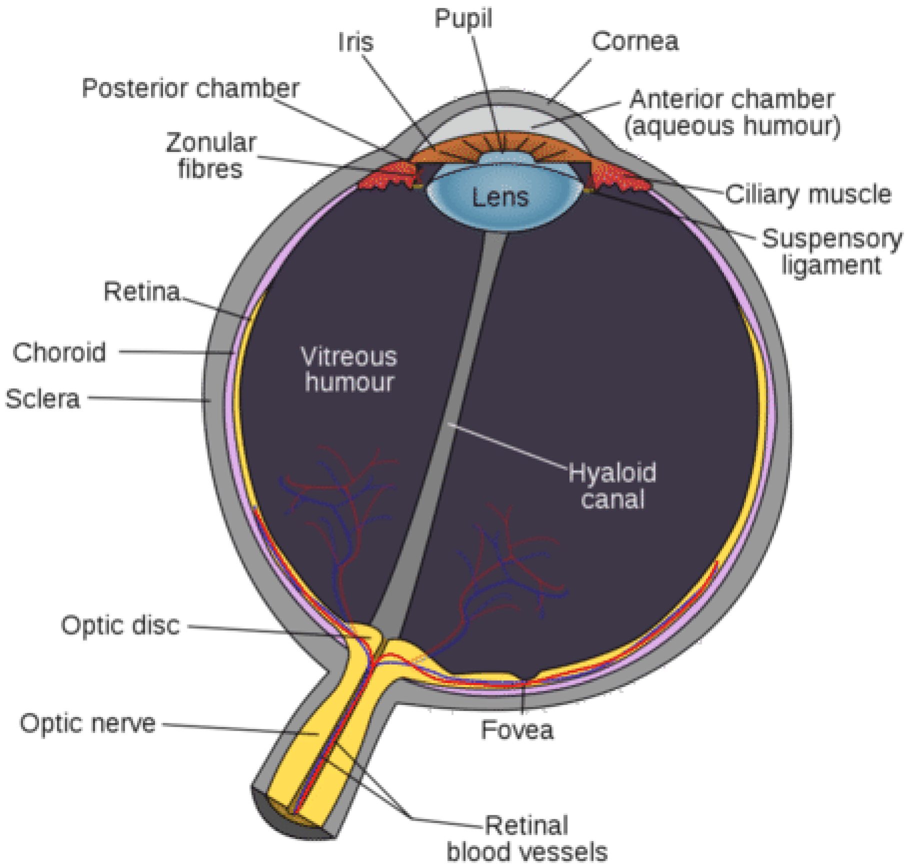
hearing, **sight**, **taste**, touch, and **smell**. But how do we hear, see, taste, touch and smell? It all has to do, obviously, with the nervous system.

The Senses

The sensory division of the peripheral nervous system (PNS) includes several sense organs—the eyes, ears, mouth, nose, and skin. Each **sense organ** has special cell, called **sensory receptor**, that respond to a particular type of stimulus. For example, the nose has sensory receptors that respond to chemicals, which we perceive as odors. Sensory receptors send nerve impulse to **sensory nerve**, which carry the nerve impulses to the central nervous system. The brain then interprets the nerve impulses to form a response.

Sight

Sight is the ability to sense light, and the eye is the organ that senses light. Light first passes through the **cornea** of the eye, which is a clear outer layer that protects the eye (see **Figure** below). Light enters the eye through an opening called the **pupil**. The light then passes through the **lens**, which focuses it on the **retina** at the back of the eye. The retina contains light receptor cells. These cells send nerve impulses to the **optic nerve**, which carries the impulses to the brain. The brain interprets the impulses and "tells" us what we are seeing.

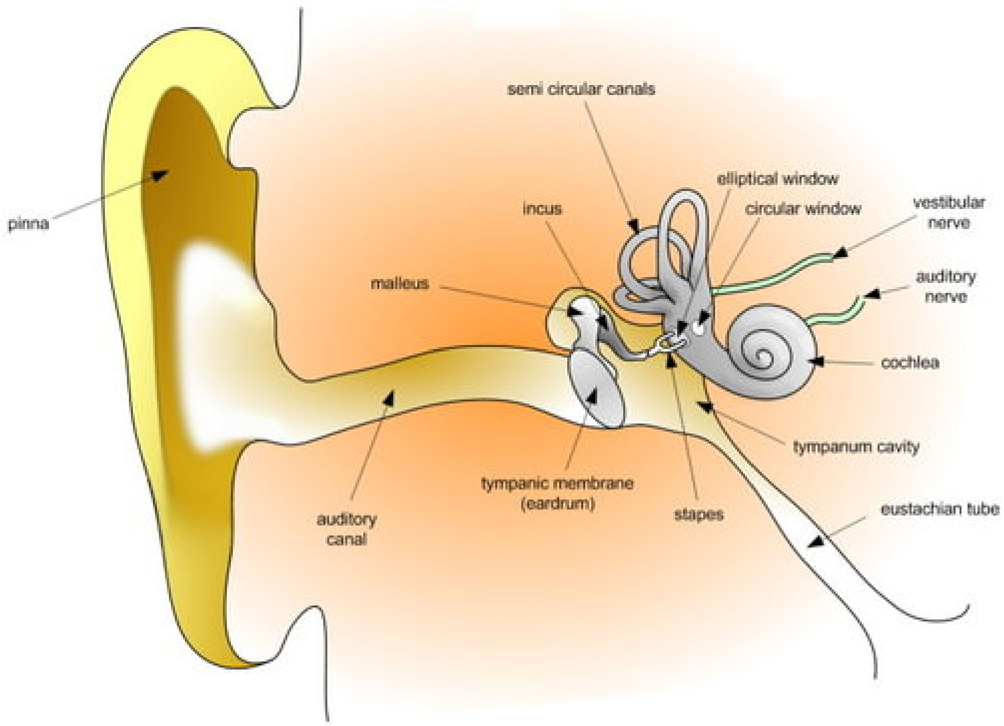


[Figure 2]

The eye is the organ that senses light and allows us to see.

Hearing

Hearing is the ability to sense sound waves, and the ear is the organ that senses sound. Sound waves enter the **auditory canal** and travel to the **eardrum** (see **Figure** below). They strike the eardrum and make it vibrate. The vibrations then travel through several other structures inside the ear and reach the **cochlea**. The **cochlea** is a coiled tube filled with liquid. The liquid moves in response to the vibrations, causing tiny hair cells lining the cochlea to bend. In response, the hair cells send nerve impulses to the **auditory nerve**, which carries the impulses to the brain. The brain interprets the impulses and "tells" us what we are hearing.



[Figure 3]

The ear is the organ that senses sound waves and allows us to hear. It also senses body position so we can keep our balance.

Balance

The ears are also responsible for the sense of balance. **Balance** is the ability to sense and maintain body position. The **semicircular canal** inside the ear (see **Figure** above) contain fluid that moves when the head changes position. Tiny hairs lining the semicircular canals sense movement of the fluid. In response, they send nerve impulses to the **vestibular nerve**, which carries the impulses to the brain. The brain interprets the impulses and sends messages to the peripheral nervous system. This system maintains the body's balance by triggering contractions of skeletal muscle as needed.

Taste and Smell

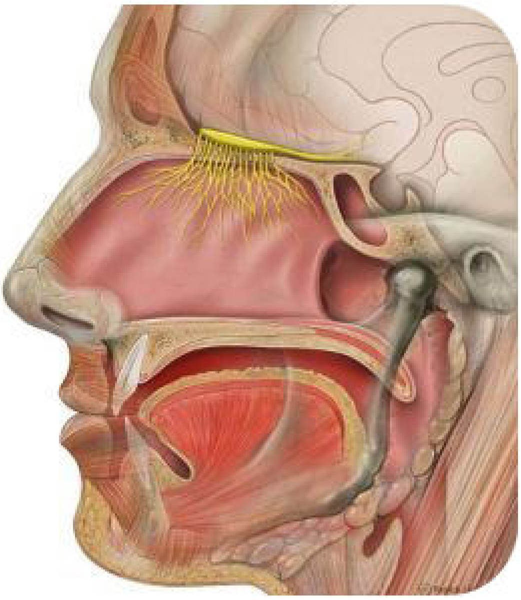
Taste and **smell** are both abilities to sense chemicals. Like other sense receptors, both **taste receptor** and **odor receptor** send nerve impulses to the brain, and the brain "tells" us what we are tasting or smelling.

Taste receptors are found in tiny bumps on the tongue called **taste buds** (see **Figure** below). There are separate taste receptors for sweet, salty, sour, bitter, and meaty tastes. The meaty taste is called *umami*.

[Figure 4]

Taste buds on the tongue contain taste receptor cells.

Odor receptors line the passages of the nose (see **Figure** below). They sense chemicals in the air. In fact, odor receptors can sense hundreds of different chemicals. Did you ever notice that food seems to have less taste when you have a stuffy nose? This occurs because the sense of smell contributes to the sense of taste, and a stuffy nose interferes with the ability to smell.



[Figure 5]

Odor receptors. Odor receptors and their associated nerves (in yellow) line the top of the nasal passages.

Touch

Touch is the ability to sense pressure. **pressure receptor** are found mainly in the skin. They are especially concentrated on the tongue, lips, face, palms of the hands, and soles of the feet. Some touch receptors sense differences in temperature or pain. How do pain receptors help maintain homeostasis? (Hint: What might happen if we couldn't feel pain?)

Why I do Science

If your kids don't like broccoli, it may not be their fault, it may just be their gene talking. Dr. Danielle Reed is a geneticist working to understand the genetics of taste. Can all people detect the same tastes? No. Why not? It has to do with a person's genes. People may actually taste foods differently.

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Science Friday: The Bouba-Kiki Effect

Given two shapes, which one is Bouba and which one is Kiki? In this video by science Friday, psychologist Kelly McCormick discusses why over 90% of tested subjects associated these made-up words with a specific shape.

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Science Friday: A Cure for The Colorblindness Blues

Colorblindness is the most common genetic disorder in the world. In this video by Science Friday, researchers Maureen and Jay Neitz discuss how their research has created a potential cure for this disorder.

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Summary

- Human senses include sight, hearing, balance, taste, smell, and touch.
- Sensory organs such as the eyes contain cells called sensory receptors that respond to particular sensory stimuli.
- Sensory nerves carry nerve impulses from sensory receptors to the central nervous system.
- The brain interprets the nerve impulses to form a response.

Review

1. List the five human senses.
2. Describe how we see.
3. Describe how we hear.
4. Why does food taste different when you have a stuffy nose?
5. What might happen if we couldn’t feel pain?

Report Content Errors

13.18 Drugs and the Nervous System

FlexBooks 2.0 > Biology For High School Diploma > Drugs and the Nervous System

Last Modified: Jul 04, 2019

[Figure 1]

Is coffee a drug?

Maybe. But that doesn't necessarily mean it is bad for you. Looks tasty, though. Other than taste, why do many people have a cup of coffee in the morning? Does it help them wake up? For many people, it does. Why? The caffeine in the coffee stimulates the central nervous system. This drug is one of the milder drugs affecting the nervous system.

Drugs and the Nervous System

A **drug** is any chemical that affects the body's structure or function. Many drugs, including both legal and illegal drugs, are **psychoactive drug**. This means that they affect the central nervous system, generally by influencing the transmission of nerve impulse. For example, some psychoactive drugs mimic neurotransmitter. At the link below, you can watch an animation showing how psychoactive drugs affect the brain.

Examples of Psychoactive Drugs

Caffeine is an example of a psychoactive drug. It is found in coffee and many other products (see **Table** below). Caffeine is a central nervous system **stimulant**. Like other stimulant drugs, it makes you feel more awake and alert. Other psychoactive drugs include alcohol, nicotine, and marijuana. Each has a different effect on the central nervous system. Alcohol, for example, is a **depressant**. It has the opposite effects of a stimulant like caffeine.

Product	Caffeine Content (mg)
Coffee (8 oz)	130
Tea (8 oz)	55
Cola (8 oz)	25
Coffee ice cream (8 oz)	60
Hot cocoa (8 oz)	10
Dark chocolate candy (1.5 oz)	30

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Drug Abuse and Addiction

Psychoactive drugs may bring about changes in mood that users find desirable, so the drugs may be abused. **drug abuse** is use of a drug without the advice of a medical professional and for reasons not originally intended. Continued use of a psychoactive drug may lead to **drug addiction**, in which the drug user is unable to stop using the drug. Over time, a drug user may need more of the drug to get the desired effect. This can lead to drug **overdose** and death.

Summary

- Drugs are chemicals that affect the body's structure or function.
- Psychoactive drugs, such as caffeine and alcohol, affect the central nervous system by influencing the transmission of nerve impulses in the brain.
- Psychoactive drugs may be abused and lead to drug addiction.

Review

1. What is a psychoactive drug? Give two examples.
2. Define drug abuse. When does drug addiction occur?

Report Content Errors

13.19 Nervous System Diseases

FlexBooks 2.0 > Biology For High School Diploma > Nervous System Diseases

Last Modified: Jul 04, 2019

[Figure 1]

Ever had a headache that just won't go away?

We all get headaches. Headaches are a relatively minor problem associated with the nervous system. But what about more serious issues of the nervous system? As you can probably imagine, these can be extremely serious.

Disorders of the Nervous System

There are several different types of problems that can affect the nervous system.

- **vascular disorder** involve problems with blood flow. For example, a stroke occurs when a blood clot blocks blood flow to part of the brain. Brain cell die quickly if their oxygen supply is cut off. This may cause paralysis and loss of other normal functions, depending on the part of the brain that is damaged.
- nervous tissue may become infected by microorganisms. **meningitis**, for example, is caused by a viral or bacterial infection of the tissue covering the brain. This may cause the brain to swell and lead to brain damage and death.

- **encephalitis** is a brain infection most often caused by virus. The immune system tries to fight off a brain infection, just as it tries to fight off other infections. But sometimes this can do more harm than good. The immune system's response may cause swelling in the brain. With no room to expand, the brain pushes against the skull. This may injure the brain and even cause death. Medicines can help fight some viral infections of the brain, but not all infections.
- Brain or spinal cord injuries may cause paralysis and other disabilities. Injuries to peripheral nerve can cause localized pain or numbness.
- Abnormal brain functions can occur for a variety of reasons. Examples include headaches, such as migraine headaches, and epilepsy, in which seizures occur.
- Nervous tissue may degenerate, or break down. **Alzheimer's disease** is an example of this type of disorder, as is **Amyotrophic lateral sclerosis**, or ALS. ALS is also known as Lou Gehrig's disease. It leads to a gradual loss of higher brain functions.
- In addition to ALS and Alzheimer's disease, other serious nervous system diseases include **multiple sclerosis**, **Huntington's disease**, and Parkinson's disease. These diseases rarely, if ever, occur in young people. Their causes and symptoms are listed below (Table below). The diseases have no known cure, but medicines may help control their symptoms.

Disease	Cause	Symptoms
Multiple Sclerosis	The immune system attacks and damages the central nervous system so neuron cannot function properly.	muscle weakness, difficulty moving, problems with coordination, difficulty maintaining balance
Huntington's Disease	An inherited gene codes for an abnormal protein that causes the death of neurons.	uncontrolled jerky movement, loss of muscle control, issues with memory and learning
Parkinson's Disease	An abnormally low level of a neurotransmitter affects the part of the brain that controls movement.	uncontrolled shaking, slowed movements, issues associated with speaking
Alzheimer's Disease	Abnormal changes in the brain cause the gradual loss of most normal brain activity.	memory loss, confusion, mood swings, gradual loss of control over mental and physical abilities

Alzheimer's Disease: Is the Cure in the Genes?

By 2050, as the U.S. population ages, 15 million Americans will suffer from Alzheimer's disease — triple today's number. But genetic studies may provide information leading to a cure.

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In April 2011, an international analysis of the genes of more than 50,000 people led to the discovery of five new genes that make Alzheimer's disease more likely in the elderly and provide clues about what might start the Alzheimer's disease process and fuel its progress in a person's brain.

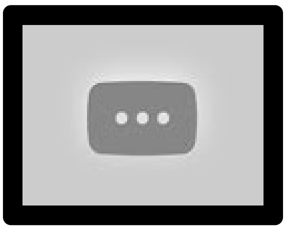
Summary

- Disorders of the nervous system include blood flow problems such as stroke, infections such as meningitis, brain injuries, and degeneration of nervous tissue, as in Alzheimer's disease.

Review

1. Identify three nervous system disorders.
2. Multiple sclerosis is a disease in which the myelin sheaths of neurons in the central nervous system break down. What symptoms might this cause? Why?

Resources



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Report Content Errors

13.20 Endocrine Glands

FlexBooks 2.0 > Biology For High School Diploma > Endocrine Glands

Last Modified: Feb 03, 2021

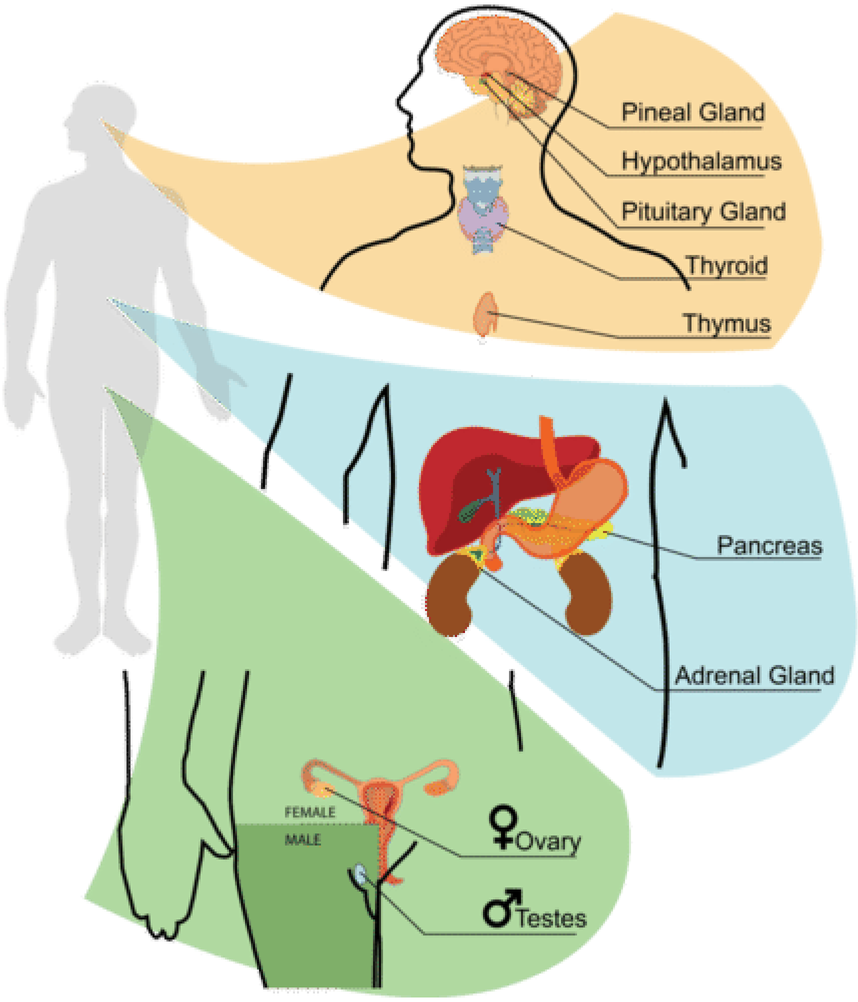
[Figure 1]

What's a hormone?

This messenger pigeon is delivering a letter, making sure it gets to where it needs to go. It could be said that hormone are biological messengers, and they originate from the **endocrine system**. The nervous system isn't the only message-relaying system of the human body. The endocrine system also carries messages. The endocrine system is a system of glands that release chemical messenger molecules into the bloodstream. The messenger molecules are hormones. Hormones act slowly compared with the rapid transmission of electrical messages by the nervous system. They must travel through the bloodstream to the cell they affect, and this takes time. On the other hand, because endocrine hormones are released into the bloodstream, they travel throughout the body. As a result, endocrine hormones can affect many cells and have body-wide effects.

Glands of the Endocrine System

The major glands of the **endocrine system** are shown in **Figure** below. You can access a similar, animated endocrine system chart at the link below.



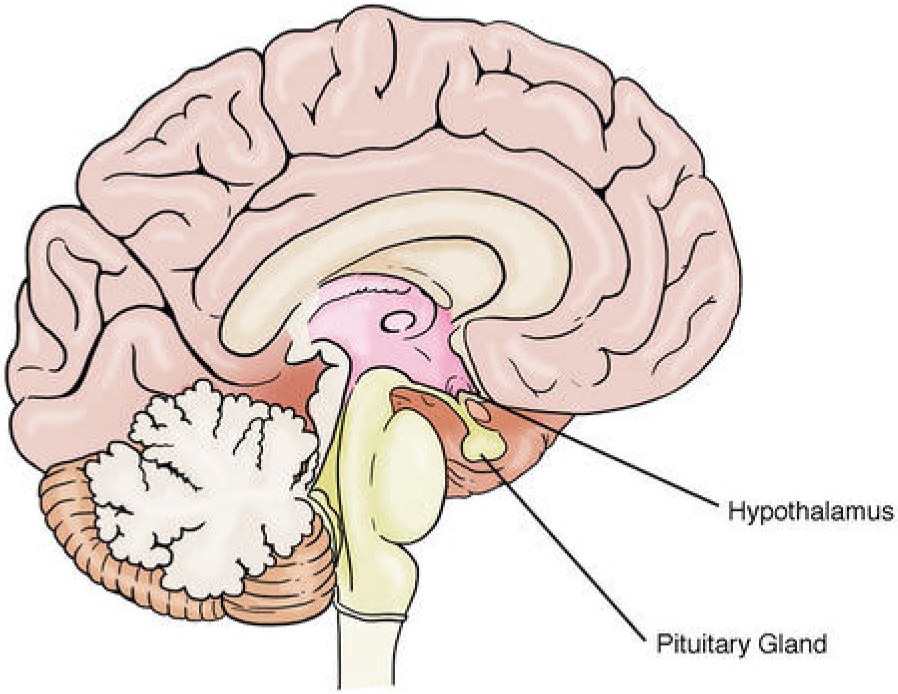
[Figure 2]

The glands of the endocrine system are the same in males and females except for the testes, which are found only in males, and ovaries, which are found only in females.

Hypothalamus

The **hypothalamus** is actually part of the brain (see **Figure** below), but it also secretes **hormones**. Some of its hormones "tell" the **pituitary gland** either to secrete or to stop secreting its hormones. In this way, the hypothalamus provides a link between the nervous and endocrine systems. The hypothalamus also produces hormones that directly regulate body processes. These hormones travel to the pituitary gland, which stores them until they are needed. The hormones include **antidiuretic hormone** and **oxytocin**.

- **Antidiuretic hormone** stimulates the kidney to conserve water by producing more concentrated urine.
- **Oxytocin** stimulates the contractions of childbirth, among other functions.



[Figure 3]

The hypothalamus and pituitary gland are located close together at the base of the brain.

Pituitary Gland

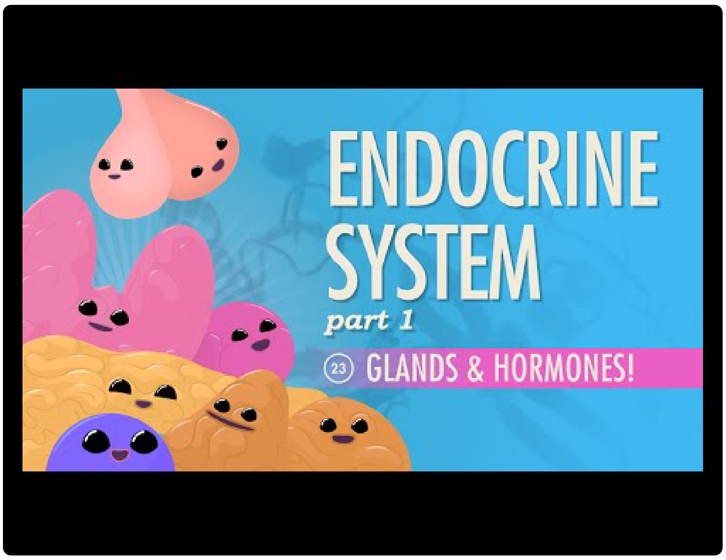
The pea-sized **pituitary gland** is attached to the hypothalamus by a thin stalk (see **Figure** above). It consists of two bulb-like lobes. The posterior (back) lobe stores hormones from the hypothalamus. The anterior (front) lobe secretes pituitary hormones. Several pituitary hormones and their effects are listed in **Table** below. Most pituitary hormones control other endocrine glands. That's why the pituitary is often called the "master gland" of the endocrine system.

Hormone	Target	Effect(s)
Adrenocorticotropic hormone (ACTH)	**adrenal glands**	Stimulates the cortex of each adrenal gland to secrete its hormones.
Thyroid-stimulating hormone (TSH)	**thyroid gland**	Stimulates the thyroid gland to secrete thyroid hormone.
Growth hormone (GH)	Body cells	Stimulates body cells to synthesize protein and grow.
follicle-stimulating hormone (FSH)	**ovary, testis**	Stimulates the ovaries to develop mature egg; stimulates the testes to produce sperm.
luteinizing hormone (LH)	Ovaries, testes	Stimulates the ovaries and testes to secrete sex hormone; stimulates the ovaries to release eggs.
Prolactin (PRL)	mammary gland	Stimulates the mammary glands to produce milk.

Other Endocrine Glands

Other glands of the endocrine system are described below. You can refer to **Figure** above to see where they are located.

- The **thyroid gland** is a large gland in the neck. Thyroid hormones increase the rate of metabolism in cells throughout the body. They control how quickly cells use energy and make proteins.
- The four **parathyroid glands** are located behind the thyroid gland. Parathyroid hormone helps keep the level of calcium in the blood within a narrow range. It stimulates bone cells to dissolve calcium in bone matrix and release it into the blood.
- The **pineal gland** is a tiny gland located at the base of the brain. It secretes the hormone **melatonin**. This hormone controls sleep-wake cycles and several other processes.
- The **pancreas** is located near the stomach. Its hormones include **insulin** and **glucagon**. These two hormones work together to control the level of glucose in the blood. **Insulin** causes excess blood glucose to be taken up by the liver, which stores the glucose as glycogen. **Glucagon** stimulates the liver to break down glycogen into glucose and release it back into the blood. The pancreas also secretes digestive enzyme into the digestive tract.
- The two **adrenal glands** are located above the kidneys. Each gland has an inner and outer part. The outer part, called the cortex, secretes hormones such as cortisol, which helps the body deal with stress, and aldosterone, which helps regulate the balance of mineral in the body. The inner part of each adrenal gland, called the medulla, secretes fight-or-flight hormones such as adrenaline, which prepare the body to respond to emergencies. For example, adrenaline increases the amount of oxygen and glucose going to the muscles.
- The **gonad** secrete sex hormones. The male gonads are called **testes**. They secrete the male sex hormone testosterone. The female gonads are called **ovaries**. They secrete the female sex hormone estrogen. Sex hormones are involved in the changes of puberty. They also control the production of gamete by the gonads.



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Further Reading

Endocrine System Diseases

Summary

- The endocrine system consists of glands that secrete hormones into the bloodstream.
- The endocrine system is regulated by a part of the brain called the hypothalamus, which also secretes hormones.
- The hypothalamus controls the pituitary gland, which is called the "master gland" of the endocrine system because its hormones regulate other endocrine glands.
- Other endocrine glands include the thyroid gland and pancreas.

Review

1. Explain how the nervous system is linked with the endocrine system.
2. List five of the major glands of the endocrine system.
3. Name three pituitary hormones, and state how they affect their targets.

Report Content Errors

13.21 Hormone

FlexBooks 2.0 > Biology For High School Diploma > Hormone

Last Modified: Aug 01, 2018

[Figure 1]

Steroid hormones. How do they work?

As hormones, they are the messengers of the endocrine system. Obviously they must change something in the cell.

How Hormones Work

Hormones are the messenger molecules of the endocrine system. Endocrine hormones travel throughout the body in the blood. However, each hormone affects only certain cells, called **target cell**. A **target cell** is the type of cell on which a hormone has an effect. A target cell is affected by a particular hormone because it has **receptor protein** that are specific to that hormone. A hormone travels through the bloodstream until it finds a target cell with a matching receptor it can bind to. When the hormone binds to a receptor, it causes a change within the cell. Exactly how this works depends on whether the hormone is a **steroid hormone** or a **non-steroid hormone**.

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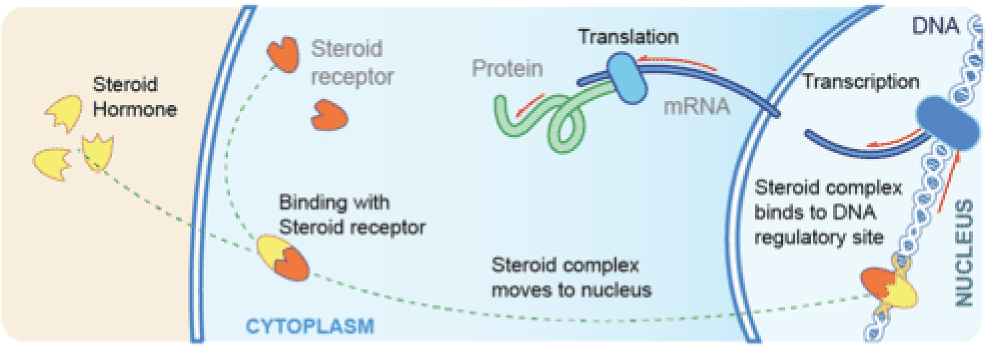
Steroid Hormones

Steroid hormones are made of lipid, such as phospholipids and cholesterol. They are fat soluble, so they can diffuse across the plasma membrane of target cells and bind with receptors in the cytoplasm of the cell (see **Figure** below). The steroid hormone and receptor form a complex that moves into the nucleus and influences the expression of gene, essentially acting as a transcription factor. Examples of steroid hormones include cortisol and sex hormone.



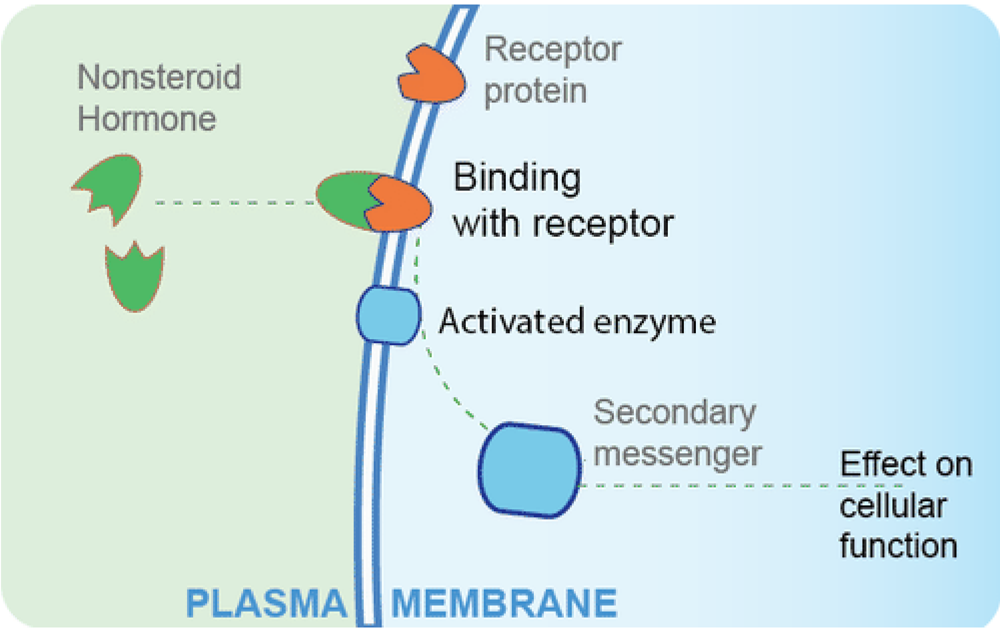
[Figure 2]

A steroid hormone crosses the plasma membrane of a target cell and binds with a receptor inside the cell.

Non-Steroid Hormones

Non-steroid hormones are made of amino acid. They are not fat soluble, so they cannot diffuse across the plasma membrane of target cells. Instead, a non-steroid hormone binds to a receptor on the cell membrane (see **Figure** below). The binding of the hormone triggers an enzyme inside the cell membrane. The enzyme activates another molecule, called the

second messenger, which influences processes inside the cell. Most endocrine hormones are non-steroid hormones, including insulin and thyroid hormones.



[Figure 3]

A non-steroid hormone binds with a receptor on the plasma membrane of a target cell. Then, a secondary messenger affects cell processes.

Summary

- Hormones work by binding to protein receptors either inside target cells or on their plasma membranes.
- The binding of a steroid hormone forms a hormone-receptor complex that affects gene expression in the nucleus of the target cell.
- The binding of a non-steroid hormone activates a second messenger that affects processes within the target cell.

Review

1. Define hormone.
2. Compare and contrast how steroid and non-steroid hormones affect target cells.

Report Content Errors

13.22 Hormone Regulation

FlexBooks 2.0 > Biology For High School Diploma > Hormone Regulation

Last Modified: Aug 01, 2018

[Figure 1]

On or off?

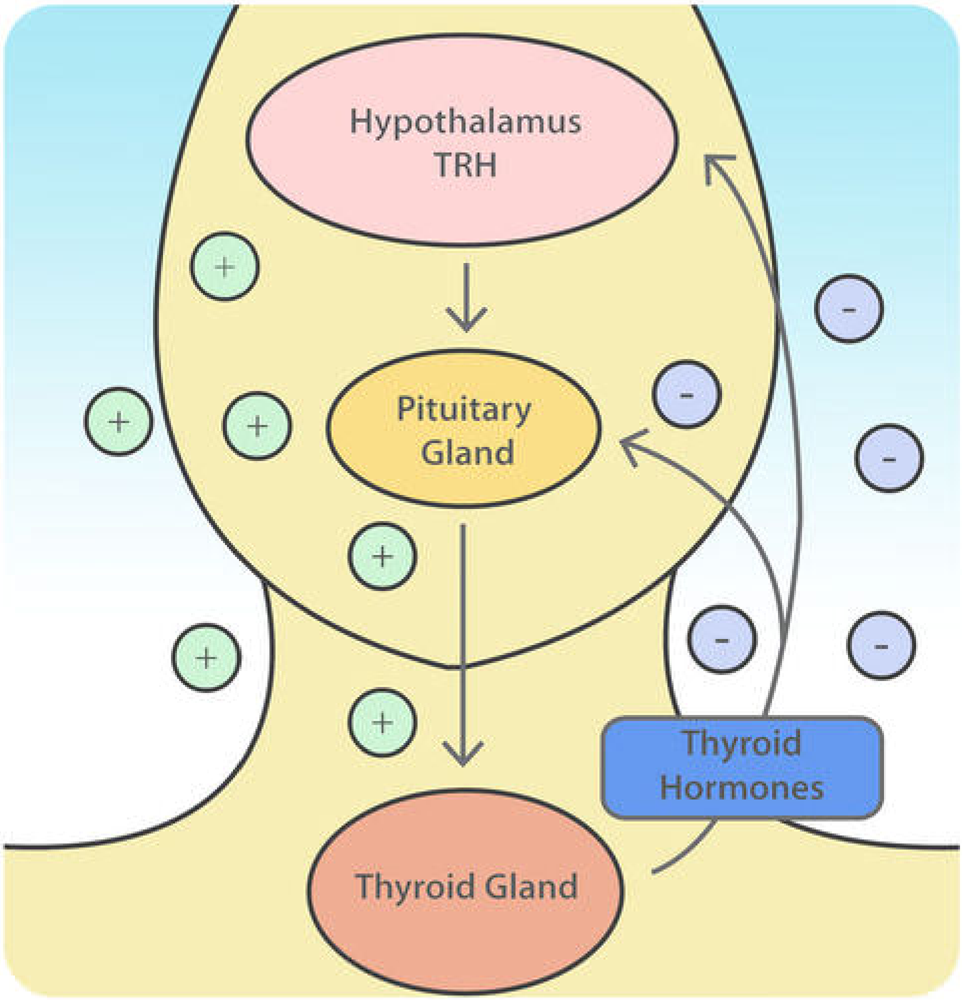
hormone alter conditions inside the cell, usually in response to a stimulus. That means they are activated at specific times. So they must be turned on and then turned back off. What turns these hormones and their responses on or off?

Hormone Regulation: Feedback Mechanisms

Hormones control many cell activities, so they are very important for homeostasis. But what controls the hormones themselves? Most hormones are regulated by feedback mechanisms. A **feedback mechanism** is a loop in which a product feeds back to control its own production. Most hormone feedback mechanisms involve **negative feedback loops**. Negative feedback keeps the concentration of a hormone within a narrow range.

Negative Feedback

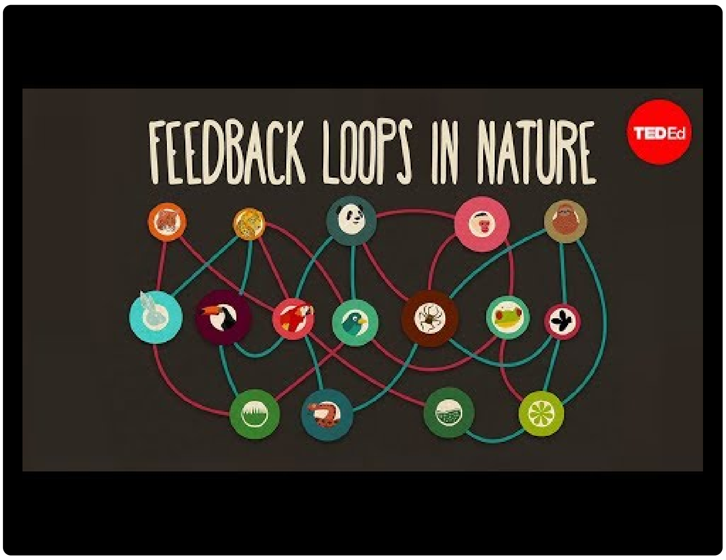
Negative feedback occurs when a product feeds back to decrease its own production. This type of feedback brings things back to normal whenever they start to become too extreme. The thyroid gland is a good example of this type of regulation. It is controlled by the negative feedback loop shown in **Figure** below.



[Figure 2]

The thyroid gland is regulated by a negative feedback loop. The loop includes the hypothalamus and pituitary gland in addition to the thyroid.

Here's how thyroid regulation works. The hypothalamus secretes thyrotropin-releasing hormone, or TRH. TRH stimulates the pituitary gland to produce thyroid-stimulating hormone, or TSH. TSH, in turn, stimulates the thyroid gland to secrete its hormones. When the level of thyroid hormones is high enough, the hormones feedback to stop the hypothalamus from secreting TRH and the pituitary from secreting TSH. Without the stimulation of TSH, the thyroid gland stops secreting its hormones. Soon, the level of thyroid hormone starts to fall too low. What do you think happens next?



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Negative feedback also controls insulin secretion by the pancreas.

Positive feedback

positive feedback occurs when a product feeds back to increase its own production. This causes conditions to become increasingly extreme. An example of positive feedback is milk production by a mother for her baby. As the baby suckles, nerve messages from the nipple cause the pituitary gland to secrete prolactin. Prolactin, in turn, stimulates the mammary gland to produce milk, so the baby suckles more. This causes more prolactin to be secreted and more milk to be produced. This example is one of the few positive feedback mechanisms in the human body. What do you think would happen if milk production by the mammary glands was controlled by negative feedback instead?

Summary

- Most hormones are controlled by negative feedback, in which the hormone feeds back to decrease its own production. This type of feedback brings things back to normal whenever they start to become too extreme.
- Positive feedback is much less common because it causes conditions to become increasingly extreme.

Review

1. What is negative feedback?
2. Why are negative feedback mechanisms more common than positive feedback mechanisms in the human body?
3. What might happen if an endocrine hormone such as thyroid hormone was controlled by positive instead of negative feedback?

4. Tasha had a thyroid test. Her doctor gave her an injection of TSH and 15 minutes later measured the level of thyroid hormone in her blood. What is TSH? Why do you think Tasha's doctor gave her an injection of TSH? How would this affect the level of thyroid hormones in her blood if her thyroid is normal?

Report Content Errors

13.23 Endocrine System Diseases

FlexBooks 2.0 > Biology For High School Diploma > Endocrine System Diseases

Last Modified: Feb 25, 2021

[Figure 1]

How tall can a person become?

This may be an exaggeration, but the world's tallest person, Robert Pershing Wadlow, stood almost nine feet tall when he died at the age of 22. Is growing that tall due to a problem with the endocrine system?

Endocrine System Disorders

Diseases of the endocrine system are relatively common. An endocrine disease usually involves the secretion of too much or not enough hormone. When too much hormone is secreted, it is called **hypersecretion**. When not enough hormone is secreted, it is called **hyposecretion**.

Hypersecretion

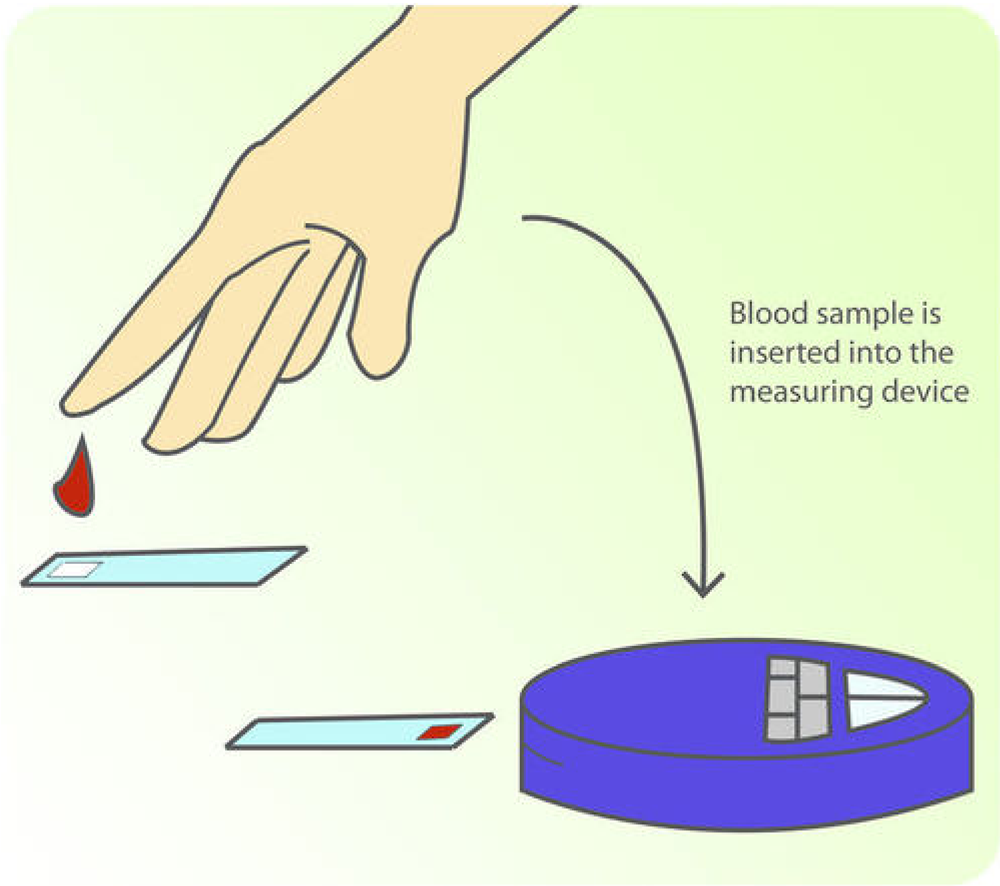
Hypersecretion by an endocrine gland is often caused by a tumor. For example, a tumor of the pituitary gland can cause hypersecretion of growth hormone. If this occurs in childhood, it results in very long arms and legs and abnormally tall stature by adulthood. The condition is commonly known as **gigantism** (see **Figure** below).

[Figure 2]

Hypersecretion of growth hormone leads to abnormal growth, often called gigantism.

Hyposecretion

Destruction of hormone-secreting cell of a gland may result in not enough of a hormone being secreted. This occurs in **type 1 diabetes**. In this case, the body's own immune system attacks and destroys cells of the pancreas that secrete insulin, making type 1 diabetes an autoimmune disease. A person with type 1 diabetes must frequently monitor the level of glucose in the blood (see **Figure** below). If the level of blood glucose is too high, insulin is injected to bring it under control. If it is too low, a small amount of sugar is consumed.



[Figure 3]

To measure the level of glucose in the blood, a drop of blood is placed on a test strip, which is read by a meter.

Hormone Resistance

In some cases, an endocrine gland secretes a normal amount of hormone, but target cell do not respond to the hormone. Often, this is because target cells have become resistant to the hormone. **type 2 diabetes** is an example of this type of endocrine disorder. In type 2 diabetes, body cells do not respond to normal amounts of insulin. As a result, cells do not take up glucose and the amount of glucose in the blood becomes too high. This type of diabetes is usually treated with medication and diet. The addition of extra insulin to the treatment can help some patients.

Summary

- Endocrine system disorders usually involve the secretion of too much or not enough hormone. For example, a tumor of the adrenal gland may lead to excessive secretion of growth hormone, which causes gigantism.
- In Type 1 diabetes, the pancreas does not secrete enough insulin, which causes high levels of glucose in the blood.

Review

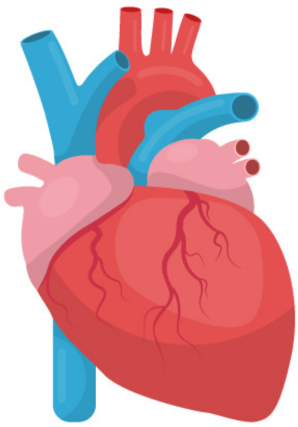
1. Define hypersecretion. Give an example of an endocrine disorder that involves hypersecretion.
2. Explain why a person with type 2 diabetes is not affected by normal amounts of insulin. Will providing extra insulin help this person?

Report Content Errors

13.24 Heart

FlexBooks 2.0 > Biology For High School Diploma > Heart

Last Modified: Feb 08, 2022



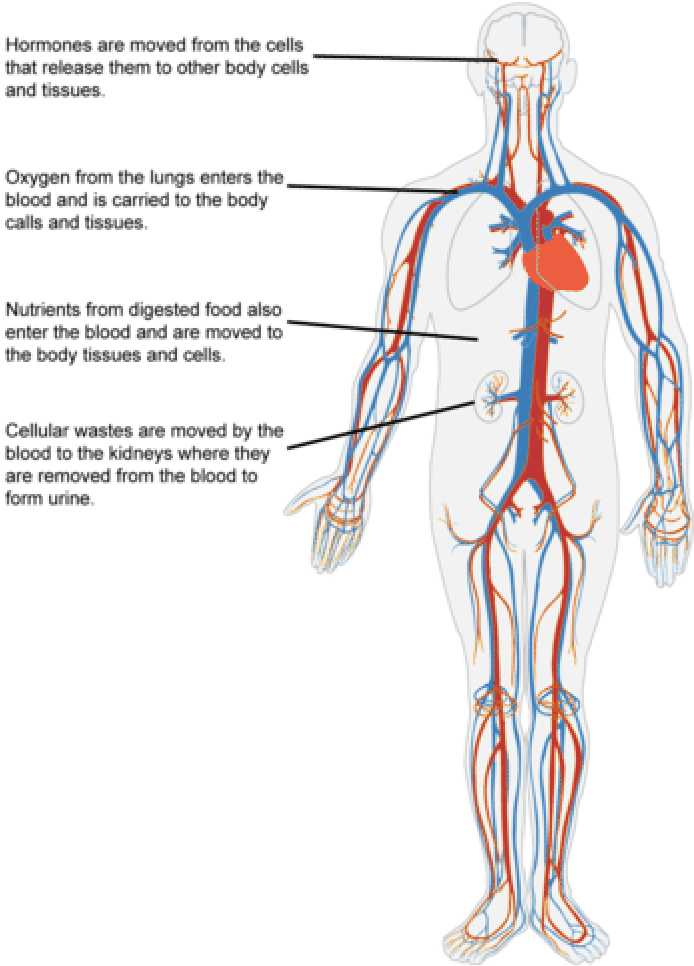
[Figure 1]

What's the most active muscle in the body?

The human heart. An absolutely remarkable organ. Obviously, its main function is to pump blood throughout the body. And it does this extremely well. On average, this muscular organ will beat about 100,000 times in one day and about 35 million times in a year. During an average lifetime, the human heart will beat more than 2.5 billion times.

The Circulatory System

The **circulatory system** can be compared to a system of interconnected, one-way roads that range from superhighways to back alleys. Like a network of roads, the job of the circulatory system is to allow the transport of materials from one place to another. As described in **Figure** below, the materials carried by the circulatory system include hormone, oxygen, cellular wastes, and nutrient from digested food. Transport of all these materials is necessary to maintain homeostasis of the body. The main components of the circulatory system are the **heart, blood vessel,** and **blood.**

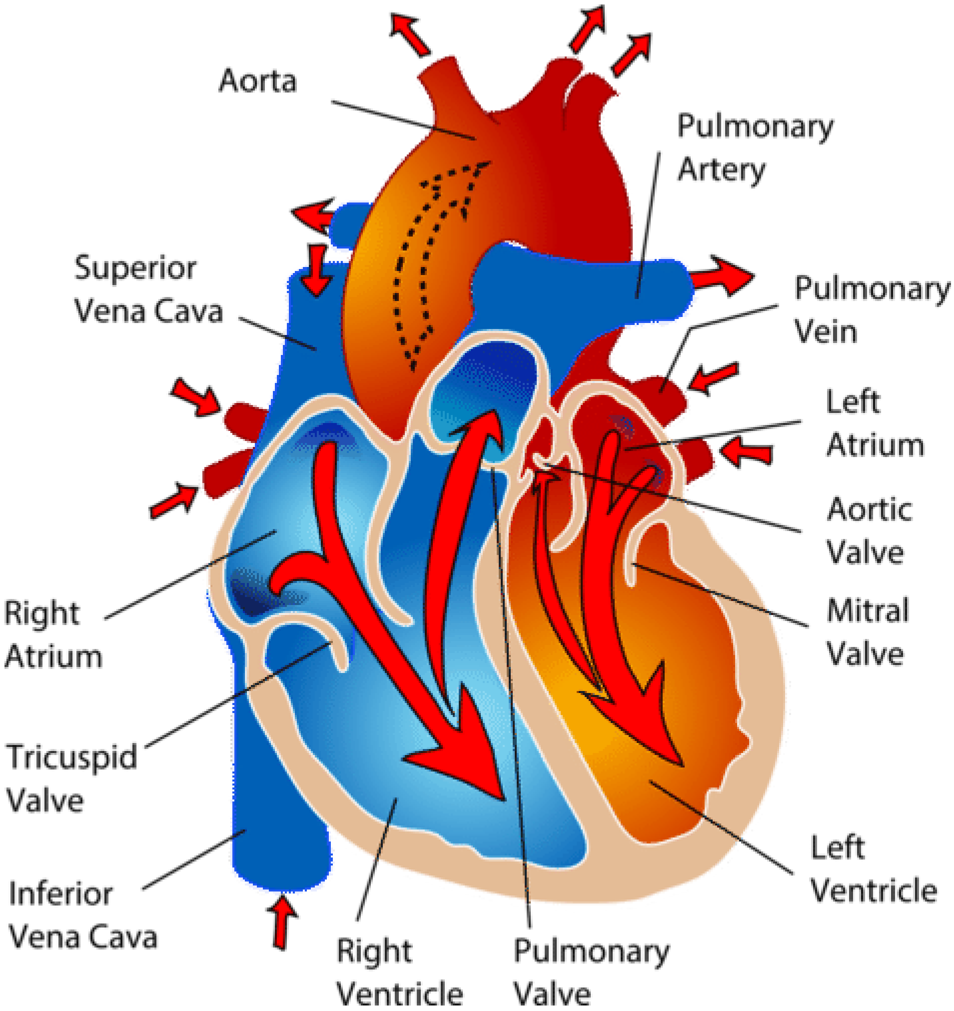


[Figure 2]

The function of the circulatory system is to move materials around the body.

The Heart

The heart is a muscular organ in the chest. It consists mainly of cardiac muscle tissue and pumps blood through blood vessels by repeated, rhythmic contractions. The heart has four chambers, as shown in **Figure** below: two upper **atrium** (singular, **atrium**) and two lower **ventricle**. Valves between chambers keep blood flowing through the heart in just one direction.



[Figure 3]

The chambers of the heart and the valves between them are shown here.

Blood Flow Through the Heart

Blood flows through the heart in two separate loops, which are indicated by the arrows in **Figure** above. You can think of them as a "left side loop" and a "right side loop." The right side of the heart collects oxygen-poor blood from the body and pumps the blood to the lung. In the lungs, carbon dioxide is released and oxygen obtained by the blood. The left side of the heart carries the oxygen-rich blood back from the lungs and pumps it to the rest of the body. The blood delivers oxygen to the body's cell, returning the oxygen-poor blood back to the heart.

1. Blood from the body enters the right atrium of the heart. The right atrium pumps the blood to the right ventricle, which pumps it to the lungs.
2. Blood from the lungs enters the left atrium of the heart. The left atrium pumps the blood to the left ventricle, which pumps it to the body.

Heartbeat

Unlike skeletal muscle, cardiac muscle contracts without stimulation by the nervous system. Instead, specialized cardiac muscle cells send out electrical impulses that stimulate the contractions. As a result, the atria and ventricles normally contract with just the right timing to keep blood pumping efficiently through the heart.

Summary

- The heart contracts rhythmically to pump blood to the lungs and the rest of the body.
- Specialized cardiac muscle cells trigger the contractions.

Review

1. What are the main components of the circulatory system?
2. Describe how blood flows through the heart.

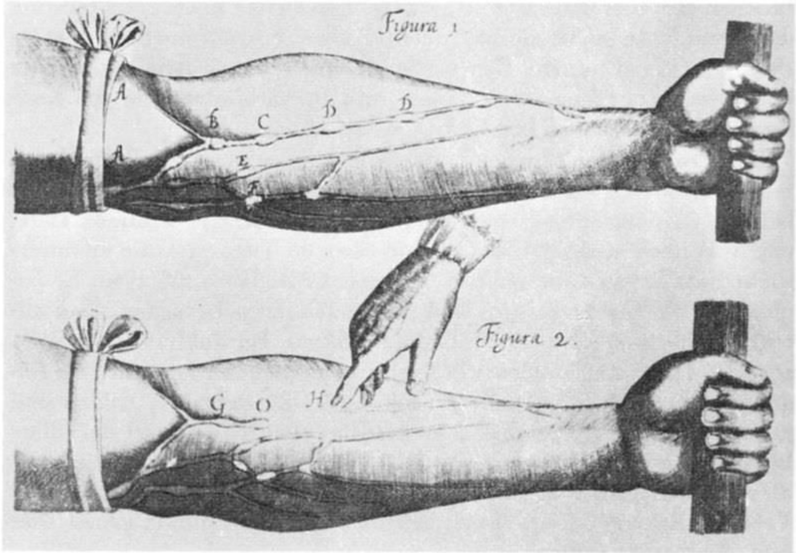
3. What controls heartbeat?

Report Content Errors

13.25 Blood Vessels

FlexBooks 2.0 > Biology For High School Diploma > Blood Vessels

Last Modified: Aug 01, 2018



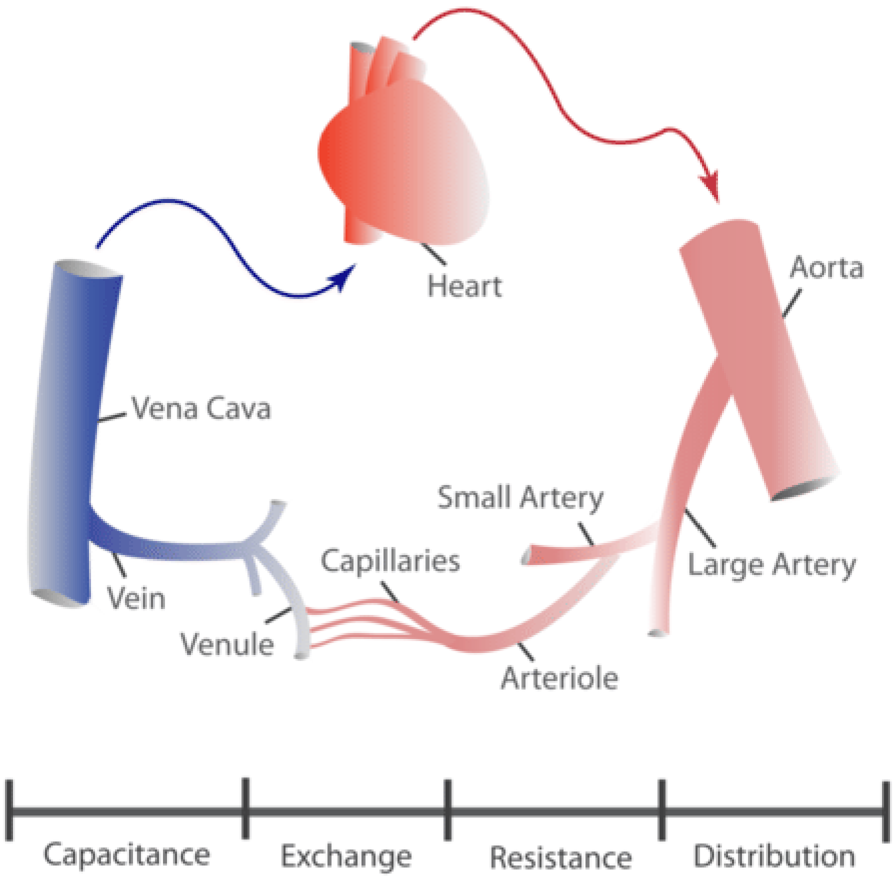
[Figure 1]

How does blood travel around the body?

Through blood vessels, of course. This image of **vein** is from William Harvey's (1578-1657) *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.* Harvey was the first to describe in detail the systemic circulation and properties of blood being pumped to the brain and body by the heart.

Blood Vessels

Blood vessels form a network throughout the body to transport blood to all the body cell. There are three major types of blood vessels: **artery**, veins, and capillaries. All three are shown in **Figure** below and described below.



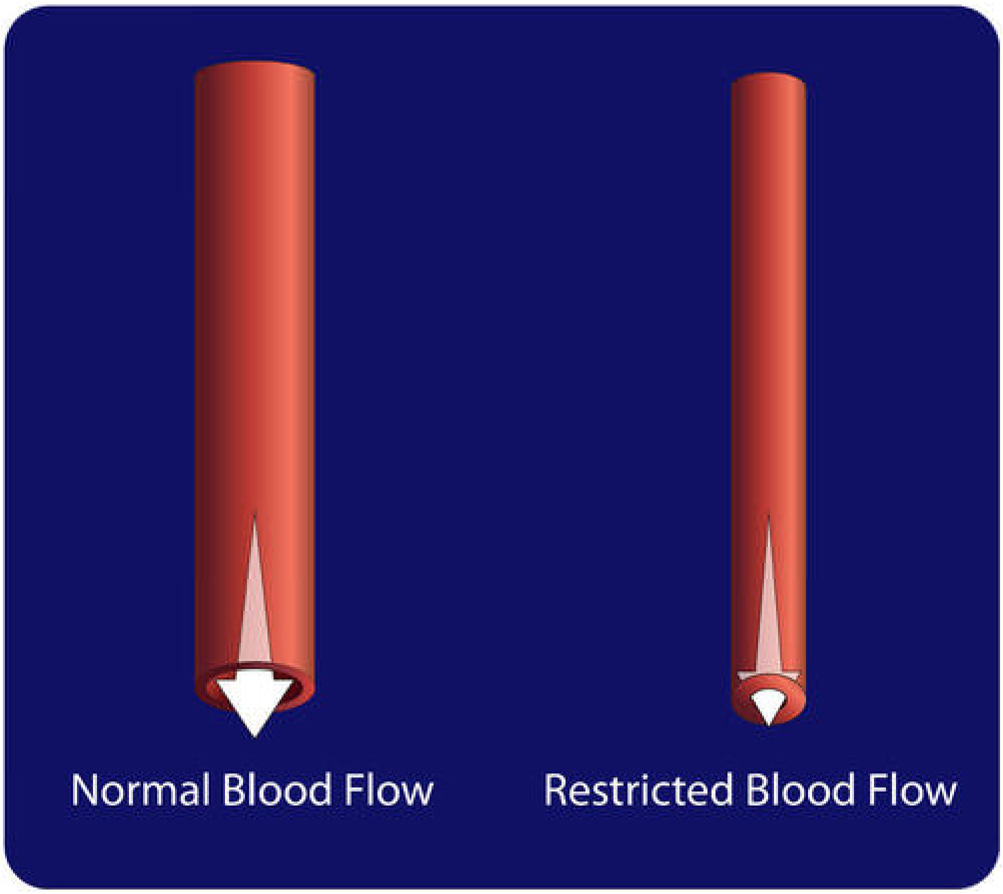
[Figure 2]

Blood vessels include arteries, veins, and capillaries.

- **Arteries** are muscular blood vessels that carry blood away from the heart. They have thick walls that can withstand the pressure of blood being pumped by the heart. Arteries generally carry oxygen-rich blood. The largest artery is the **aorta**, which receives blood directly from the heart.
- **Veins** are blood vessels that carry blood toward the heart. This blood is no longer under much pressure, so many veins have valves that prevent backflow of blood. Veins generally carry deoxygenated blood. The largest vein is the **inferior vena cava**, which carries blood from the lower body to the heart. The **superior vena cava** brings blood back to the heart from the upper body.
- **Capillaries** are the smallest type of blood vessels. They connect very small arteries and veins. The exchange of gases and other substances between cells and the blood takes place across the extremely thin walls of capillaries.

Blood Vessels and Homeostasis

Blood vessels help regulate body processes by either constricting (becoming narrower) or dilating (becoming wider). These actions occur in response to signals from the autonomic nervous system or the endocrine system. **constriction** occurs when the muscular walls of blood vessels contract. This reduces the amount of blood that can flow through the vessels (see **Figure** below). **dilation** occurs when the walls relax. This increases blood flows through the vessels.



[Figure 3]

When a blood vessel constricts, less blood can flow through it.

Constriction and dilation allow the circulatory system to change the amount of blood flowing to different organ. For example, during a fight-or-flight response, dilation and constriction of blood vessels allow more blood to flow to skeletal muscle and less to flow to digestive organs. Dilation of blood vessels in the skin allows more blood to flow to the body surface so the body can lose heat. Constriction of these blood vessels has the opposite effect and helps conserve body heat.

Blood Vessels and Blood Pressure

The force exerted by circulating blood on the walls of blood vessels is called **blood pressure**. Blood pressure is highest in arteries and lowest in veins. When you have your blood pressure checked, it is the blood pressure in arteries that is measured. High blood pressure, or **hypertension**, is a serious health risk but can often be controlled with lifestyle changes or medication.

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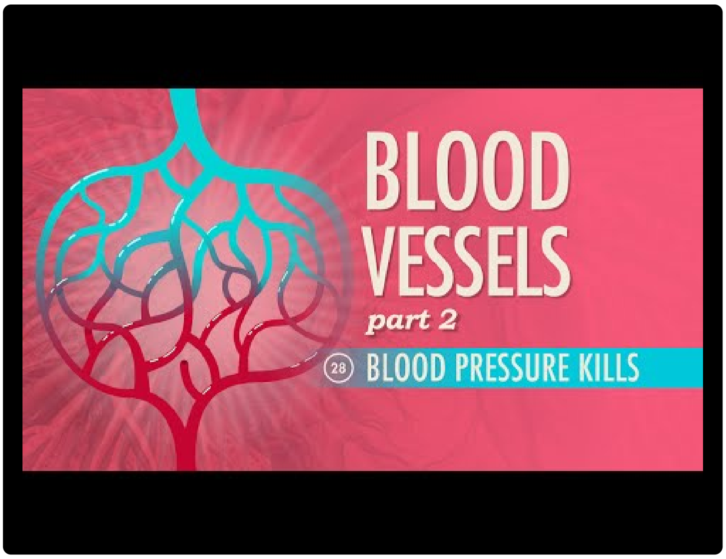

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Summary

- Arteries carry blood away from the heart, veins carry blood toward the heart, and capillaries connect arteries and veins.

Review

1. How do arteries differ from veins?

2. What is blood pressure? What is hypertension?
3. To take your pulse, you press your fingers against an artery near the surface of the body. What are you feeling and measuring when you take your pulse? Why can't you take your pulse by pressing your fingers against a vein?

Report Content Errors

13.26 Circulatory System

FlexBooks 2.0 > Biology For High School Diploma > Circulatory System

Last Modified: Jul 09, 2021

[Figure 1]

How does oxygen get into the blood?

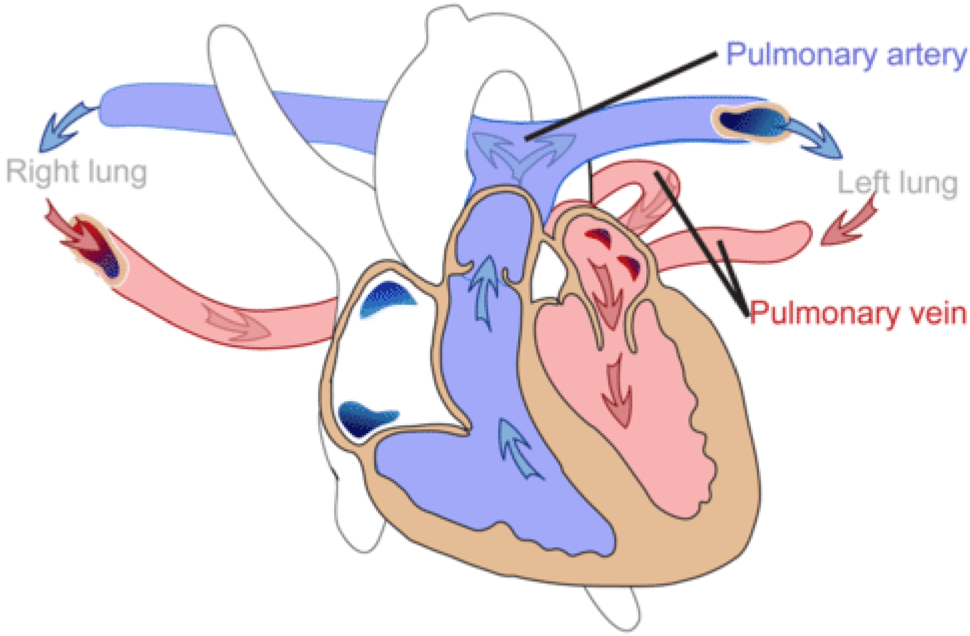
The main function of the circulatory system is to pump blood carrying oxygen around the body. But how does that oxygen get into the blood in the first place? You may already know that this occurs in the lung. So the blood must also be pumped to the lungs, and this happens separately from the rest of the body.

Pulmonary and Systemic Circulations

The circulatory system actually consists of two separate systems: **pulmonary circulation** and **systemic circulation**.

Pulmonary Circulation

Pulmonary circulation is the part of the circulatory system that carries blood between the heart and lungs (the term "pulmonary" means "of the lungs"). It is illustrated in **Figure** below. Deoxygenated blood leaves the right ventricle through **pulmonary artery**, which transport it to the lungs. In the lungs, the blood gives up carbon dioxide and picks up oxygen. The oxygenated blood then returns to the left atrium of the heart through pulmonary vein.

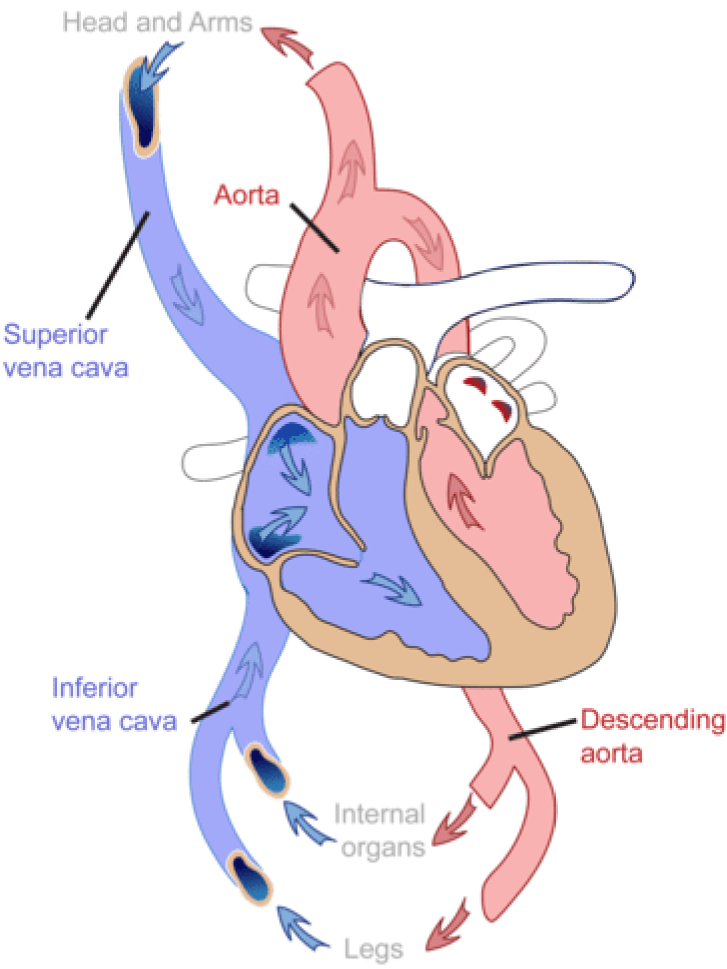


[Figure 2]

The pulmonary circulation carries blood between the heart and lungs.

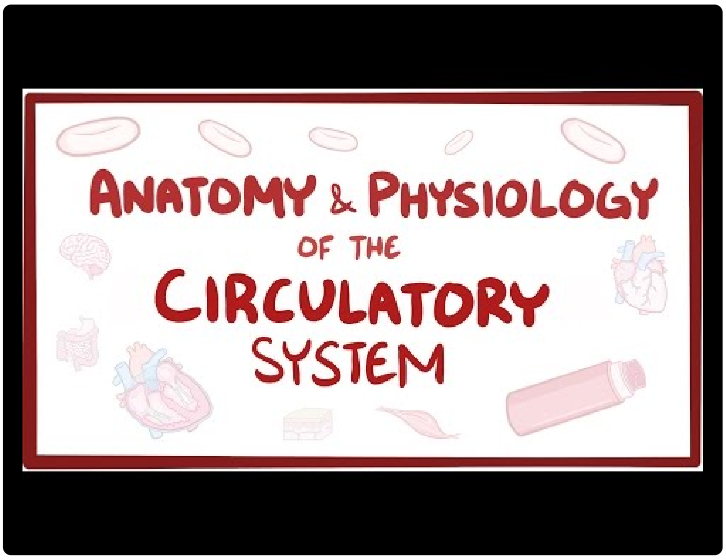
Systemic Circulation

Systemic circulation is the part of the circulatory system that carries blood between the heart and body. It is illustrated in **Figure** below. Oxygenated blood leaves the left ventricle through the aorta. The aorta and other artery transport the blood throughout the body, where it gives up oxygen and picks up carbon dioxide. The deoxygenated blood then returns to the right atrium through veins.



[Figure 3]

The systemic circulation carries blood between the heart and body.



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Summary

- The pulmonary circulation carries blood between the heart and lungs.
- The systemic circulation carries blood between the heart and body.

Review

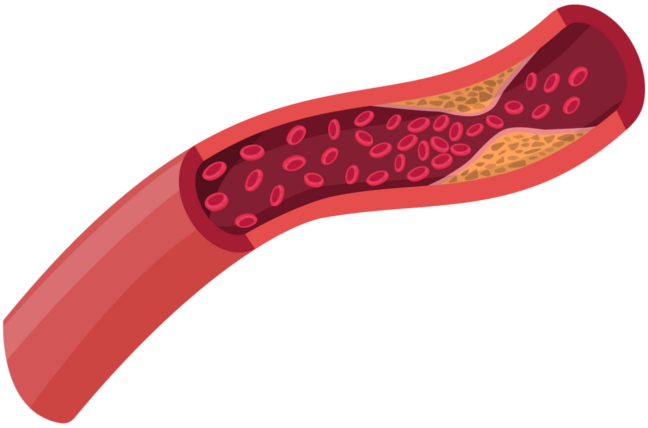
1. Compare and contrast pulmonary and systemic circulations.

Report Content Errors

13.27 Cardiovascular Diseases

FlexBooks 2.0 > Biology For High School Diploma > Cardiovascular Diseases

Last Modified: Aug 24, 2020



[Figure 1]

Eat healthy, exercise, and don't smoke. Why?

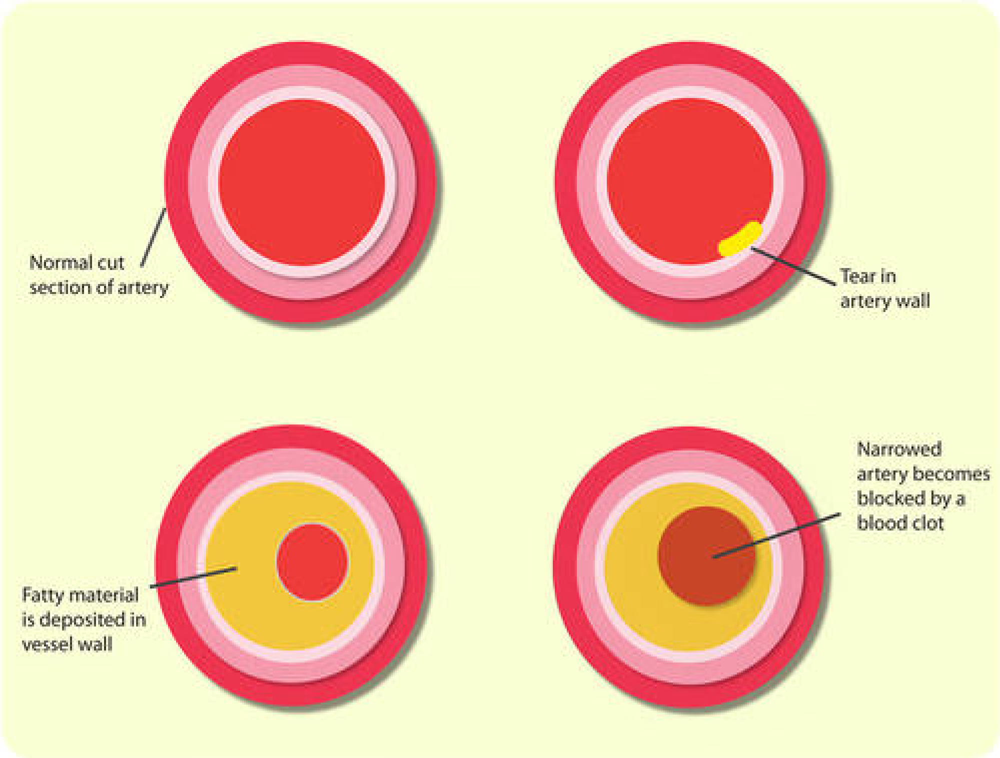
Normally blood needs to flow freely through our artery. **plaque** in an artery can restrict the flow of blood. As you can probably imagine, this is not an ideal situation. And eating right, exercising, and not smoking can help keep your arteries healthy.

Cardiovascular Disease

Diseases of the heart and blood vessel, called **cardiovascular diseases (CVD)**, are very common. The leading cause of CVD is **atherosclerosis**.

Atherosclerosis

Atherosclerosis is the buildup of plaque inside arteries (see **Figure** below). **Plaque** consists of cell debris, cholesterol, and other substances. Factors that contribute to plaque buildup include a high-fat diet and smoking. As plaque builds up, it narrows the arteries and reduces blood flow.



[Figure 2]

The fatty material inside the artery on the right is plaque. Notice how much narrower the artery has become. Less blood can flow through it than the normal artery.

Atherosclerosis normally begins in late childhood and is typically found in most major arteries. It does not usually have any early symptoms. Causes of atherosclerosis include a high-fat diet, high cholesterol, smoking, obesity, and diabetes. Atherosclerosis becomes a threat to health when the plaque buildup prevents blood circulation in the heart or the brain. A blocked blood vessel in the heart can cause a **heart attack**. Blockage of the circulation in the brain can cause a **stroke**.

Ways to prevent atherosclerosis include eating healthy foods, getting plenty of exercise and not smoking. A diet high in saturated fat and cholesterol can raise your body's cholesterol levels, which can lead to increased plaque in your arteries. Cholesterol and saturated fat are found mostly in animal products, such as meat, egg, milk and other dairy products.

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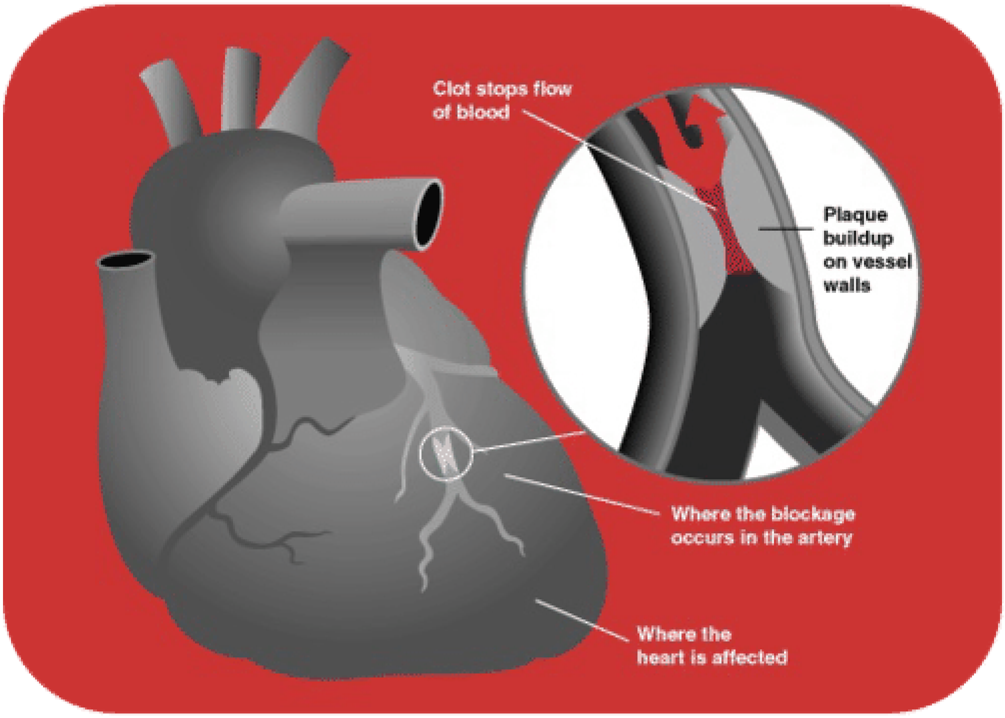
Coronary Heart Disease

Atherosclerosis of arteries that supply the heart muscle is called **coronary heart disease**. This disease may or may not have symptoms, such as chest pain. As the disease progresses, there is an increased risk of heart attack. A **heart attack** occurs when the blood supply to part of the heart muscle is blocked and cardiac muscle fibers die. Coronary heart disease is the leading cause of death of adults in the United States.

The image below shows the way in which a blocked coronary artery can cause a heart attack. The loss of oxygen to the heart muscle cause that part of the tissue to die. Maybe one day, stem cell therapy will allow for the replacement of the dead cells with new cardiac muscle cells.



[Figure 3]

A blockage in a coronary artery stops oxygen from getting to part of the heart muscle, so areas of the heart that depend on the blood flow from the blocked artery are starved of oxygen.

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Stroke

Atherosclerosis in the arteries of the brain can also lead to a stroke. A **stroke** is a loss of brain function due to a blockage of the blood supply to the brain. Risk factors for stroke include old age, high blood pressure, having a previous stroke, diabetes, high cholesterol, and smoking. The best way to reduce the risk of stroke is to have low blood pressure.

Preventing Cardiovascular Disease

Many factors may increase the risk of developing coronary heart disease and other CVDs. The risk of CVDs increases with age and is greater in males than females at most ages. Having a close relative with CVD also increases the risk. These factors cannot be controlled, but other risk factors can, including smoking, lack of exercise, and high-fat diet. By making healthy lifestyle choices, you can reduce your risk of developing CVD.

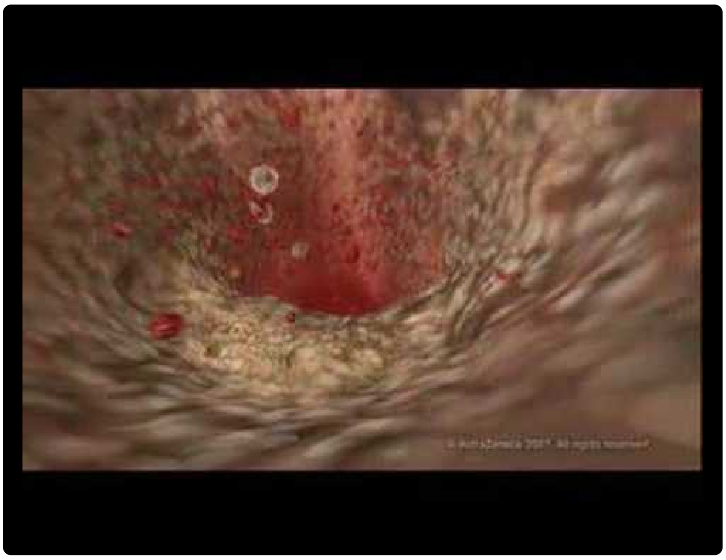
Summary

- A disease that affects the heart or blood vessels is called a cardiovascular disease (CVD).
- The leading cause of CVD is atherosclerosis, or the buildup of plaque inside arteries.
- Healthy lifestyle choices can reduce the risk of developing CVD.

Review

1. What is atherosclerosis? What is the result of atherosclerosis?
2. List controllable factors that increase the risk of cardiovascular disease.
3. What is the leading cause of death of adults in the Inited States?
4. How can you reduce your risk of developing CVD?

Resources



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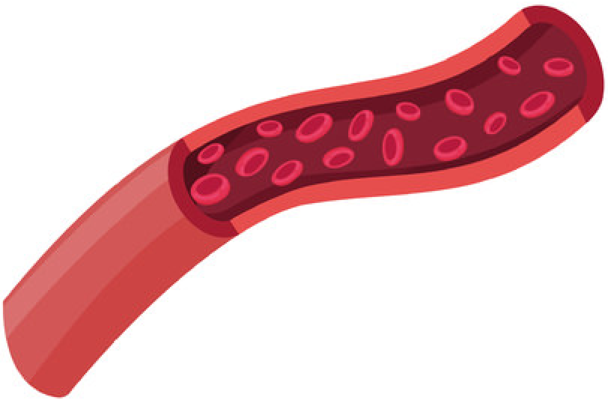
Report Content Errors

13.28 Blood

FlexBooks 2.0 > Biology For High School Diploma > Blood

Last Modified: Jul 31, 2021



[Figure 1]

What exactly is blood?

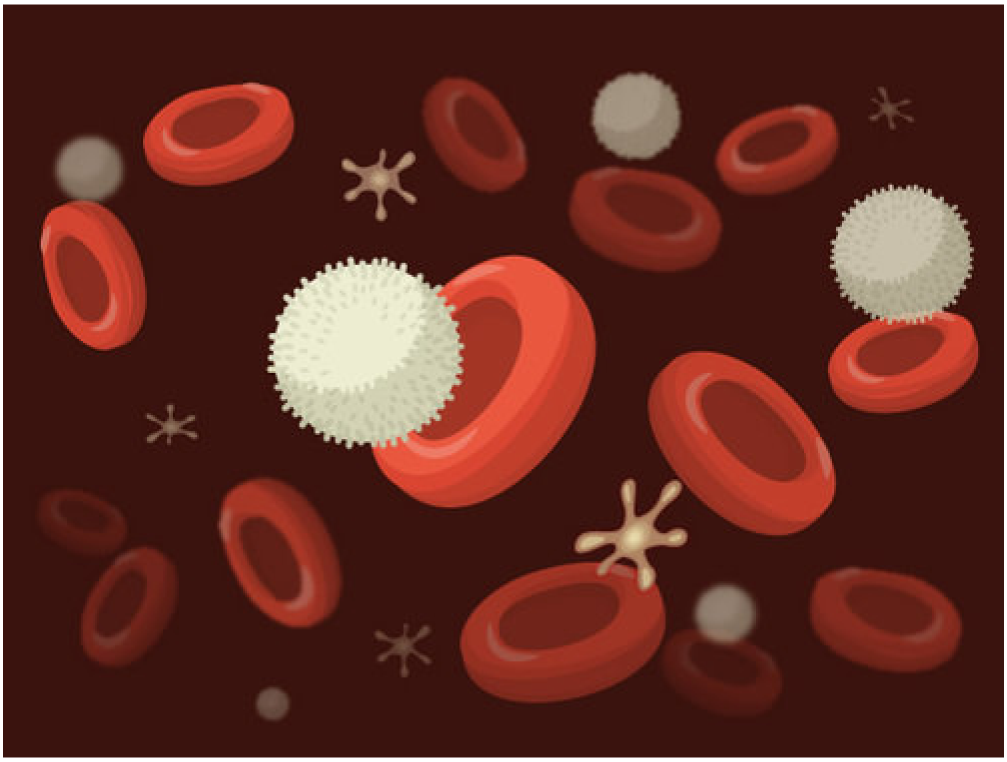
All your cell need oxygen, as oxygen is the final electron acceptor during cellular respiration. How do they get this oxygen? From blood. Blood cells flow through the vessels of the human circulatory system. But what exactly is blood? It does transport oxygen, but also has other functions.

Blood

Blood is a fluid connective tissue. It circulates throughout the body through blood vessel by the pumping action of the heart. Blood in artery carries oxygen and nutrient to all the body's cells. Blood in vein carries carbon dioxide and other wastes away from the cells to be excreted. Blood also defends the body against infection, repairs body tissue, transports hormone, and controls the body's pH.

Composition of Blood

The fluid part of blood is called **plasma**. It is a watery golden-yellow liquid that contains many dissolved substances and blood cells. Types of blood cells in plasma include **red blood cell**, **white blood cell**, and **platelet** (see **Figure** below).



[Figure 2]

Cells in blood include red blood cells, white blood cells, and platelets.

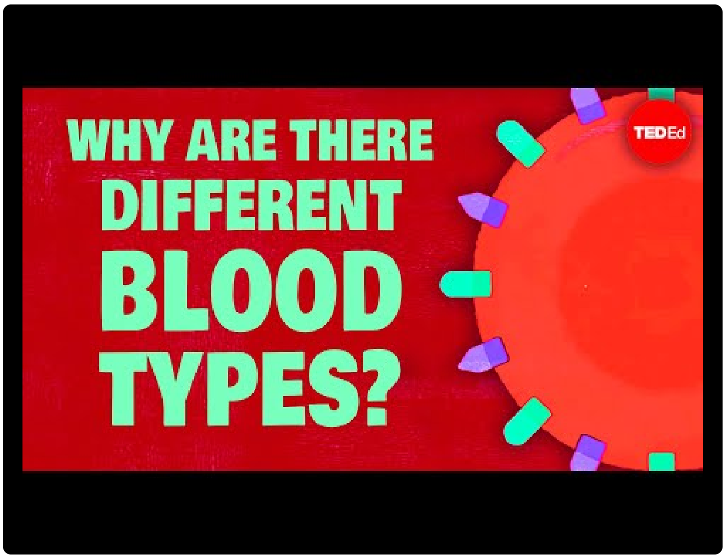
- The trillions of **red blood cells** in blood plasma carry oxygen. Red blood cells contain **hemoglobin**, a protein with iron that binds with oxygen. Red blood cells are made in the marrow of long bone, rib bones, the skull, and the vertebra. These cells survive for about 120 days, and then they are destroyed. Mature red blood cells lack a nucleus and other organelle, allowing for more hemoglobin, and therefore more oxygen to be carried by each cell.
- **White blood cells** are generally larger than red blood cells but far fewer in number. They defend the body against foreign bacterium, virus and other pathogen. For example, white blood cells called **phagocyte** swallow and destroy microorganisms and debris in the blood, neutrophils engulf bacteria and other parasite, and lymphocyte fight infections caused by bacteria and viruses.
- **Platelets** are cell fragments involved in blood clotting. They stick to tears in blood vessels and to each other, forming a plug at the site of injury. They also release chemicals that are needed for clotting to occur.

blood type is a genetic characteristic associated with the presence or absence of certain molecules, called **antigen**, on the surface of red blood cells. The most commonly known blood types are the ABO and Rhesus blood types.

- **ABO blood type** is determined by two common antigens, often referred to simply as antigens A and B. A person may have blood type A (only antigen A), B (only antigen B), AB (both antigens), or O (no antigens).

- **Rhesus blood type** is determined by one common antigen. A person may either have the antigen (Rh^+) or lack the antigen (Rh^-).

Blood type is important for medical reasons. A person who needs a blood transfusion must receive blood that is the same type as his or her own. Otherwise, the transfused blood may cause a potentially life-threatening reaction in the patient's bloodstream.



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Summary

- Blood is a fluid connective tissue that contains a liquid component called plasma.
- Blood also contains dissolved substances and blood cells.
- Red blood cells carry oxygen, white blood cells defend the body, and platelets help blood clot.

Review

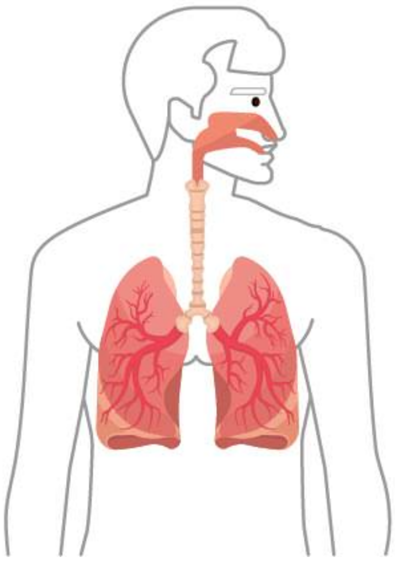
1. What type of tissue is blood?
2. Identify three types of blood cells and their functions.
3. People with type O blood are called "universal donors" because they can donate blood to anyone else, regardless of their ABO blood type. Explain why.

Report Content Errors

13.29 Respiratory System

FlexBooks 2.0 > Biology For High School Diploma > Respiratory System

Last Modified: Aug 01, 2018



[Figure 1]

Where does oxygen get into blood?

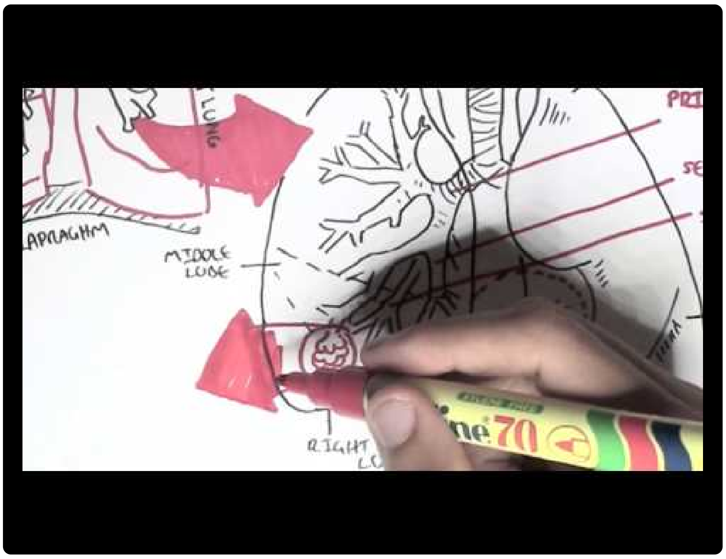
red blood cell are like trucks that transport cargo on a highway system. Their cargo is oxygen, and the highways are blood vessel. Where do red blood cells pick up their cargo of oxygen? The answer is the **lung**. The lungs are organ of the respiratory system. The respiratory system is the body system that brings air containing oxygen into the body and releases carbon dioxide into the atmosphere.

Respiration

The job of the **respiratory system** is the exchange of gases between the body and the outside air. This process, called **respiration**, actually consists of two parts. In the first part, oxygen in the air is drawn into the body and carbon dioxide is released from the body through the respiratory tract. In the second part, the circulatory system delivers the oxygen to body cell and picks up carbon dioxide from the cells in return. The **lungs** are organs of the respiratory system. It is in the lungs where oxygen is transferred from the respiratory system to the circulatory system.

The use of the word “respiration” in relation to gas exchange is different from its use in the term **cellular respiration**. Recall that cellular respiration is the metabolic process by which cells obtain energy by “burning” glucose. Cellular respiration uses oxygen and releases carbon dioxide. Respiration by the respiratory system supplies the oxygen and takes away the carbon dioxide.

- Respiration is the process in which gases are exchanged between the body and the outside air.
- The lungs and other organs of the respiratory system bring oxygen into the body and release carbon dioxide into the atmosphere.



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Review

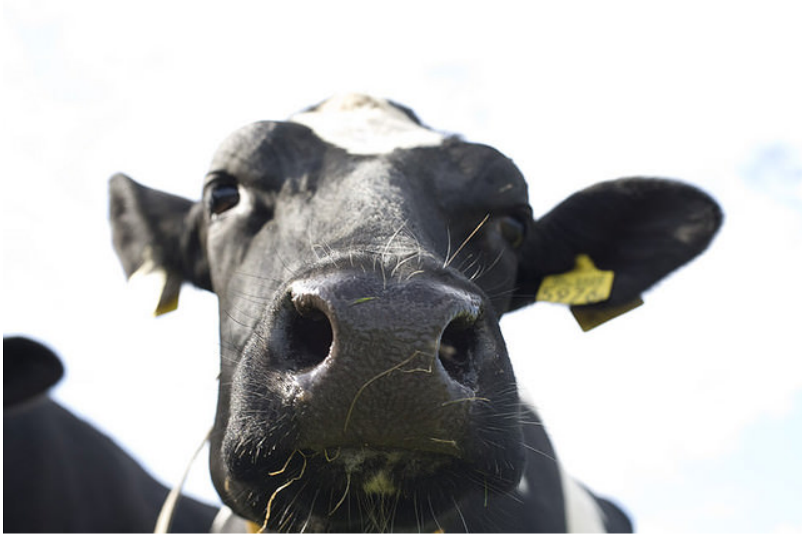
1. What is respiration?
2. Describe the two parts of respiration.
3. How is respiration different from cellular respiration?

Report Content Errors

13.30 Respiratory System Organs

FlexBooks 2.0 > Biology For High School Diploma > Respiratory System Organs

Last Modified: Jul 20, 2020



[Figure 1]

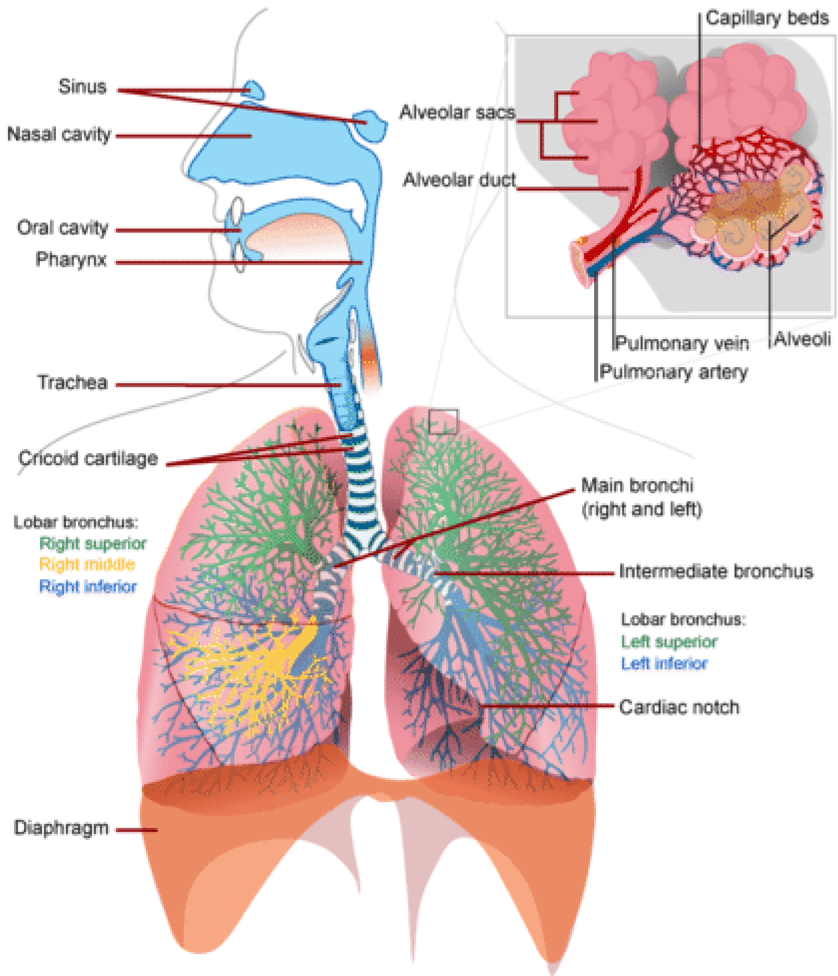
Are all noses alike?

It all starts with the nose. OK, in humans maybe not the nose pictured above, but one similar to the nose below. Though the passage of air is probably similar in cows and humans. Air comes in and then where does it go?

[Figure 2]

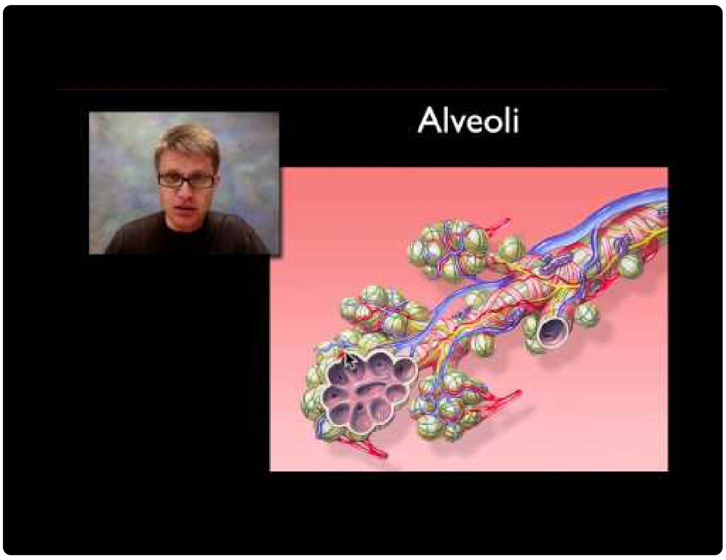
Organs of the Respiratory System

The organ of the respiratory system that bring air into the body are divided among the upper **respiratory tract** and lower respiratory tract. These organs are shown in **Figure** below. In addition to the **lung**, these organs include the **pharynx**, **larynx**, **trachea** and bronchus. The **nasal cavity** is also part of the respiratory system. The nose and nasal cavity filter, warm, and moisten the air we inhale. Hairs and mucus produced in the nose trap particles in the air and prevent them from reaching the lungs.



[Figure 3]

The organs of the respiratory system move air into and out of the body.



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- The **pharynx** is a long tube that is shared with the digestive system. Both food and air travel through the pharynx.
- The **larynx**, or voice box, contains vocal cords, which allow us to produce vocal sounds. Air passes through thin tissue in the larynx, producing sound.
- The **trachea**, or windpipe, is a long tube that leads down to the chest.
- The trachea divides as it enters the lungs to form the right and left **bronchi**, which branch into smaller bronchiole within each lung. The bronchioles lead to alveolus, the sites of gas exchange.

Further Reading

Respiratory System Disorders

Summary

- The organs of the respiratory system include the lungs, pharynx, larynx, trachea, and bronchi.

Review

1. Describe the main organs of the respiratory system.

Report Content Errors

13.31 Breathing

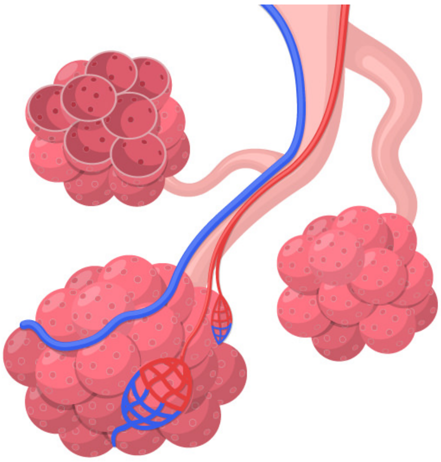
FlexBooks 2.0 > Biology For High School Diploma > Breathing

Last Modified: Jul 20, 2020

[Figure 1]

Grapes. Why? What do these have in common with a breath of air?

Below are the parts of the **lung** where oxygen moves from the lungs into the blood. If the **alveolus** below were purple, they could resemble a bunch of grapes. Of course, as the alveoli are in the lungs, they must be very small to provide enough area for the exchange of gases. In fact, there are about 300 million alveoli in the adult lung.



[Figure 2]

Journey of a Breath of Air

Take in a big breath of air through your nose. As you inhale, you may feel the air pass down your throat and notice your chest expand. Now exhale and observe the opposite events occurring. inhaling and exhaling may seem like simple actions, but they are just part of the complex process of respiration, which includes these four steps:

1. **ventilation**
2. **pulmonary gas exchange**
3. **Gas transport**
4. **Peripheral gas exchange**

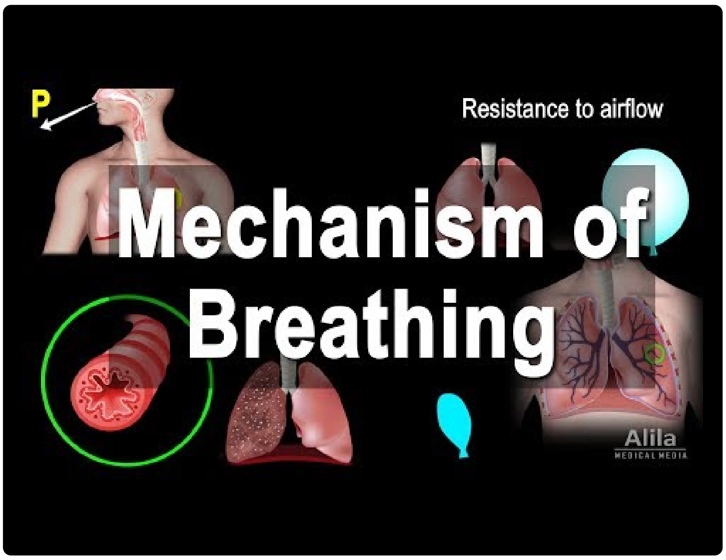
Ventilation

Respiration begins with ventilation. This is the process of moving air in and out of the lungs. The **lungs** are the organ in which gas exchange takes place between blood and air.

- Air enters the respiratory system through the nose. As the air passes through the nasal cavity, mucus and hairs trap any particles in the air. The air is also warmed and moistened so it won't harm delicate tissue of the lungs.
- Next, the air passes through the **pharynx**, a long tube that is shared with the digestive system. A flap of connective tissue called the **epiglottis** closes when food is swallowed to prevent choking.
- From the pharynx, air next passes through the **larynx**, or voice box. The larynx contains vocal cords, which allow us to produce vocal sounds.
- After the larynx, air moves into the **trachea**, or windpipe. This is a long tube that leads down to the chest.
- In the chest, the trachea divides as it enters the lungs to form the right and left **bronchus**. The bronchi contain cartilage, which prevents them from collapsing. Mucus in the bronchi traps any remaining particles in air. Tiny, hair-like structures called **cilia** line the bronchi and sweep the particles and mucus toward the throat so they can be expelled from the body.
- Finally, air passes from the bronchi into smaller passages called **bronchiole**. The bronchioles end in tiny air sac called **alveoli**.

Pulmonary Gas Exchange

Pulmonary gas exchange is the exchange of gases between inhaled air and the blood. It occurs in the alveoli of the lungs. Alveoli (singular, alveolus) are grape-like clusters surrounded by networks of thin-walled pulmonary capillaries. After you inhale, there is a greater concentration of oxygen in the alveoli than in the blood of the pulmonary capillaries, so oxygen diffuses from the alveoli into the blood across the capillaries (see **Figure** below). Carbon dioxide, in contrast, is more concentrated in the blood of the pulmonary capillaries than in the alveoli, so it diffuses in the opposite direction.



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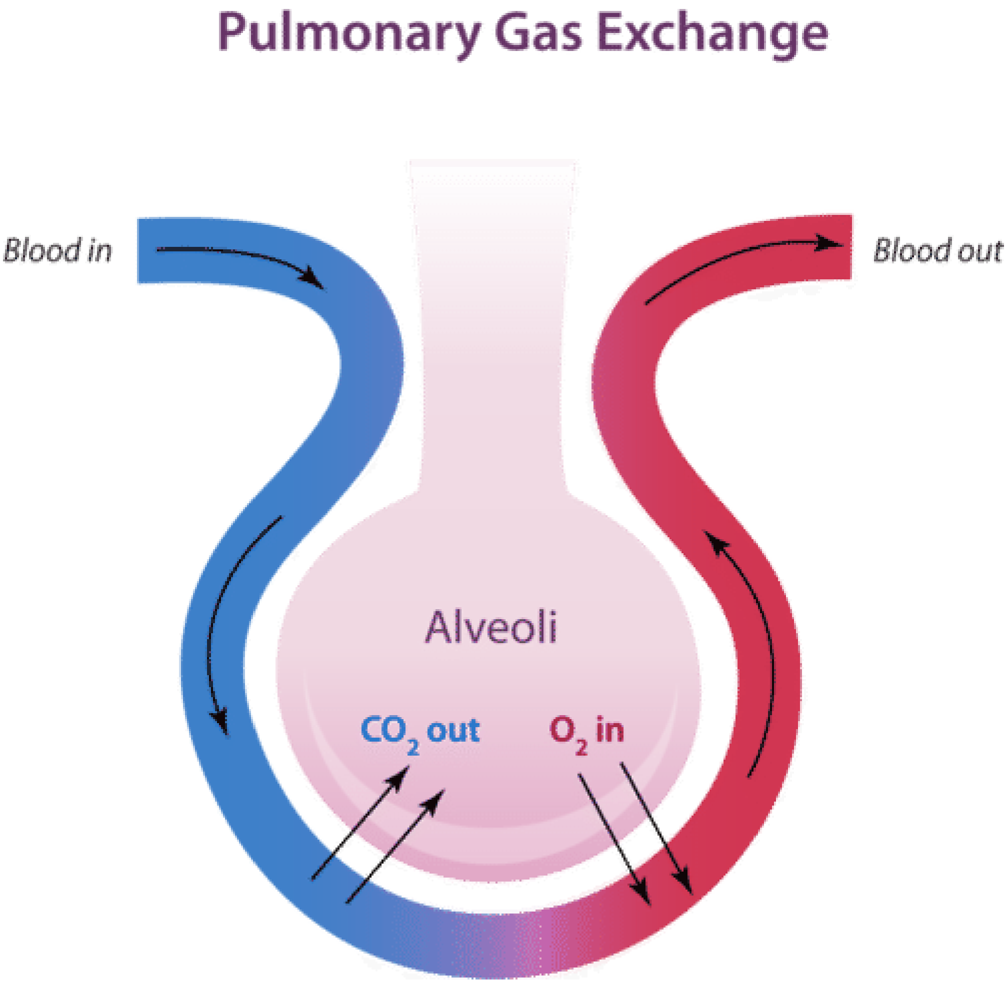


[Figure 3]

Alveoli are tiny sacs in the lungs where gas exchange takes place.

Gas Transport

After the blood in the pulmonary capillaries becomes saturated with oxygen, it leaves the lungs and travels to the heart. The heart pumps the oxygen-rich blood into artery, which carry it throughout the body. Eventually, the blood travels into capillaries that supply body tissues. These capillaries are called **peripheral capillary**.

Peripheral Gas Exchange

The cell of the body have a much lower concentration of oxygen than does the oxygenated blood in the peripheral capillaries. Therefore, oxygen diffuses from the peripheral capillaries into body cells. Carbon dioxide is produced by cells as a byproduct of cellular respiration, so it is more concentrated in the cells than in the blood of the peripheral capillaries. As a result, carbon dioxide diffuses in the opposite direction.

Back to the Lungs

The carbon dioxide from body cells travels in the blood from the peripheral capillaries to vein and then to the heart. The heart pumps the blood to the lungs, where the carbon dioxide diffuses into the alveoli. Then, the carbon dioxide passes out of the body through the other structures of the respiratory system, bringing the process of respiration full circle.

Gas Exchange and Homeostasis

Gas exchange is needed to provide cells with the oxygen they need for cellular respiration. Cells cannot survive for long without oxygen. Gas exchange is also needed to carry away carbon dioxide waste. Some of the carbon dioxide in the blood dissolves to form carbonic acid, which keeps blood pH within a normal range.

Blood pH may become unbalanced if the rate of breathing is too fast or too slow. When breathing is too fast, blood contains too little carbon dioxide and becomes too basic. When breathing is too slow, blood contains too much carbon dioxide and becomes too acidic. Clearly, to maintain proper blood pH, the rate of breathing must be regulated.

Further Reading

Regulation of Breathing

Summary

- Respiration begins with ventilation, the process of moving air into and out of the lungs.
- Gas exchange in the lungs takes place across the thin walls of pulmonary arteries in tiny air sacs called alveoli.
- Oxygenated blood is transported by the circulatory system from lungs to tissues throughout the body.

- Gas exchange between blood and body cells occurs across the walls of peripheral capillaries.
- Gas exchange helps maintain homeostasis by supplying cells with oxygen, carrying away carbon dioxide waste, and maintaining proper pH of the blood.

Review

1. Outline the pathway of a breath of air from the nose to the alveoli.
2. Describe how pulmonary gas exchange occurs.
3. What is peripheral gas exchange.
4. Sometimes people who are feeling anxious breathe too fast and become lightheaded. This is called hyperventilation. Hyperventilation can upset the pH balance of the blood, resulting in blood that is too basic. Explain why.

Report Content Errors

13.32 Regulation of Breathing

FlexBooks 2.0 > Biology For High School Diploma > Regulation of Breathing

Last Modified: May 21, 2021

[Figure 1]

What allows you to take a deep breath?

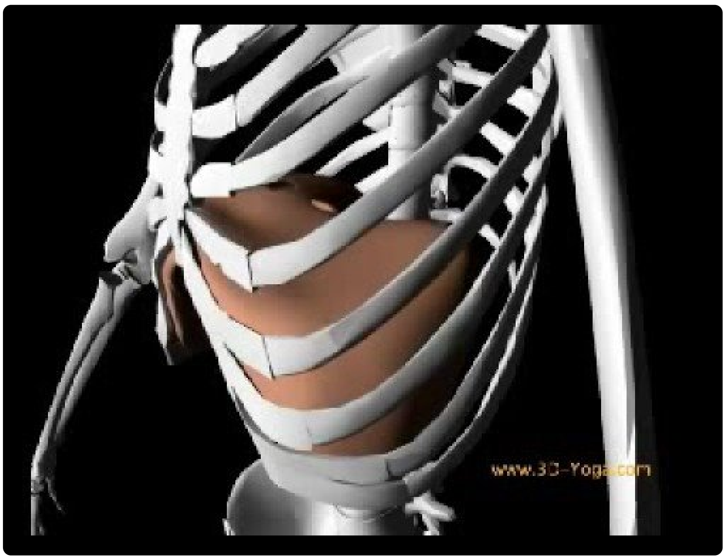
Deep breath in...now blow out those candles. We've all done that. Taking that deep breath in is an active process. You can usually feel your chest move. Why? Obviously, muscles in your chest are doing the work.

Regulation of Breathing

To understand how breathing is regulated, you first need to understand how breathing occurs.

How Breathing Occurs

inhaling is an active movement that results from the contraction of a muscle called the **diaphragm**. The **diaphragm** is large, sheet-like muscle below the lung (see **Figure** below). When the diaphragm contracts, the ribcage expands and the contents of the abdomen move downward. This results in a larger chest volume, which decreases air pressure inside the lungs. With lower air pressure inside than outside the lungs, air rushes into the lungs. When the diaphragm relaxes, the opposite events occur. The volume of the chest cavity decreases, air pressure inside the lungs increases, and air flows out of the lungs, like air rushing out of a balloon.



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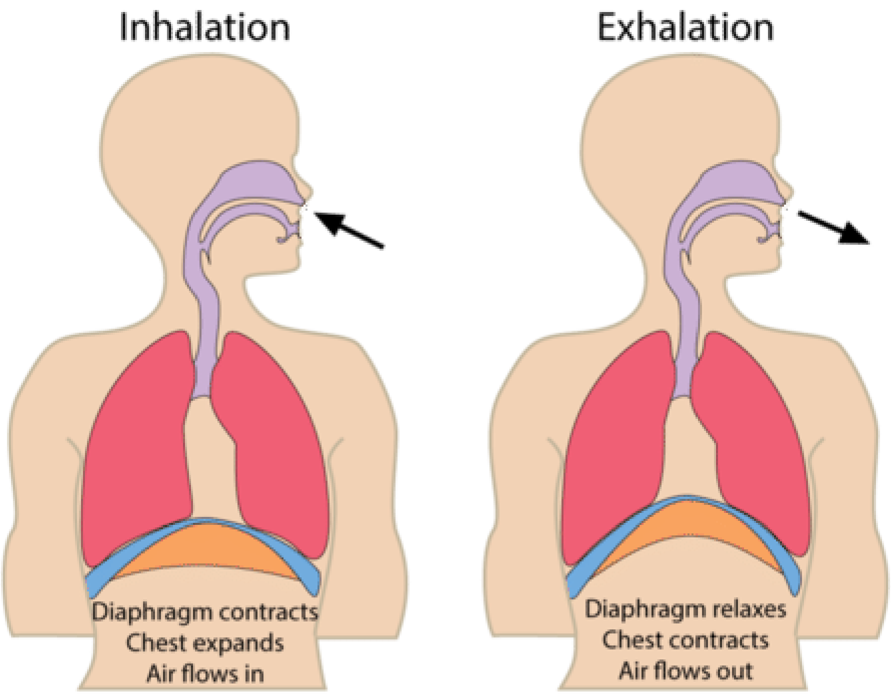


[Figure 2]

Breathing depends on contractions of the diaphragm.

Control of Breathing

The regular, rhythmic contractions of the diaphragm are controlled by the brain stem. It sends nerve impulse to the diaphragm through the autonomic nervous system. The brain stem monitors the level of carbon dioxide in the blood. If the level becomes too high, it "tells" the diaphragm to contract more often. Breathing speeds up, and the excess carbon dioxide is released into the air. The opposite events occur when the level of carbon dioxide in the blood becomes too low. In this way, breathing keeps blood pH within a narrow range.

Summary

- Breathing occurs due to repeated contractions of a large muscle called the diaphragm.
- The rate of breathing is regulated by the brain stem. It monitors the level of carbon dioxide in the blood and triggers faster or slower breathing as needed to keep the level within a narrow range.

Review

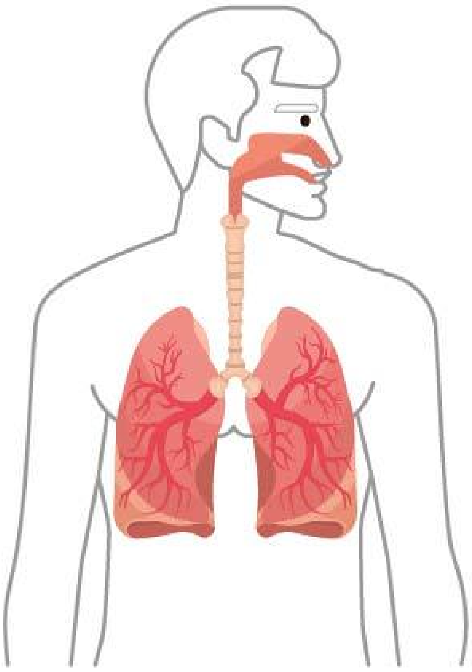
1. Explain why contraction of the diaphragm causes the lungs to fill with air.
2. Explain how the rate of breathing is controlled.

Report Content Errors

13.33 Respiratory System Disorders

FlexBooks 2.0 > Biology For High School Diploma > Respiratory System Disorders

Last Modified: May 16, 2021



[Figure 1]

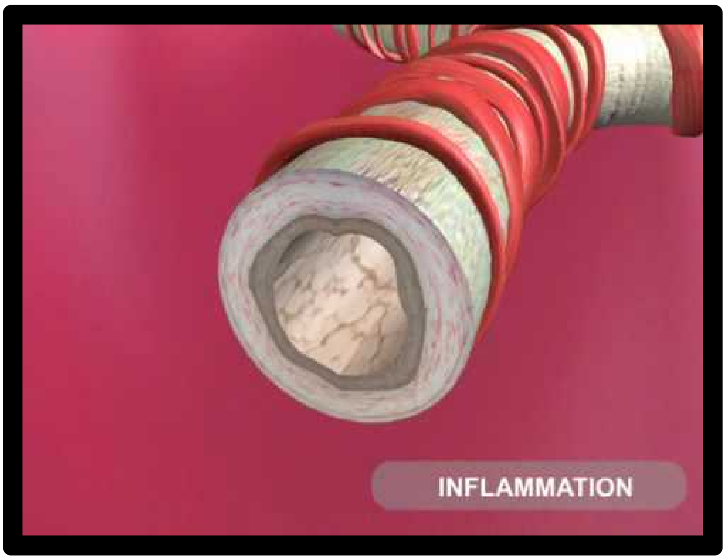
Does making ATP start with the lungs?

The importance of a nice pair of healthy lung is obvious. We all need oxygen to get into our lungs, so the oxygen can be transferred to the blood, so it can be transported around our body, so each cell can receive its fair share of oxygen, allowing oxygen to serve as the final electron acceptor during the electron transport chain of cellular respiration, allowing the cell to produce lots of ATP. And it all starts with the lungs.

Diseases of the Respiratory System

When you have a cold, your nasal passages may become so congested that it's hard to breathe through your nose. Many other diseases also affect the respiratory system, most of them more serious than the common cold. Some lung diseases, such as lung cancer, can be especially dangerous. The following list includes just a sample of respiratory system diseases.

- **asthma** is a disease in which the air passages of the lungs periodically become too narrow, often with excessive mucus production. This causes difficulty breathing, coughing, and chest tightness. An asthma attack may be triggered by allergen, strenuous exercise, stress, or other factors.



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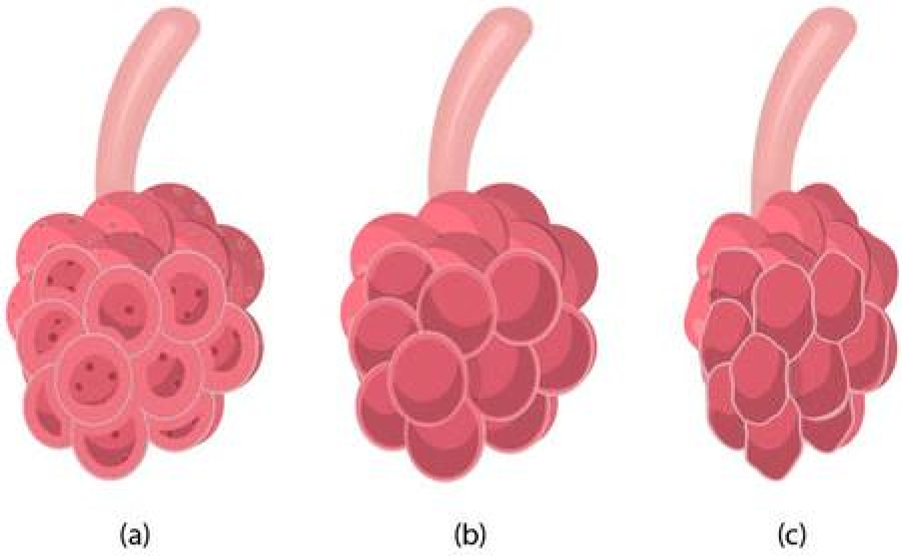
- **pneumonia** is a disease in which some of the alveolus of the lungs fill with fluid so gas exchange cannot occur. Symptoms usually include coughing, chest pain, and difficulty breathing. Pneumonia may be caused by an infection or injury of the lungs.
- **emphysema** is a lung disease in which walls of the alveoli break down so less gas can be exchanged in the lungs (see **Figure** below). This causes shortness of breath. The damage to the alveoli is usually caused by smoking and is irreversible.



[Figure 2]

Pneumonia and emphysema are caused by damage to the alveoli of the lungs. (a) Pneumonia, (b) Healthy, (c) Emphysema.

Causes of Respiratory Diseases

Many respiratory diseases are caused by pathogen. Certain bacterium, virus, and fungus are pathogens of the respiratory system. The common cold and flu are caused by viruses. tuberculosis, whooping cough, and acute bronchitis are caused by bacteria. The pathogens that cause colds, flu, and TB can be passed from person to person by coughing and sneezing.

air pollution is another significant cause of respiratory disease. The quality of the air you breathe can affect the health of your lungs. Asthma, heart and lung diseases, allergy, and several types of cancers are all linked to air quality. Air pollution is not just found outdoors; indoor air pollution can also be responsible for health problems.

Smoking is the most significant cause of respiratory disease as well as cardiovascular disease and cancer. Exposure to tobacco smoke by smoking or by breathing air that contains tobacco smoke is the leading cause of preventable death in the United States. Regular smokers die about 10 years earlier than nonsmokers. The Centers for Disease Control and Prevention (CDC) describes tobacco use as "the single most important preventable risk to human health in developed countries and an important cause of [early] death worldwide."

Summary

- Diseases of the respiratory system include asthma, pneumonia, and emphysema.

Review

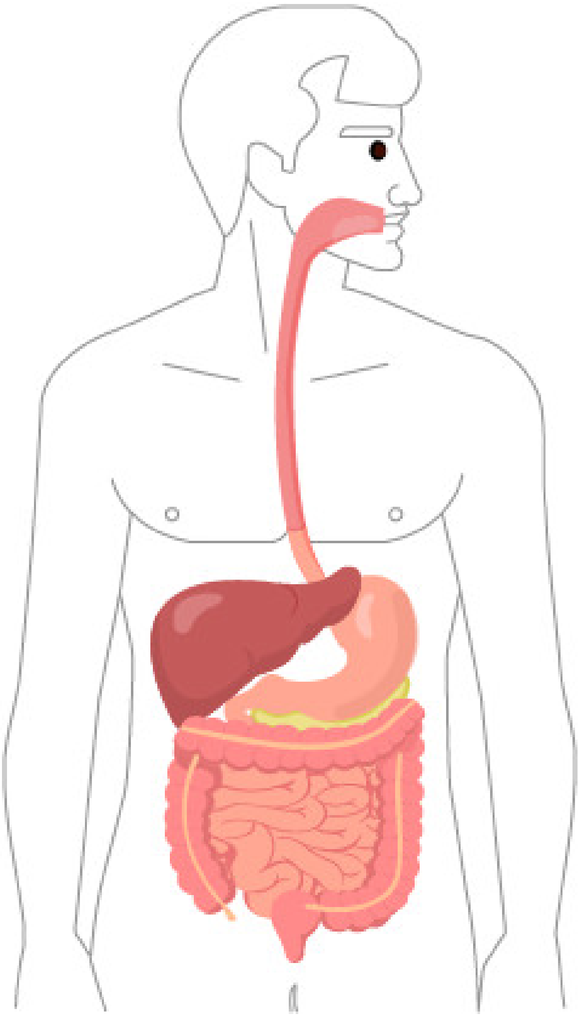
1. Identify and describe three diseases of the respiratory system, and state what triggers or causes each disease.

Report Content Errors

13.34 Digestive System Organs

FlexBooks 2.0 > Biology For High School Diploma > Digestive System Organs

Last Modified: Aug 01, 2018



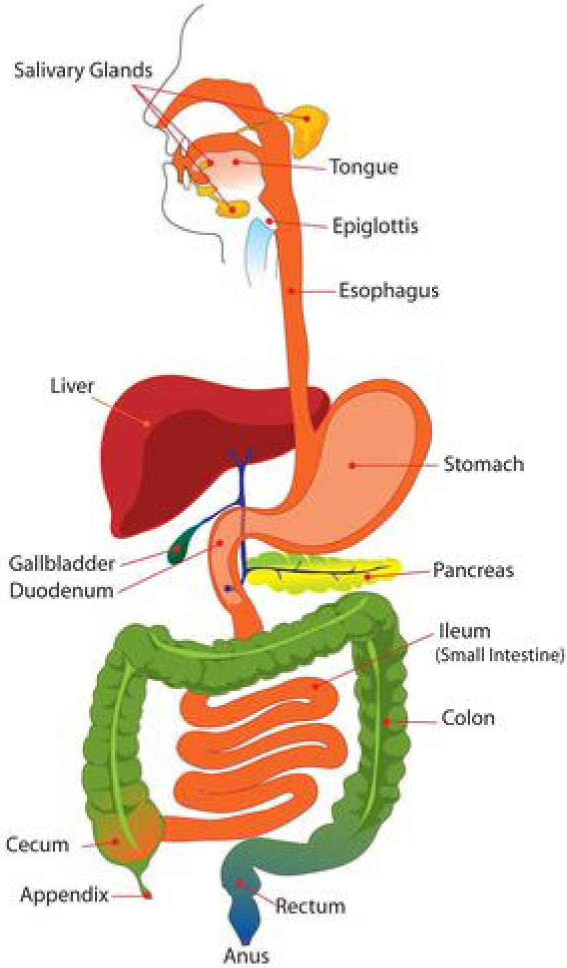
[Figure 1]

Specifically, our energy comes from what?

The respiratory and circulatory systems work together to provide cell with the oxygen they need for cellular respiration. Cells also need glucose for cellular respiration. Glucose is a simple sugar that comes from the food we eat. To get glucose from food, **digestion** must occur. This process is carried out by the **digestive system**.

Overview of the Digestive System

The **digestive system** consists of organ that break down food and absorb nutrient such as glucose. Organs of the digestive system are shown in **Figure** below. Most of the organs make up the **gastrointestinal tract**. The rest of the organs are called **accessory organ**.

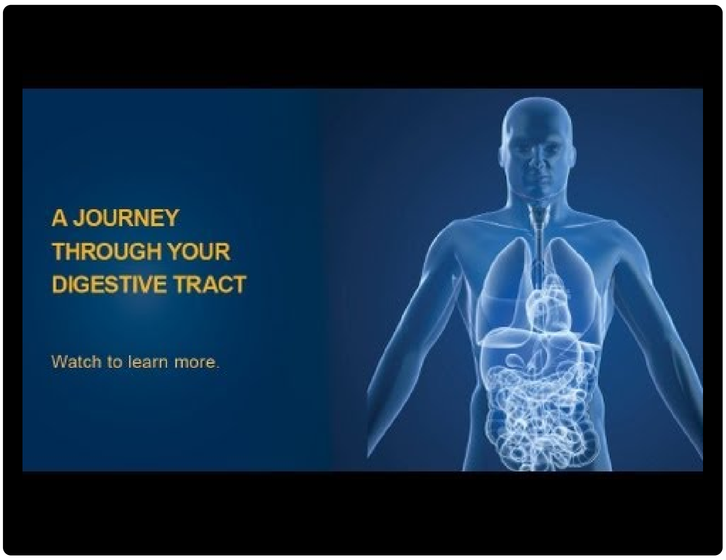


[Figure 2]

The digestive system includes organs from the mouth to the anus.

The Gastrointestinal Tract

The gastrointestinal (GI) tract is a long tube that connects the mouth with the anus. It is more than 9 meters (30 feet) long in adults and includes the esophagus, stomach, and small and large intestines. Food enters the mouth, passes through the other organs of the GI tract, and then leaves the body through the anus.



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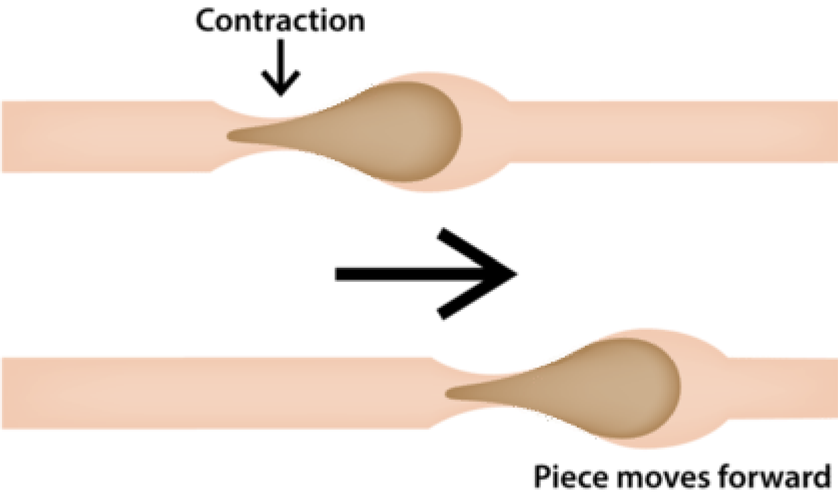
The organs of the GI tract are lined with **mucous membranes** that secrete digestive enzyme and absorb nutrients. The organs are also covered by layers of muscle that enable **peristalsis**. **Peristalsis** is an involuntary muscle contraction that moves rapidly along an organ like a wave (see **Figure** below).



[Figure 3]

Peristalsis pushes food through the GI tract.

Accessory Organs of Digestion

Other organs involved in digestion include the liver, gall bladder, and pancreas. They are called accessory organs because food does not pass through them. Instead, they secrete or store substances needed for digestion.

Functions of the Digestive System

The digestive system has three main functions: digestion of food, **absorption** of nutrients, and **elimination** of solid food waste. **Digestion** is the process of breaking down food into components the body can absorb. It consists of two types of processes: **mechanical digestion** and **chemical digestion**.

- **Mechanical digestion** is the physical breakdown of chunks of food into smaller pieces. This type of digestion takes place mainly in the mouth and stomach.
- **Chemical digestion** is the chemical breakdown of large, complex food molecules into smaller, simpler nutrient molecules that can be absorbed by the blood. This type of digestion begins in the mouth and stomach but occurs mainly in the small intestine.

After food is digested, the resulting nutrients are absorbed. **Absorption** is the process in which substances pass into the bloodstream, where they can circulate throughout the body. Absorption of nutrients occurs mainly in the small intestine. Any remaining matter from food that cannot be digested and absorbed passes into the large intestine as waste. The waste later passes out of the body through the anus in the process of **elimination**.

Summary

- The digestive system consists of organs that break down food, absorb nutrients, and eliminate waste.
- The breakdown of food occurs in the process of digestion.

Review

1. What organs make up the gastrointestinal tract? What are the accessory organs of digestion?
2. Describe peristalsis and its role in digestion.
3. Define mechanical and chemical digestion.

Report Content Errors

13.35 Digestive System

FlexBooks 2.0 > Biology For High School Diploma > Digestive System

Last Modified: Aug 06, 2018

[Figure 1]

What's the first step in the digestion process?

It all starts with the mouth. food goes in, you chew it up, swallow it, then what happens? The process of turning that food into energy and protein and other things necessary for life begins. But it all starts with the mouth.

The Start of Digestion: Mouth to Stomach

Does the sight or aroma of your favorite food make your mouth water? When this happens, you are getting ready for digestion.

Mouth

The mouth is the first digestive organ that food enters. The sight, smell, or taste of food stimulates the release of digestive enzyme by **salivary gland** inside the mouth. The major salivary enzyme is **amylase**. It begins the **chemical digestion** of carbohydrate by breaking down starch into sugar.

The mouth also begins the process of **mechanical digestion**. Sharp teeth in the front of the mouth cut or tear food when you bite into it (see **Figure** below). Broad teeth in the back of the mouth grind food when you chew. Food is easier to chew because it is moistened by **saliva** from the salivary glands. The tongue helps mix the food with saliva and also helps you swallow. After you swallow, the chewed food passes into the pharynx.

[Figure 2]

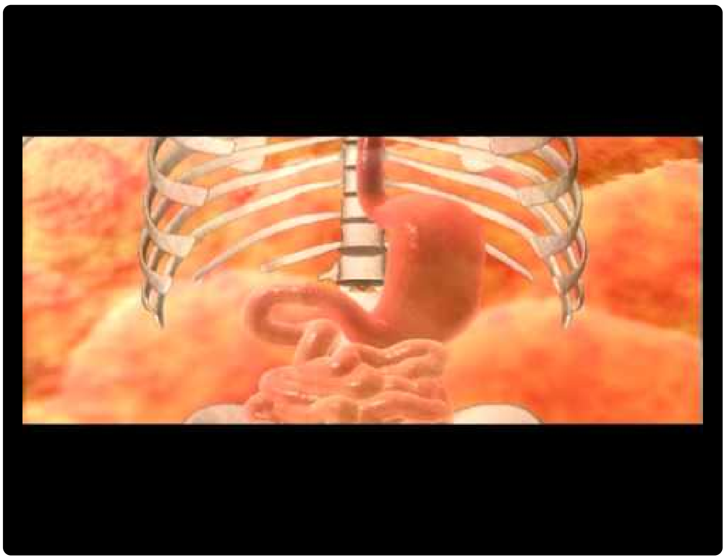
Teeth are important for mechanical digestion.

Esophagus

From the pharynx, the food moves into the **esophagus**. The **esophagus** is a long, narrow tube that passes food from the pharynx to the **stomach** by peristalsis. The esophagus has no other digestive functions. At the end of the esophagus, a muscle called a sphincter controls the entrance to the stomach. The sphincter opens to let food into the stomach and then closes again to prevent food from passing back into the esophagus.

Stomach

The **stomach** is a sac-like organ in which food is further digested both mechanically and chemically. (To see an animation of how the stomach digests food, go to the link below.) Churning movement of the stomach's thick, muscular walls complete the mechanical breakdown of food. The churning movements also mix food with digestive fluids secreted by the stomach. One of these fluids is hydrochloric acid. It kills bacterium in food and gives the stomach the low (acidic) pH needed by digestive enzymes that work in the stomach. The main enzyme is **pepsin**, which chemically digests protein.



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The stomach stores the partly digested food until the small intestine is ready to receive it. When the small intestine is empty, a sphincter opens to allow the partially digested food to enter the small intestine.

Further Reading

Digestive System Diseases

Summary

- Digestion consists of mechanical and chemical digestion.
- Mechanical digestion occurs in the mouth and stomach.
- Chemical digestion occurs mainly in the small intestine.
- The pancreas and liver secrete fluids that aid in digestion.

Review

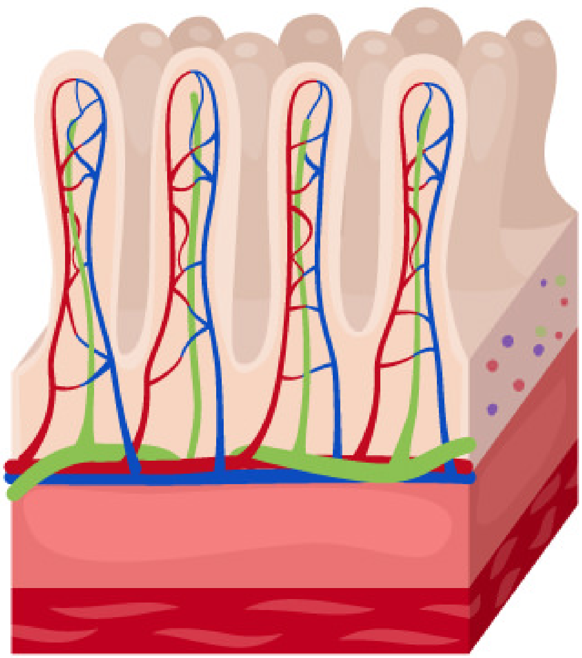
1. What is amylase and what is its role?
2. Describe functions of the stomach.
3. What is pepsin?

Report Content Errors

13.36 Small Intestine

FlexBooks 2.0 > Biology For High School Diploma > Small Intestine

Last Modified: Feb 29, 2020



[Figure 1]

These projections absorb. Absorb what?

Imagine the inside walls of the 23 feet of your small intestine covered with these finger-like projections. Why? What's their purpose, and why is the small intestine so long? These projections absorb. Absorb what? mineral and nutrient from food. And the length of the small intestine allows as much of these important substances to be absorbed as possible.

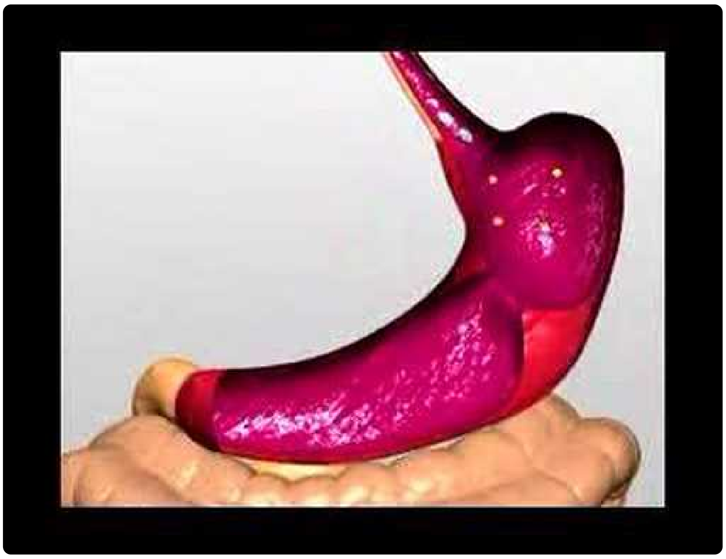
Digestion and Absorption: The Small Intestine

The **small intestine** is a narrow tube about 7 meters (23 feet) long in adults. It is the site of most chemical digestion and virtually all absorption. The small intestine consists of three parts: the duodenum, jejunum and ileum.

Digestion in the Small Intestine

The **duodenum** is the first and shortest part of the small intestine. Most chemical digestion takes place here, and many digestive enzyme are active in the duodenum (see **Table** below). Some are produced by the duodenum itself. Others are produced by the pancreas and secreted into the duodenum.

Enzyme	What It Digests	Where It Is Made
amylase	carbohydrate	pancreas
Trypsin	protein	pancreas
Lipase	lipid	pancreas, duodenum
Maltase	carbohydrates	duodenum
Peptidase	proteins	duodenum



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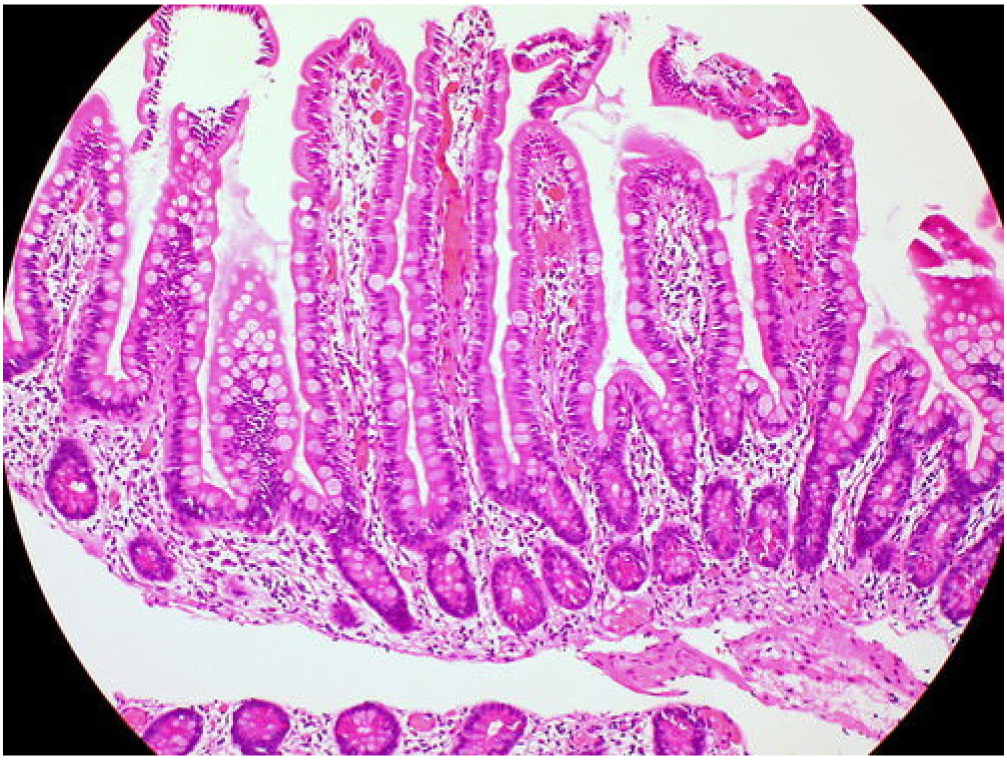
The **liver** is an organ of both digestion and excretion. It produces a fluid called **bile**, which is secreted into the duodenum. Some bile also goes to the **gall bladder**, a sac-like organ that stores and concentrates bile and then secretes it into the small intestine. In the duodenum, bile breaks up large globules of lipids into smaller globules that are easier for enzymes to break down. Bile also reduces the acidity of food entering from the highly acidic stomach. This is important because digestive enzymes that work in the duodenum need a neutral environment. The pancreas contributes to the neutral environment by secreting bicarbonate, a basic substance that neutralizes acid.

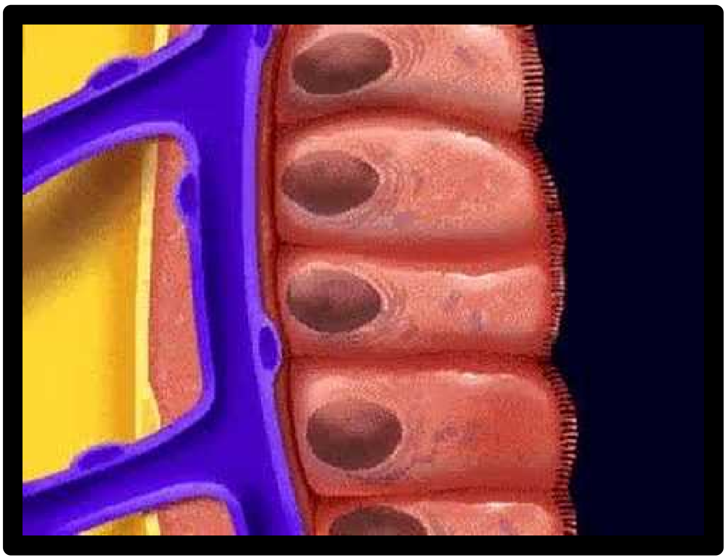
Absorption in the Small Intestine

The **jejunum** is the second part of the small intestine, where most nutrients are absorbed into the blood. As shown in **Figure** below, the mucous membrane lining the jejunum is covered with millions of microscopic, fingerlike projections called **villus** (singular, villus). Villi contain many capillaries, and nutrients pass from the villi into the bloodstream through the capillaries. Because there are so many villi, they greatly increase the surface area for absorption. In fact, they make the inner surface of the small intestine as large as a tennis court!



[Figure 2]

This image shows intestinal villi greatly magnified. They are actually microscopic.



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The **ileum** is the third part of the small intestine. A few remaining nutrients are absorbed here. Like the jejunum, the inner surface of the ileum is covered with villi that increase the surface area for absorption.

Summary

- Virtually all absorption of nutrients takes place in the small intestine, which has a very large inner surface area because it is covered with millions of microscopic villi.

Review

1. Name the parts of the small intestine.
2. Where are most nutrients absorbed?
3. What is digested by trypsin, by lipase, and by maltase?
4. Describe the functions of the three parts of the small intestine.
5. What role do villi play in absorption?

Report Content Errors

13.37 Large Intestine

FlexBooks 2.0 > Biology For High School Diploma > Large Intestine

Last Modified: Aug 01, 2018

[Figure 1]

Liquid to solid. What does this mean?

Well, that's exactly what the large intestine does. It takes the remains of digested food — that is, food in which all the nutrient and mineral have been removed, and prepares it for elimination.

The Large Intestine and Its Functions

From the small intestine, any remaining food wastes pass into the large intestine. The **large intestine** is a relatively wide tube that connects the small intestine with the anus. Like the small intestine, the large intestine also consists of three parts: the cecum (or caecum), colon, and **rectum**.

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Absorption of Water and Elimination of Wastes

The **cecum** is the first part of the large intestine, where wastes enter from the small intestine. The wastes are in a liquid state. As they pass through the **colon**, which is the second part of the large intestine, excess water is absorbed. The remaining solid wastes are called **feces**. Feces accumulate in the **rectum**, which is the third part of the large intestine. As the rectum fills, the feces become compacted. After a certain amount of feces accumulate, they are eliminated from the body. A sphincter controls the anus and opens to let feces pass through.

Bacteria in the Large Intestine

Trillions of bacterium normally live in the large intestine. Most of them are helpful. In fact, we wouldn't be able to survive without them. Some of the bacteria produce vitamin, which are absorbed by the large intestine. Other functions of intestinal bacteria include:

- controlling the growth of harmful bacteria.
- breaking down indigestible food components.
- producing substances that help prevent colon cancer.
- breaking down toxins before they can poison the body.

Summary

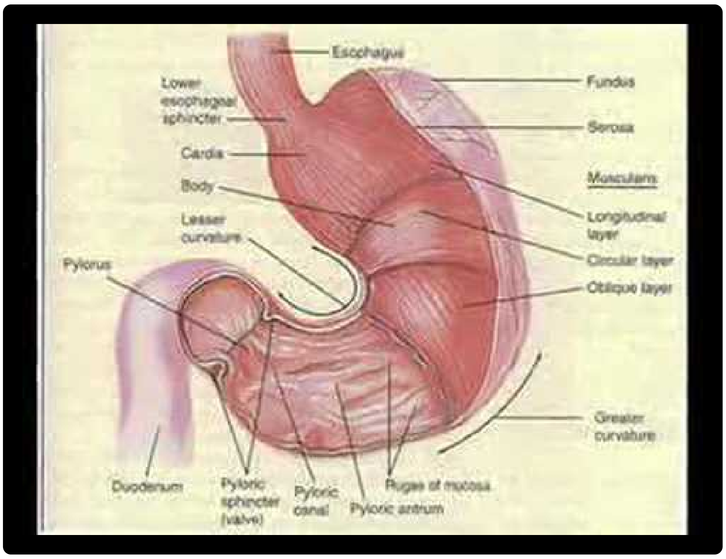
- The absorption of water from digestive wastes and the elimination of the remaining solid wastes occur in the large intestine.

- The large intestine also contains helpful bacteria.

Review

1. Describe the functions of the three parts of the large intestine.
2. How do bacteria in the large intestine help keep us healthy?

Resources



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Report Content Errors

13.38 Digestive System Diseases

FlexBooks 2.0 > Biology For High School Diploma > Digestive System Diseases

Last Modified: Jul 04, 2019

[Figure 1]

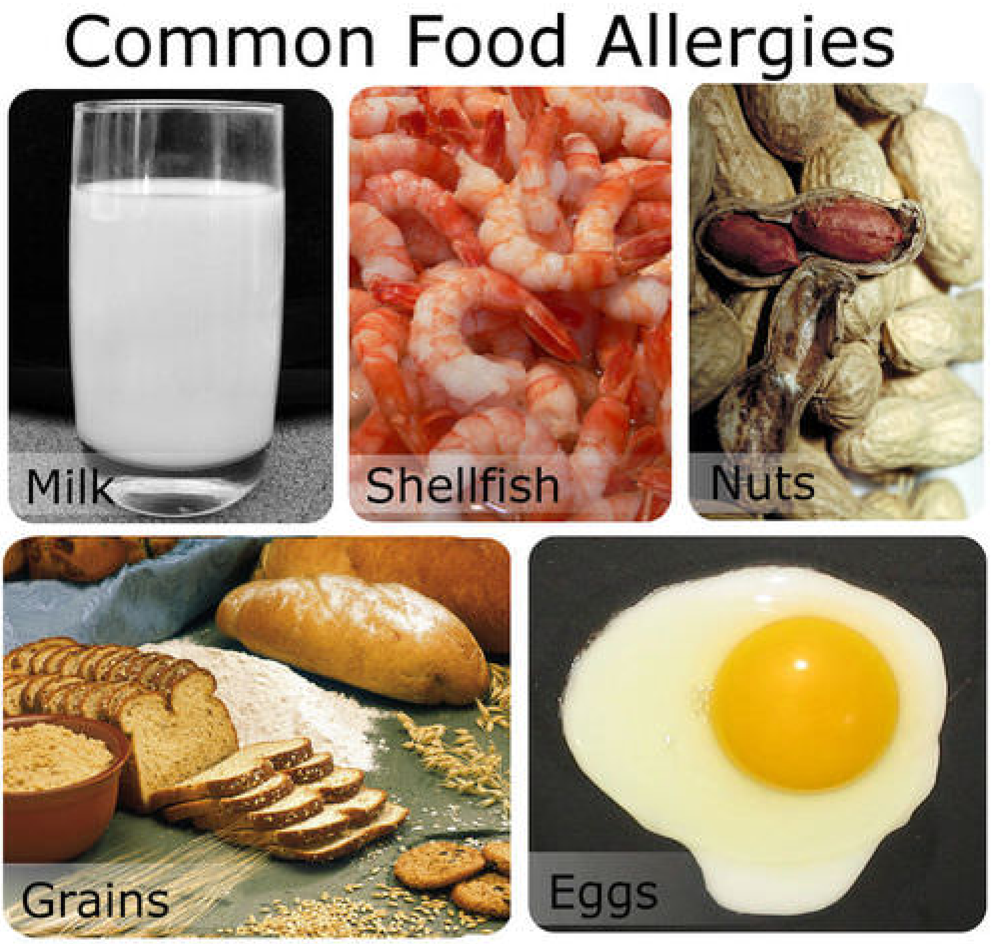
What's worse than an upset stomach?

You've probably had an upset stomach. Most likely it was due to something you ate. But imagine bleeding from your stomach. That's a little different than your stomach just being upset. Stomach **ulcer** can be very serious.

Diseases of the Digestive System

Many diseases can affect the digestive system. Three of the most common diseases that affect the digestive system are food allergy, ulcers, and heartburn. Foodborne illnesses and food intolerance are also serious issues associated with the digestive system.

- Food **allergies** occur when the immune system reacts to substances in food as though they were harmful "foreign invaders." Foods that are most likely to cause allergies are pictured in **Figure** below, and include nuts, egg, grains and milk. Symptoms of food allergies often include vomiting and diarrhea. Symptoms of food allergies include itching and swelling of the lips and mouth. More serious symptoms include trouble breathing. In some instances, a food allergy can trigger anaphylaxis, which is an extremely severe reaction. Emergency medical treatment is critical for this condition, which left untreated, can lead to death.



[Figure 2]

These foods are the most common causes of food allergies.

- **Ulcers** are sores in the lining of the stomach or duodenum that are usually caused by bacterial infections. They may also be caused by the acidic environment of the stomach. Stomach acids may damage the lining of the stomach. Symptoms typically include abdominal pain and bleeding.

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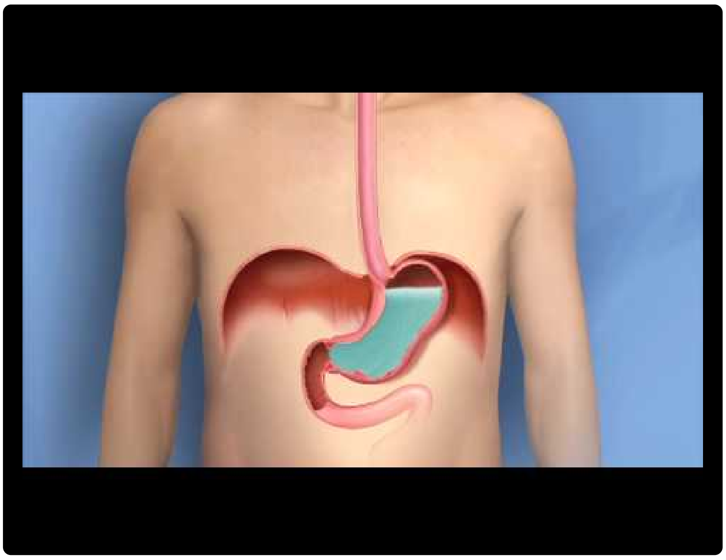
- **Heartburn** is a painful burning sensation in the chest caused by stomach acid backing up into the esophagus. The stomach acid may eventually cause serious damage to the esophagus unless the problem is corrected.



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Summary

- Digestive system diseases include food allergies, ulcers, and heartburn.

Review

1. Describe two diseases of the digestive system.
2. List three foods that cause common food allergies.

Report Content Errors

13.39 Food and Nutrients

FlexBooks 2.0 > Biology For High School Diploma > Food and Nutrients

Last Modified: Oct 30, 2019

[Figure 1]

Are these really good for you?

Fresh fruit and vegetables. Every child's favorite. Especially those vegetables. When your mother tells you to "eat your vegetables," there is a reason for that. Yes, they are actually good for you.

Food and Nutrients

Did you ever hear the saying, “You are what you eat”? It’s not just a saying. It’s actually true. What you eat plays an important role in your health. Eating a variety of the right types of foods promotes good health and provides energy for growth and activity. This is because healthful foods are rich in **nutrient**. **Nutrients** are substances the body needs for energy, building materials, and control of body processes. There are six main classes of nutrients: **carbohydrate**, **protein**, **lipid**, water, **vitamin**, and **mineral**. These six classes are categorized as **macronutrient** or **micronutrient** depending on how much of them the body needs.

Macronutrients

Nutrients the body needs in relatively large amounts are called **macronutrients**. They include carbohydrates, proteins, lipids, and water. All macronutrients except water can be used by the body for energy. (The energy in food is measured in a unit called a **Calorie**.) The exact amount of each macronutrient that an individual needs depends on many factors, including gender and age. Recommended daily intakes by teens of three macronutrients are shown in **Table** below. Based on your gender and age, how many grams of proteins should you eat each day?

Gender/Age	Carbohydrates (g/day)	Proteins (g/day)	Water (L/day) (includes water in food)
Males 9–13 years	130	34	2.4
Males 14-18 years	130	52	3.3
Females 9-13 years	130	34	2.1
Females 14-18 years	130	46	2.3

- **Carbohydrates** include sugars, starches, and fiber. Sugars and starches are used by the body for energy. One gram of carbohydrates provides 4 of energy. Fiber, which is found in plant foods, cannot be digested but is needed for good health. Simple carbohydrates are small carbohydrates found in foods such as fruits and milk. These carbohydrates include lactose, fructose and glucose. Complex carbohydrates are much larger molecules. starch, which is a complex carbohydrate found in vegetables and grains, is made of thousands of glucose units bonded together.
- Dietary **proteins** are broken down during digestion to provide the amino acid needed for protein synthesis. Any extra proteins in the diet not needed for this purpose are used for energy or stored as fat. One gram of proteins provides 4 Calories of energy. Eating protein provides the amino acids for your cell to produce your own antibody, muscle fiber and enzyme (as well as many other types of proteins).
- **Lipids** provide the body with energy and serve other vital functions, such as protecting neuron and providing the membranes that surround all cells. One gram of lipids provides 9 Calories of energy. You need to eat small amounts of lipids for good health. However, large amounts can be harmful, especially if they contain saturated fatty acid from animal foods.
- Water is essential to life because biochemical reaction take place in water. Most people can survive only a few days without water.

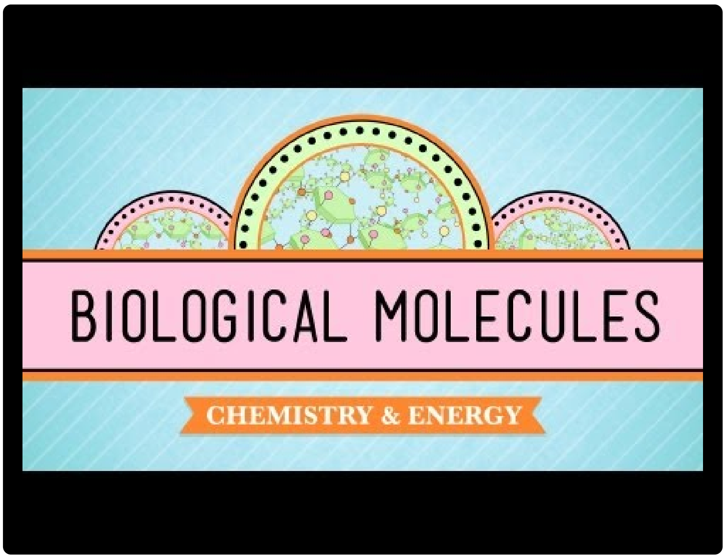
Micronutrients

Nutrients the body needs in relatively small amounts are called **micronutrients**. They include vitamins and minerals. **Vitamins** are organic compound that are needed by the body to function properly. Several vitamins are described in **Table** below. Vitamins play many roles in good health, ranging from maintaining good vision to helping blood clot. vitamin B12 is produced by bacterium in the large intestine. **vitamin D** is synthesized by the skin when it is exposed to UV light. Most other vitamins must be obtained from foods like those listed in **Table** below.

Vitamin	Function	Good Food Sources
A	good vision	carrots, spinach
B12	normal nerve function	meat, milk
C	making connective tissue	oranges, red peppers
D	healthy bone and teeth	salmon, egg
E	normal cell membrane	vegetable oils, nuts
K	blood clotting	spinach, soybeans

Minerals are chemical element that are essential for body processes. They include **calcium**, which helps form strong bones and teeth, and potassium, which is needed for normal nerve and muscle function. Good sources of minerals include leafy, green vegetables, whole grains, milk, and meats.

Vitamins and minerals do not provide energy, but they are still essential for good health. The necessary amounts can usually be met with balanced eating. However, people who do not eat enough of the right foods may need vitamin or mineral supplements.



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Summary

- Nutrients are substances that the body needs for energy, building materials, and control of body processes.
- Carbohydrates, proteins, lipids, and water are nutrients needed in relatively large amounts.
- Vitamins and minerals are nutrients needed in much smaller amounts.

Review

1. Based on your gender and age, how many grams of proteins should you eat each day?
2. Compare and contrast macronutrients and micronutrients. Give examples of each.
3. What are minerals? Give two examples.
4. What is a good source of vitamin A?
5. Why do you need vitamin D?

Report Content Errors

13.40 Balanced Eating

FlexBooks 2.0 > Biology For High School Diploma > Balanced Eating

Last Modified: May 07, 2021

[Figure 1]

Why is the *good* stuff in the smallest segment of this diagram?

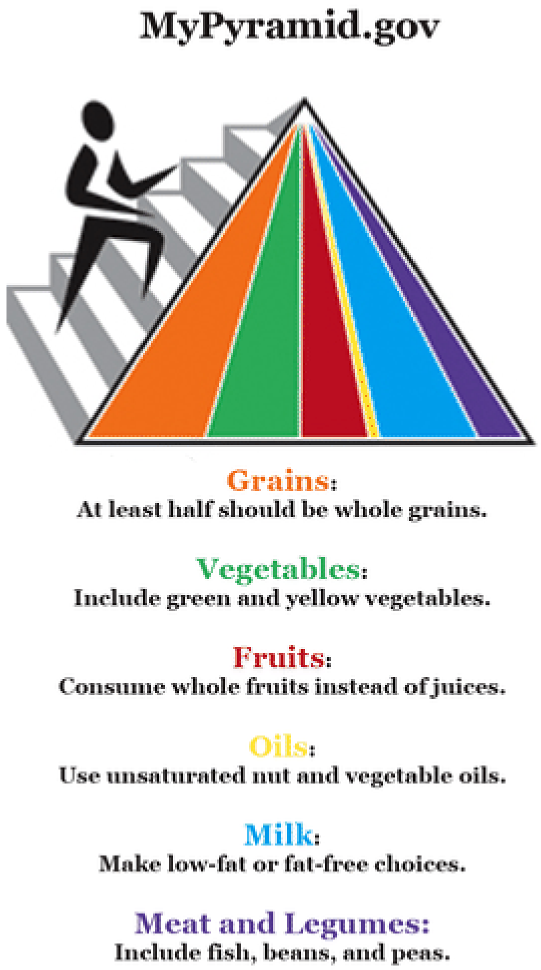
If you're like most high school kids, one of the first things you do after school is search for something to eat. And you look for the chips or candy. As this diagram shows, you can eat those. Just not a lot.

Balanced Eating

Balanced eating is a way of eating that promotes good health. It means eating the right balance of different foods to provide the body with all the nutrient it needs. Fortunately, you don't need to measure and record the amounts of different nutrients you each day in order to balance your eating. Instead, you can use **MyPlate**, **MyPyramid**, and food labels.

MyPyramid and MyPlate

MyPyramid shows the relative amounts of foods in different food groups you should eat each day (see **Figure** below).



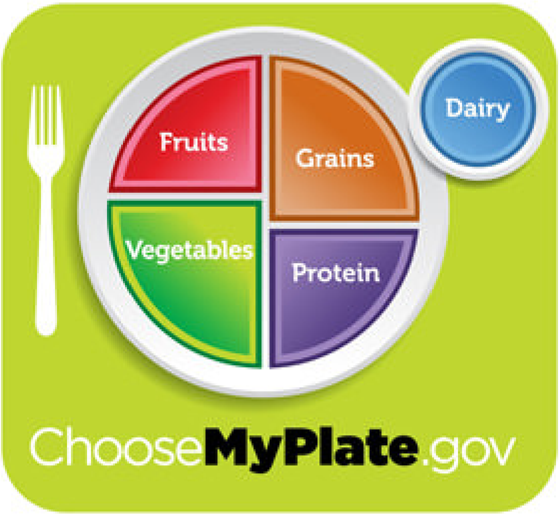
[Figure 2]

MyPyramid is a visual guideline for balanced eating.

Each food group represented by a colored band in MyPyramid is a good source of nutrients. The key in **Figure** above shows the food group each band represents. The wider the band, the more you should eat from that food group. The white tip of MyPyramid represents foods that should be eaten only once in a while, such as ice cream and potato chips. They contain few nutrients and may contribute excess Calorie to the diet.

The figure "walking" up the side of MyPyramid represents the role of physical activity in balanced eating. Regular exercise helps you burn any extra energy that you consume in foods and provides many other health benefits. You should be active for about an hour a day most days of the week. The more active you are, the more energy you will use.

In June 2011, the United States Department of Agriculture replaced My Pyramid with **MyPlate.** MyPlate depicts the relative daily portions of various food groups. See http://www.choosemyplate.gov/ for further information.



[Figure 3]

MyPlate is a visual guideline for balanced eating, replacing MyPyramid in 2011.

The following guidelines accompany MyPlate:

- Balancing Calories
  - Enjoy your food, but eat less.
  - Avoid oversized portions.
- Foods to Increase
  - Make half your plate fruit and vegetables.
  - Make at least half your grains whole grains.
  - Switch to fat-free or low-fat (1%) milk.
- Foods to Reduce
  - Compare sodium in foods like soup, bread, and frozen meals - and choose the foods with lower numbers.
  - Drink water instead of sugary drinks.

Food Labels

Packaged foods are required by law to carry a nutrition facts label, like the one in **Figure** below. The labels show the nutrient content and ingredients of foods. Reading labels can help you choose foods that are high in nutrients you need more of (such as proteins) and low in nutrients you need less of (such as fats).

Nutrition Facts

Serving Size	½ cup (52 g)
Servings Per Container	8
Amount Per Serving	
Calories 200	Calories from Fat 45
Daily Value*	
Total Fat 5 g	**8 %**
Saturated Fat 2.5 g	**13 %**
Trans fat 0 g	
Cholesterol 0 mg	**0 %**
Sodium 160 mg	**7 %**
Total Carbohydrate 37 g	**12 %**
Dietary Fiber 1 g	**4 %**
Sugars 17 g	
Protein 2 g	

Vitamin A	0 %	Vitamin C	0 %	Calcium	0 %
Iron	10 %	Thiamin	10 %	Riboflavin	0 %
Niacin	20 %	Vitamin B_6	0 %	Folic Acid	10 %

*Percent Daily Values are based on a 2000 Calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Ingredients: Enriched wheat flour (wheat flour, iron, Vitamin B_1, folic acid), high fructose corn syrup, vegetable oil (canola and soybean oil, partially hydrogenated palm kernel oil), sugar, salt, raisins, cornstarch, whole grain oats, baking soda, artificial flavor, caramel color

Reading a Nutrition Facts Label:

1. Energy
There are 200 Calories (kilocalories) in one serving. One serving is ½ cup. Therefore, there are 200 kilocalories in ½ cup.

2. Macronutrients
a. The grams on the left show the amounts of macronutrients that are supplied by one serving. For example, 5 grams of total fat are supplied by one serving.
b. The percents on the right show the percents of macronutrient needs that are supplied by one serving. Percents are based on a 2000-kilocalorie/day diet. If you need more than 2000 kilocalories/day, one serving supplies a smaller percent of each macronutrient. If you need less than 2000 kilocalories/day, one serving supplies a larger percent of each macronutrient.

3. Micronutrients
Percents of selected vitamins and minerals supplied by one serving are listed near the bottom of the label.

4. Ingredients
Ingredients in the food are listed in descending order. Those listed first are present in the largest amounts.

[Figure 4]

Nutrition facts labels like this one can help you make good food choices.

You should also look for ingredients such as whole grains, vegetables, and fruits. Avoid foods that contain processed ingredients, such as white flour or white rice. Processing removes nutrients. As a result, processed foods generally supply fewer nutrients than whole foods, even when they have been enriched or fortified with added nutrients.

Weight Gain and Obesity

Any unused energy in food, whether it comes from carbohydrate, protein, or lipid, is stored in the body as fat. An extra 3,500 Calories of energy results in the storage of almost half a kilogram (1 pound) of stored body fat. People who consistently consume more food energy then they need may become obese. **obesity** occurs when the **body mass index** is 30.0 kg/m^2 or greater. **Body mass index (BMI)** is an estimate of the fat content of the body. It is calculated by dividing a person's weight (in kilograms) by the square of the person's height (in meters). Obesity increases the risk of health problems such as type 2 diabetes and hypertension.

Eating Disorders

Some people who are obese have an **eating disorder**, called binge eating disorder, in which they compulsively overeat. An **eating disorder** is a mental illness in which people feel compelled to eat in a way that causes physical, mental, and emotional health problems. Other eating disorders include anorexia nervosa and bulimia nervosa. Treatments for eating disorders include counseling and medication.

Summary

- Balanced eating promotes good health.
- MyPlate, MyPyramid, and food labels are tools that can help you choose the right foods for balanced eating.
- Eating too much and exercising too little can lead to weight gain and obesity.
- Some people who are obese have an eating disorder. Eating disorders are mental illnesses that require treatment by health professionals.

Review

1. Explain how to use MyPyramid and food labels to choose foods for balanced eating.
2. What is an eating disorder? Give an example.
3. Aleesha weighs 80 kg and is 1.6 m tall. What is her body mass index? Is she obese?

Report Content Errors

13.41 Excretory System

FlexBooks 2.0 > Biology For High School Diploma > Excretory System

Last Modified: May 16, 2021

[Figure 1]

What do you do with your waste?

Toxic waste must be disposed of properly or there can be serious consequences. Your waste needs to be removed from you. And that is the role of the excretory system. The excretory system gets rid of waste and excess water.

Excretion

If you exercise on a hot day, you are likely to lose a lot of water in sweat. Then, for the next several hours, you may notice that you do not pass **urine** as often as normal and that your urine is darker than usual. Do you know why this happens? Your body is low on water and trying to reduce the amount of water lost in urine. The amount of water lost in urine is controlled by the **kidney**, the main organ of the excretory system.

excretion is the process of removing wastes and excess water from the body. It is one of the major ways the body maintains homeostasis. Although the kidneys are the main organs of excretion, several other organs also excrete wastes. They include the large intestine, liver, skin, and lung. All of these organs of excretion, along with the kidneys, make up the **excretory system**. The roles of the excretory organs other than the kidney are summarized below:

- The large intestine eliminates solid wastes that remain after the digestion of food.
- The liver breaks down excess amino acid and toxins in the blood.

- The skin eliminates excess water and salts in sweat.
- The lungs exhale water vapor and carbon dioxide.

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Further Reading

Excretory System Diseases

Summary

- Excretion is the process of removing wastes and excess water from the body. It is one of the major ways the body maintains homeostasis.
- Organs of excretion make up the excretory system. They include the kidneys, large intestine, liver, skin, and lungs.

Review

1. What is excretion?
2. List organs of the excretory system and their functions.

Report Content Errors

13.42 Urinary System

FlexBooks 2.0 > Biology For High School Diploma > Urinary System

Last Modified: May 16, 2021

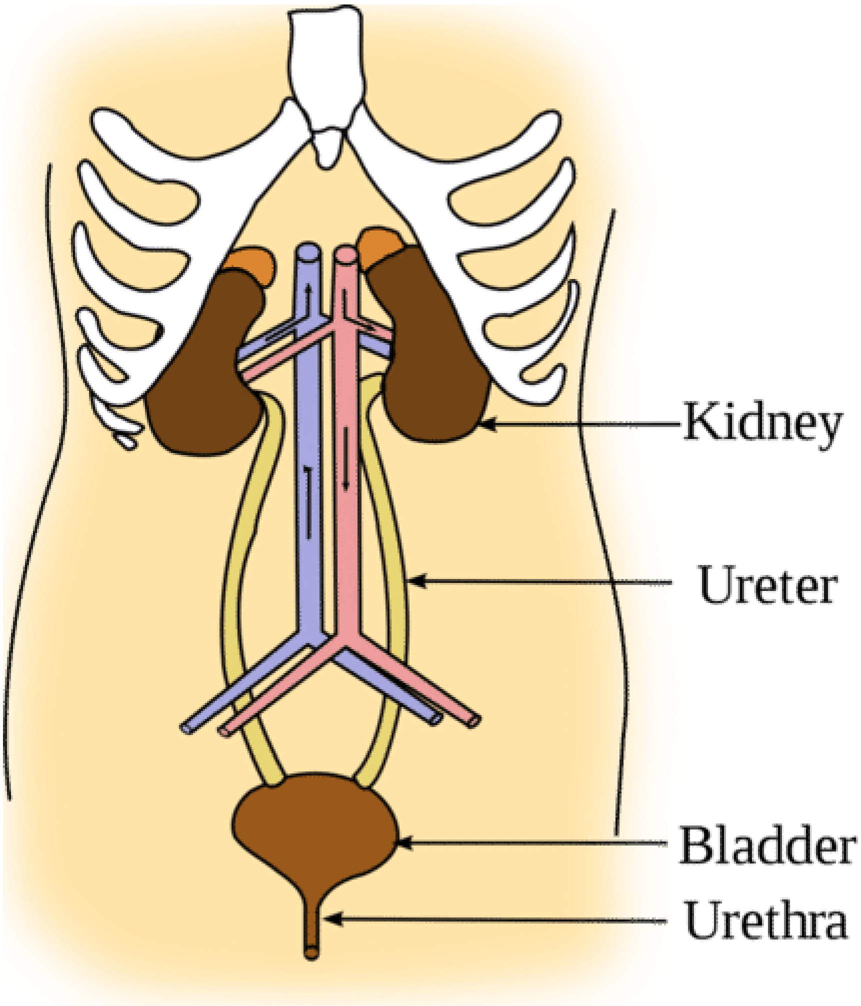
[Figure 1]

How is it determined what's waste and what's not?

Getting rid of waste and excess water is a major process of maintaining homeostasis. Such a basic process is actually very complex. It involves an intricate exchange of material through the **kidney**.

Urinary System

The **kidneys** are part of the **urinary system**, which is shown in **Figure** below. The main function of the urinary system is to filter waste products and excess water from the blood and excrete them from the body.

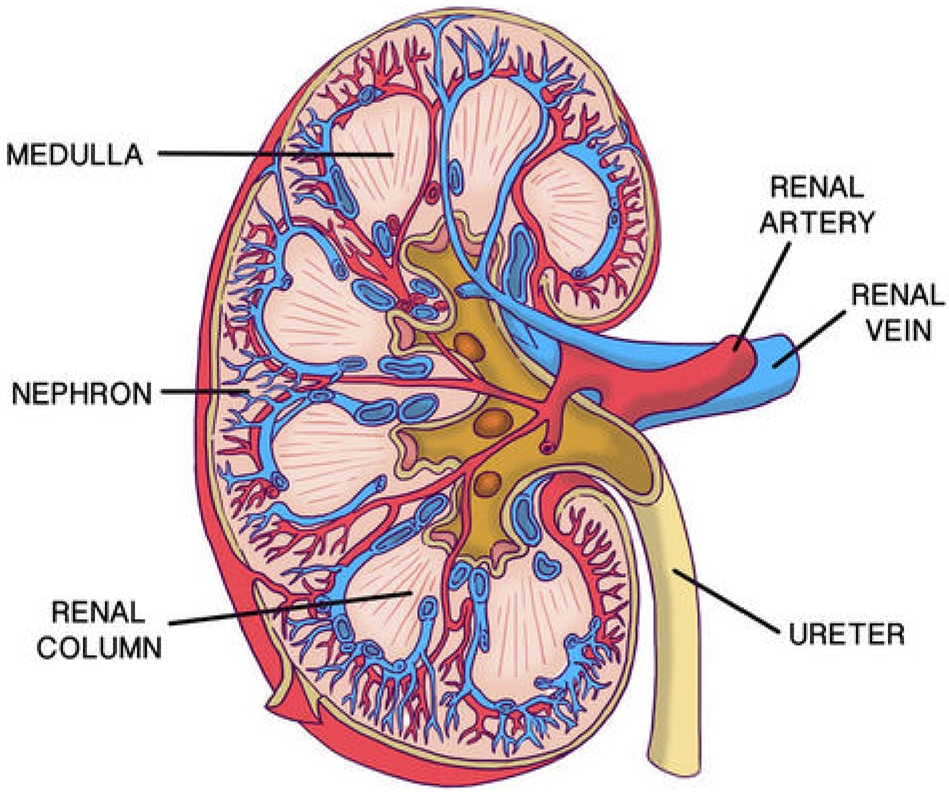


[Figure 2]

The kidneys are the chief organs of the urinary system.

Kidneys and Nephrons

The kidneys are a pair of bean-shaped organ just above the waist. A cross-section of a kidney is shown in **Figure** below. The function of the kidney is to filter blood and form **urine**. **Urine** is the liquid waste product of the body that is excreted by the urinary system. **nephron** are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons!

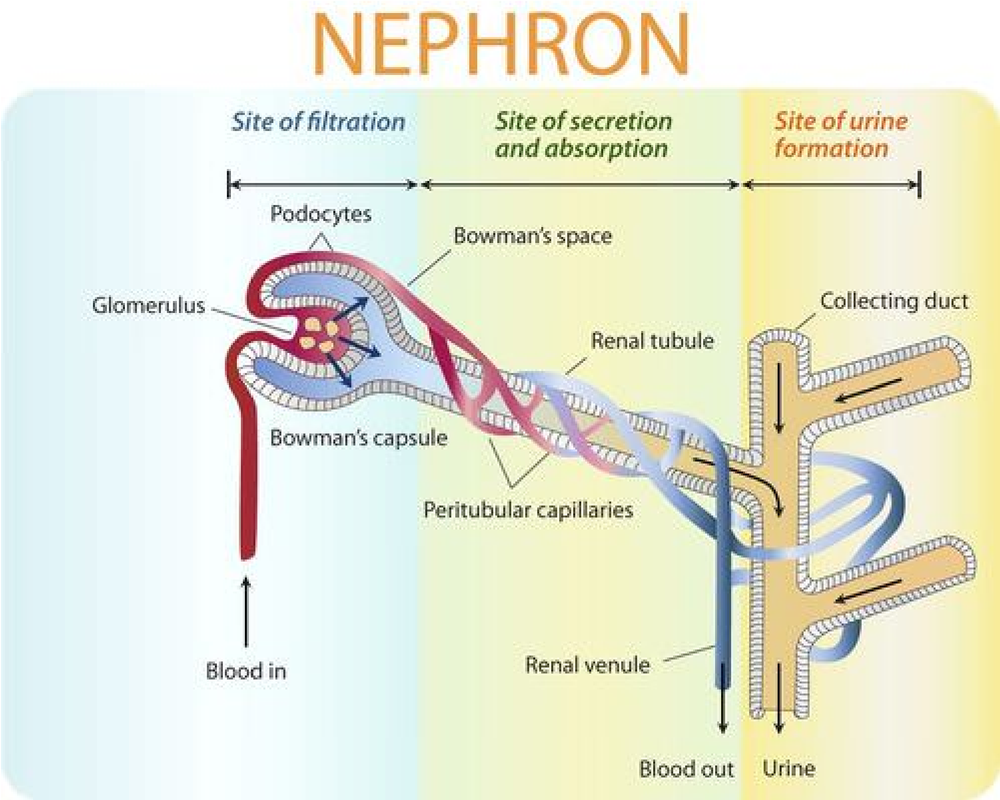


[Figure 3]

Each kidney is supplied by a renal artery and renal vein.

As shown in **Figure** below, each nephron acts as a tiny filtering plant. It filters blood and forms urine in the following steps:

1. Blood enters the kidney through the **renal artery**, which branches into capillaries. When blood passes through capillaries of the **glomerulus** of a nephron, blood pressure forces some of the water and dissolved substances in the blood to cross the capillary walls into **Bowman's capsule**.
2. The filtered substances pass to the **renal tubule** of the nephron. In the renal tubule, some of the filtered substances are reabsorbed and returned to the bloodstream. Other substances are secreted into the fluid.
3. The fluid passes to a collecting duct, which reabsorbs some of the water and returns it to the bloodstream. The fluid that remains in the collecting duct is urine.

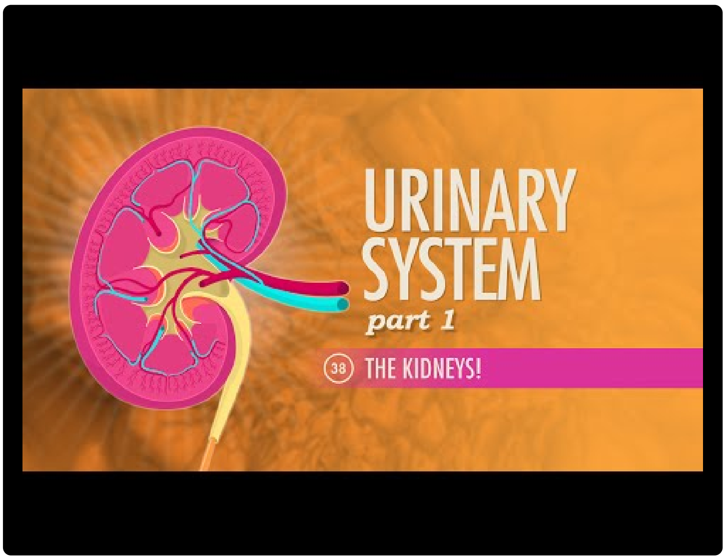


[Figure 4]

The parts of a nephron and their functions are shown in this diagram.

Excretion of Urine

From the collecting ducts of the kidneys, urine enters the **ureters**, two muscular tubes that move the urine by peristalsis to the **bladder** (see **Figure** above). The **bladder** is a hollow, sac-like organ that stores urine. When the bladder is about half full, it sends a nerve impulse to a sphincter to relax and let urine flow out of the bladder and into the **urethra**. The **urethra** is a muscular tube that carries urine out of the body. Urine leaves the body through another sphincter in the process of **urination**. This sphincter and the process of urination are normally under conscious control.



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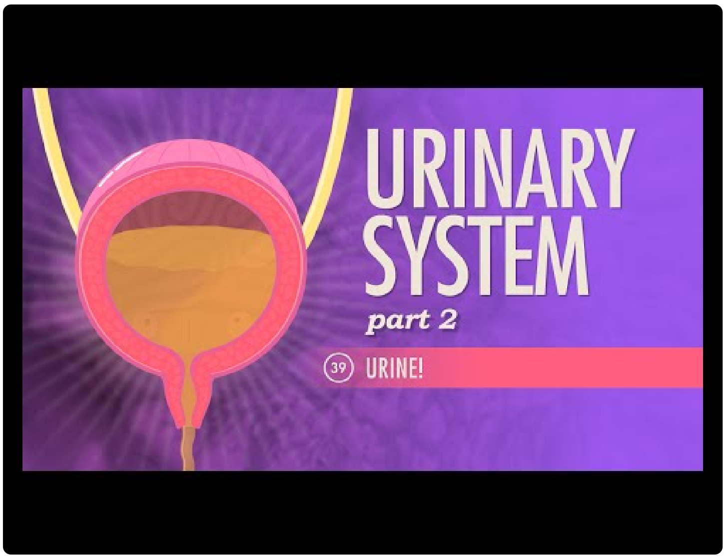

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Summary

- The kidneys filter blood and form urine. They are part of the urinary system, which also includes the ureters, bladder, and urethra.
- Each kidney has more than a million nephrons, which are the structural and functional units of the kidney.
- Each nephron is like a tiny filtering plant.

Review

1. Describe how nephrons filter blood and form urine.

2. State the functions of the ureters, bladder, and urethra.

Report Content Errors

13.43 Kidneys

FlexBooks 2.0 > Biology For High School Diploma > Kidneys

Last Modified: Aug 01, 2018

[Figure 1]

Why is a bean-shaped organ so important?

Shown above are the isolated kidneys from many little mice. OK, they're really just kidney beans. But this is what the important kidney looks like. Why is it so important? Your kidneys filter and remove wastes from your blood.

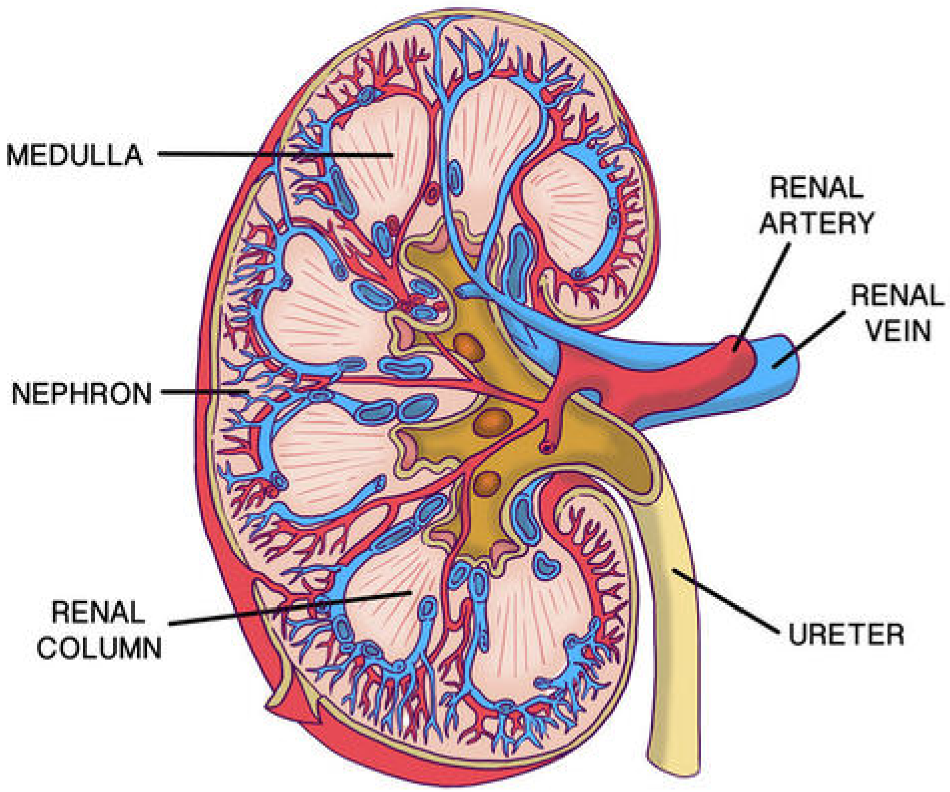
The Kidneys

The kidneys are a pair of bean-shaped organ just above the waist. They are important organs with many functions in the body, including producing hormone, absorbing mineral, and filtering blood and producing **urine**.

A cross-section of a kidney is shown in **Figure** below. The function of the kidney is to filter blood and form urine. **Urine** is the liquid waste product of the body that is excreted by the urinary system. Wastes in the blood come from the normal breakdown of tissue, such as muscles, and from food. The body uses food for energy. After the body has taken the nutrient it needs from food, some of the wastes are absorbed into the blood. If the kidneys did not remove them, these wastes would build up in the blood and damage the body.

Kidneys and Nephrons

The actual removal of wastes from the blood occurs in tiny units inside the kidneys called **nephron**. **Nephrons** are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons! This is further discussed in the *Urinary System* concept.



[Figure 2]

Each kidney is supplied by a renal artery and renal vein.

Kidneys and Homeostasis

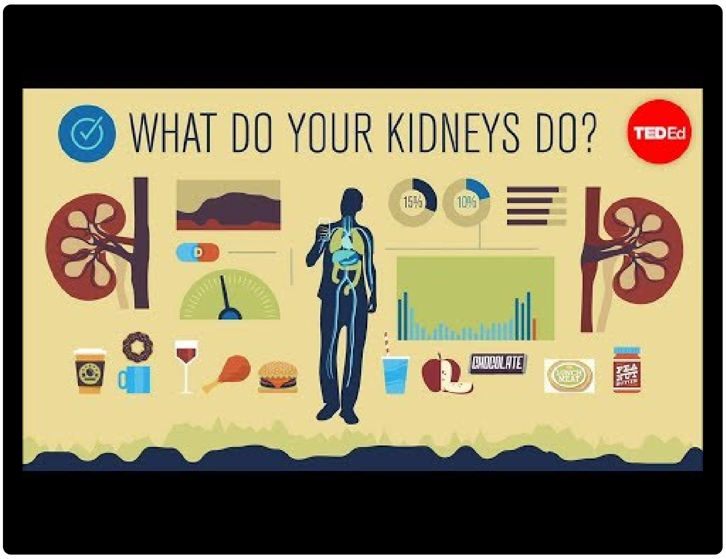
The kidneys play many vital roles in **homeostasis**. They work with many other organ system to do this. For example, they work with the circulatory system to filter blood, and with the urinary system to remove wastes.

The kidneys filter all the blood in the body many times each day and produce a total of about 1.5 liters of **urine**. The kidneys control the amount of water, ion, and other substances in the blood by excreting more or less of them in urine. The kidneys also secrete **hormones** that help maintain homeostasis. **erythropoietin**, for example, is a kidney hormone that stimulates bone marrow to produce red blood cell when more are needed. They also secrete renin, which regulates blood pressure, and calcitriol, the active form of **vitamin D**, which helps maintain calcium for bone. The kidneys themselves are also regulated by hormones. For example, **antidiuretic hormone** from the hypothalamus stimulates the kidneys to produce more concentrated urine when the body is low on water.

Other Functions

In addition to filtering blood and producing urine, the kidneys are also involved in maintaining the water level in the body, and regulating red blood cell levels and blood pressure.

- As the kidneys are mainly involved in the production of urine, they react to changes in the body's water level throughout the day. As water intake decreases, the kidneys adjust accordingly and leave water in the body instead of helping remove it through the urine, maintaining the water level in the body.
- The kidneys also need constant pressure to filter the blood. When the blood pressure drops too low, the kidneys increase the pressure. One way is by producing angiotensin, a blood vessel-constricting protein. This protein also signals the body to retain sodium and water. Together, the constriction of blood vessel and retention of sodium and water help restore normal blood pressure.
- When the kidneys don't get enough oxygen, they send out a signal in the form of the hormone erythropoietin, which stimulates the bone marrow to produce more oxygen-carrying red blood cells.



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Summary

- The kidneys maintain homeostasis by controlling the amount of water, ions, and other substances in the blood.
- Kidneys also secrete hormones that have other homeostatic functions.

Review

1. What is the nephron? How many nephrons are in each kidney?
2. Explain how the kidneys maintain homeostasis.
3. What is the role of antidiuretic hormone?

Report Content Errors

13.44 Excretory System Diseases

FlexBooks 2.0 > Biology For High School Diploma > Excretory System Diseases

Last Modified: Jul 04, 2019

[Figure 1]

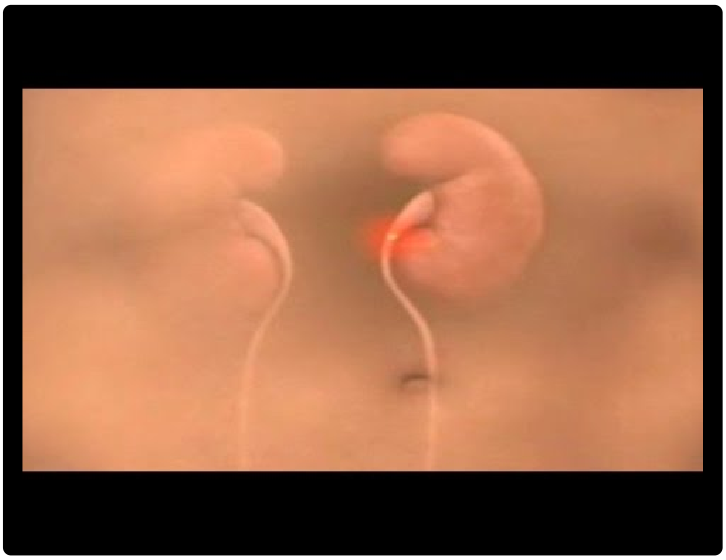
How do you block the flow of urine?

kidney stone. Imagine having that travel through your excretory system. OK, that's not a kidney stone, but you get the idea. Kidney stones can be more than a few millimeters in diameter. Painful? Sometimes extremely uncomfortable. And how does a stone leave the kidney? The same way urine does.

Kidney Disease and Dialysis

A person can live a normal, healthy life with just one kidney. However, at least one kidney must function properly to maintain life. Diseases that threaten the health and functioning of the kidneys include kidney stones, infections, and diabetes.

- **Kidney stones** are mineral crystals that form in urine inside the kidney. Kidney stones can form when substances in the urine, such as calcium, oxalate, and phosphorus, become highly concentrated. They may be extremely painful. If they block a ureter, they must be removed so urine can leave the kidney and be excreted. A kidney stone may not cause symptoms until it moves around within your kidney or passes into your ureter. A stone may stay in the kidney or travel down the urinary tract. Kidney stones vary in size. A small stone may pass on its own, causing little or no pain. A larger stone may get stuck along the urinary tract and can block the flow of urine, causing severe pain or bleeding.



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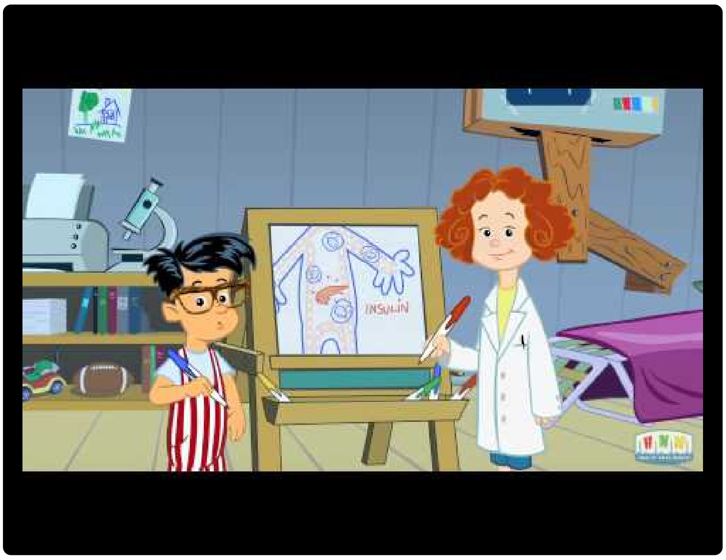
- Bacterial infections of the urinary tract, especially the bladder, are very common. Bladder infections can be treated with antibiotic prescribed by a doctor. If untreated, they may lead to kidney damage.
- Uncontrolled **diabetes** may damage capillaries of nephron. As a result, the kidneys lose much of their ability to filter blood. This is called **kidney failure**. The only cure for kidney failure is a kidney transplant, but it can be treated with **dialysis**. **Dialysis** is a medical procedure in which blood is filtered through a machine (see **Figure** below).



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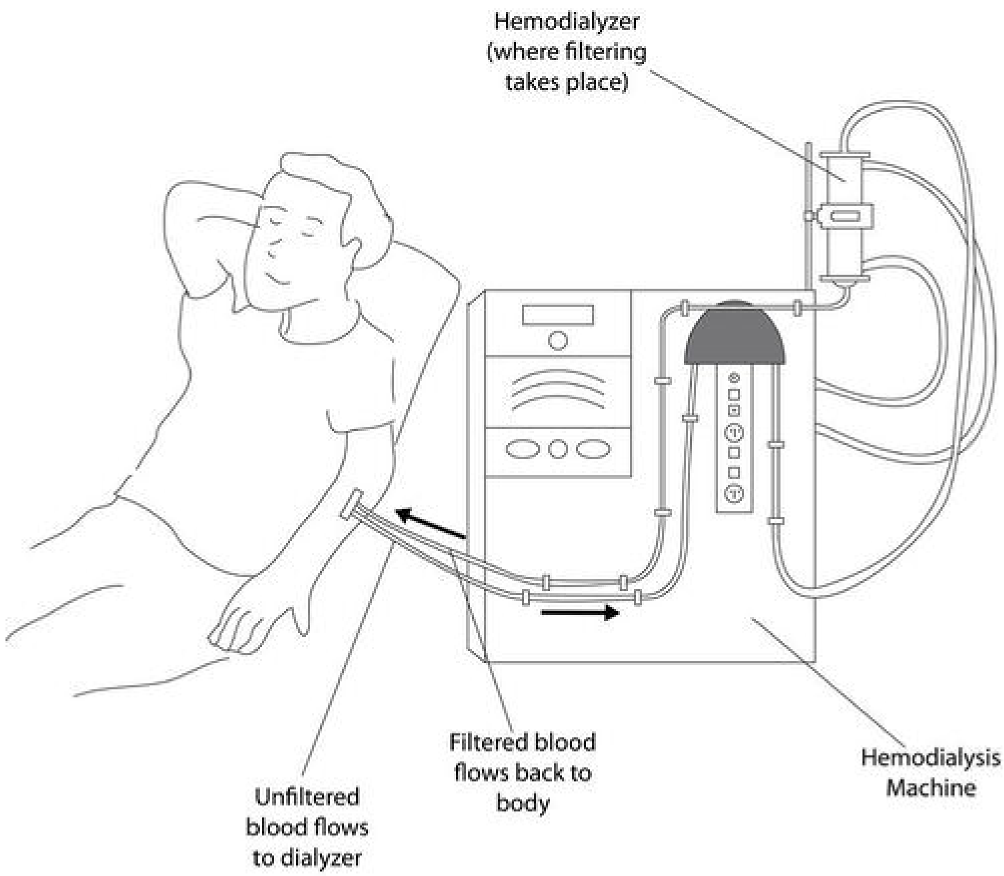


[Figure 2]

A dialysis machine filters a patient's blood.

Summary

- Kidney diseases include kidney stones, infections, and kidney failure due to diabetes.
- Kidney failure may be treated with dialysis.

Review

1. Tom was seriously injured in a car crash. As a result, he had to have one of his kidneys removed. Does Tom need dialysis? Why or why not?
2. What are kidney stones? How do they form?

Report Content Errors

13.45 Innate Immune System

FlexBooks 2.0 > Biology For High School Diploma > Innate Immune System

Last Modified: Jan 25, 2022

[Figure 1]

How does your body keep most enemies out?

Many would consider the moat around this castle, together with the thick stone castle walls, as the first line of defense. Their role is to keep the enemy out, and protect what's inside.

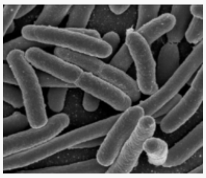
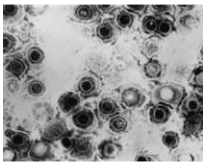
The First Line of Defense

[Figure 2]

Does this organism look like a space alien? A scary creature from a nightmare? In fact, it's a 1-cm long worm that lives in the human body and causes serious harm. It enters the body through a hair follicle of the skin when it's in a much smaller stage of its life cycle. Like this worm, many other organisms can make us sick if they manage to enter our body. Fortunately for us, our **immune system** is able to keep out most such invaders.

The **immune system** protects the body from worms, germs, and other agents of harm. The immune system is like a medieval castle. The outside of the castle was protected by a moat and high stone walls. Inside the castle, soldiers were ready to fight off any invaders that managed to get through the outer defenses. Like a medieval castle, the immune system has a series of defenses. In fact, it has three lines of defense. Only **pathogen** that are able to get through all three lines of defense can harm the body.

The body's first line of defense consists of different types of barriers that keep most pathogens out of the body. **Pathogens** are disease-causing agents, such as bacterium and virus. These and other types of pathogens are described in the **table** below. Regardless of the type of pathogen, however, the first line of defense is always the same.

Type of Pathogen	Description	Diseases associated with pathogens of this type
Bacteria  [Figure 3] Escherichia coli	Single-celled organism without a nucleus.	Strep throat, staph infections, tuberculosis, food poisoning, tetanus, pneumonia, syphilis
Viruses  [Figure 4] Herpes simplex	Non-living particles that reproduce by taking over living cell.	Common cold, flu, herpes, cold sores, measles, ADIS, genital warts, chicken pox, small pox.
fungus  [Figure 5] Death-cap mushroom	Simple organisms, including mushrooms and yeasts, that grow as single cells or thread-like filaments.	ringworm, athlete's foot, candidiasis, histoplasmosis, mushroom poisoning.
protozoan  [Figure 6] Giardia lamblia	Single-celled organism with a nucleus.	malaria, "traveller's diarhea", giardiasis, trypanosomiasis, sleeping sickness

Mechanical Barriers

mechanical barrier physically block pathogens from entering the body. The skin is the most important mechanical barrier. In fact, it is the single most important defense the body has. The outer layer of the skin is tough and very difficult for pathogens to penetrate.

Mucous membranes provide a mechanical barrier at body openings. They also line the respiratory, GI, urinary, and reproductive tracts. Mucous membranes secrete **mucus**, a slimy substance that traps pathogens. The membranes also have hair-like cilia. The **cilia** sweep mucus and pathogens toward body openings where they can be removed from the body. When you sneeze or cough, pathogens are removed from the nose and throat (see **Figure** below). Tears wash pathogens from the eyes, and urine flushes pathogens out of the urinary tract.

[Figure 7]

A sneeze can expel many pathogens from the respiratory tract. That's why you should always cover your mouth and nose when you sneeze.

Chemical Barriers

chemical barrier destroy pathogens on the outer body surface, at body openings, and on inner body linings. Sweat, mucus, tears, and saliva all contain enzyme that kill pathogens. Urine is too acidic for many pathogens, and semen contains zinc, which most pathogens cannot tolerate. In addition, stomach acid kills pathogens that enter the GI tract in food or water.

Biological Barriers

biological barrier are living organisms that help protect the body. Millions of harmless bacteria live on the human skin. Many more live in the GI tract. The harmless bacteria use up food and space so harmful bacteria cannot grow.

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Summary

- Barriers that keep out pathogens are the body's first line of defense.
- The first line of defense includes mechanical, chemical, and biological barriers.

Review

1. What is the role of the body's first line of defense?
2. Identify three types of barriers in the body's first line of defense. Give an example of each type of barrier.
3. Which type of pathogen causes the common cold? Which type causes athlete's foot?

Report Content Errors

13.46 Inflammatory Response

FlexBooks 2.0 > Biology For High School Diploma > Inflammatory Response

Last Modified: Aug 06, 2018

[Figure 1]

What happens when an enemy gets past the first line of defense?

For this running back to make it past the first line of defense, there usually has to be a hole or break in the line. He then runs into the secondary, or the second line of defense. Whenever the skin is broken, it is possible for pathogen to easily enter your body. They get past the first line of defense, and run into the second line of defense.

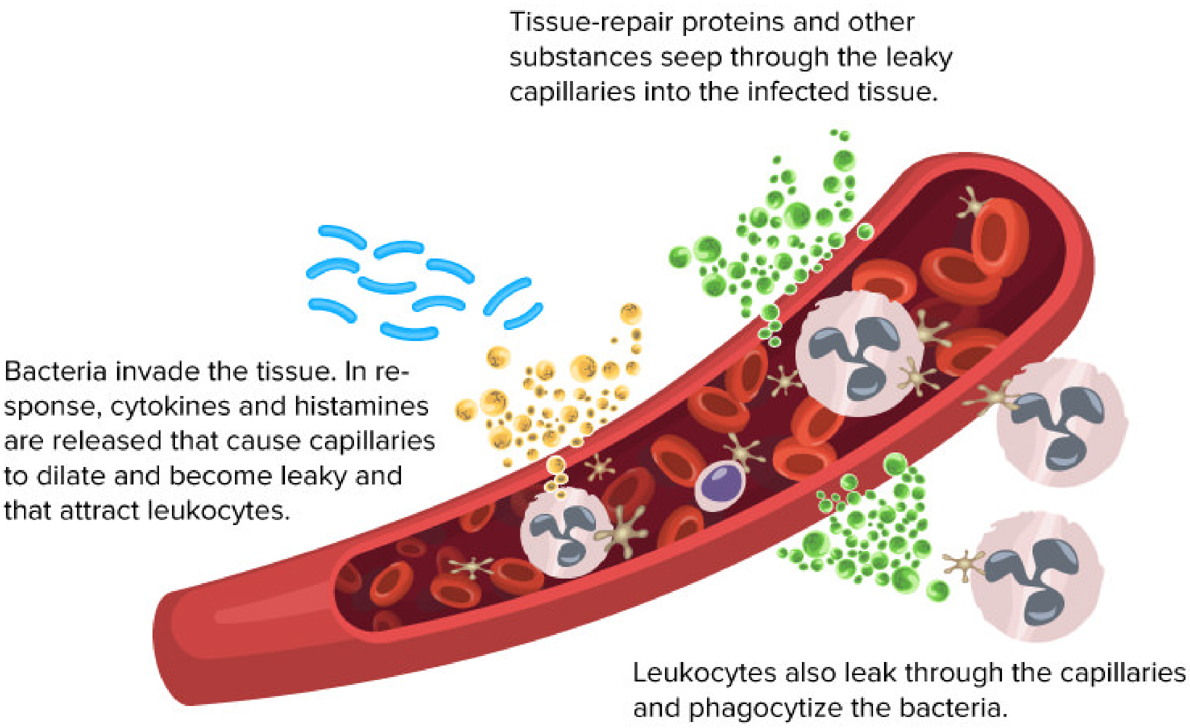
The Second Line of Defense

If you have a cut on your hand, the break in the skin provides a way for pathogens to enter your body. Assume bacterium enter through the cut and infect the wound. These bacteria would then encounter the body's second line of defense.

Inflammatory Response

The cut on your hand may become red, warm, and swollen. These are signs of an **inflammatory response.** This is the first reaction of the body to tissue damage or infection. As explained in **Figure** below, the response is triggered by chemicals called **cytokine** and **histamine**, which are released when tissue is injured or infected. The chemicals communicate with other cell and coordinate the inflammatory response. You can see an

animation of the inflammatory response at this link:
http://www.sumanasinc.com/webcontent/animations/content/inflammatory.html.



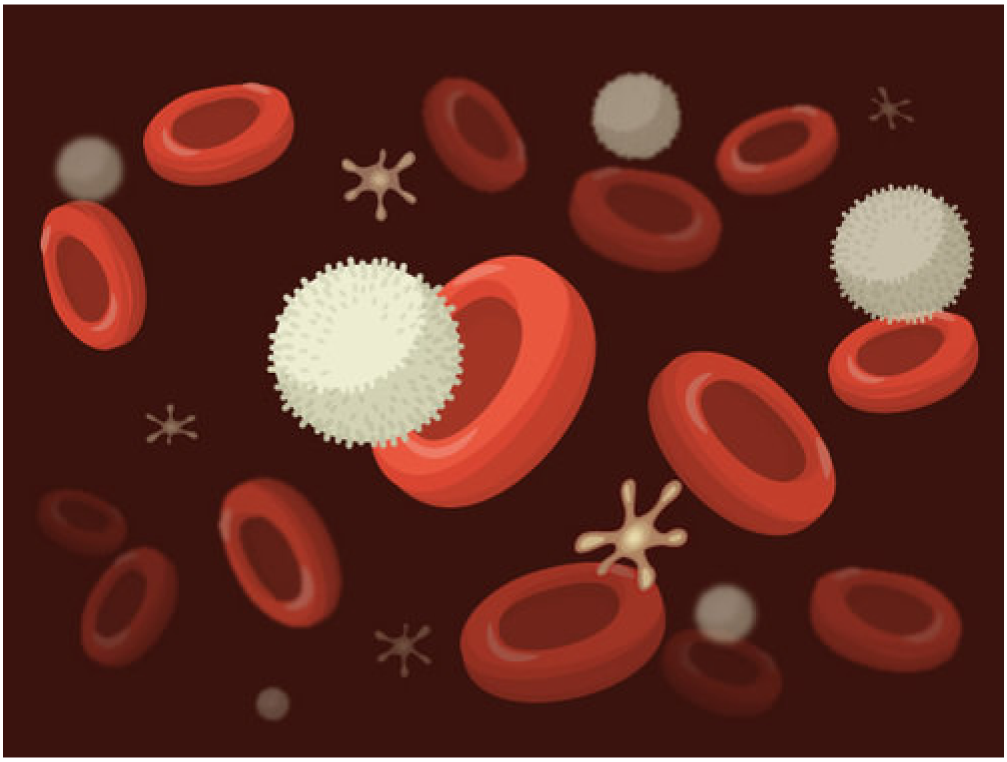
[Figure 2]

This drawing shows what happens during the inflammatory response. Why are changes in capillaries important for this response?

Leukocytes

The chemicals that trigger an inflammatory response attract **leukocyte** to the site of injury or infection. **Leukocytes** are white blood cell. Their role is to fight infections and get rid of debris. Leukocytes may respond with either a nonspecific or a **specific defense**.

- A **nonspecific defense** is the same no matter what type of pathogen is involved. An example of a nonspecific defense is **phagocytosis.** This is the process in which leukocytes engulf and break down pathogens and debris. It is illustrated in **Figure** below. The immune system's first line of defense is also a nonspecific defense.
- A **specific defense** is tailored to a particular pathogen. Leukocytes involved in this type of defense are part of the immune response and are described in other concepts.



[Figure 3]

In this image, leukocytes (white) are attacking pathogens (star-shaped).

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Further Reading

Allergies

Summary

- The second line of defense attacks pathogens that manage to enter the body.
- The second line of defense includes the inflammatory response and phagocytosis by nonspecific leukocytes.

Review

1. What is a nonspecific defense?
2. What is the body's second life of defense? When does it take effect?
3. Identify the roles of nonspecific leukocytes in the body's second line of defense.
4. Jera cut her finger. The next day, the skin around the cut became red and warm. Why are these signs of infection?

Report Content Errors

13.47 Lymphatic System

FlexBooks 2.0 > Biology For High School Diploma > Lymphatic System

Last Modified: Feb 29, 2020

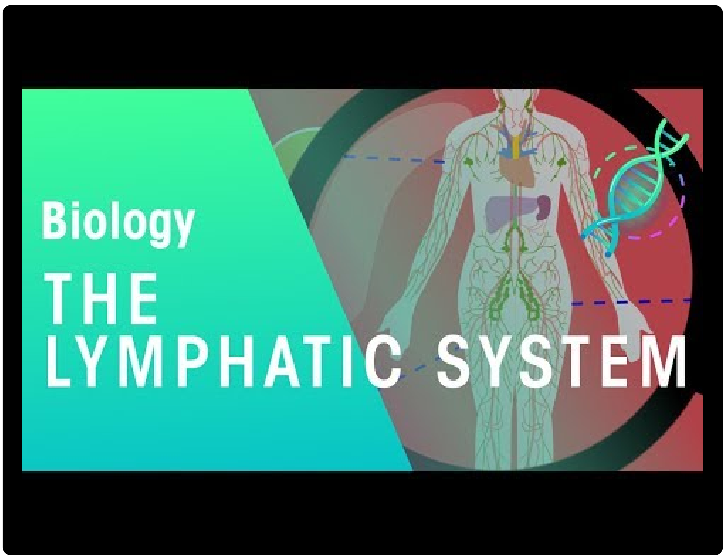
[Figure 1]

What happens when your tonsils cause more problems than they solve?

Almost all of us have had a sore throat at some time. Maybe you had your tonsils out when you were younger? Why? Your tonsils are two lumps of tissue that work as germ fighters for your body. But sometimes germs like to hang out there, where they cause infections. In other words, your tonsils can cause more problems than they solve. So, you have them taken out.

Lymphatic System

Like the immune systems of other vertebrate, the human immune system is adaptive. If pathogen manage to get through the body's first two lines of defense, the third line of defense takes over. The third line of defense is referred to as the **immune response**. This defense is specific to a particular pathogen, and it allows the immune system to "remember" the pathogen after the infection is over. If the pathogen tries to invade the body again, the immune response against that pathogen will be much faster and stronger.



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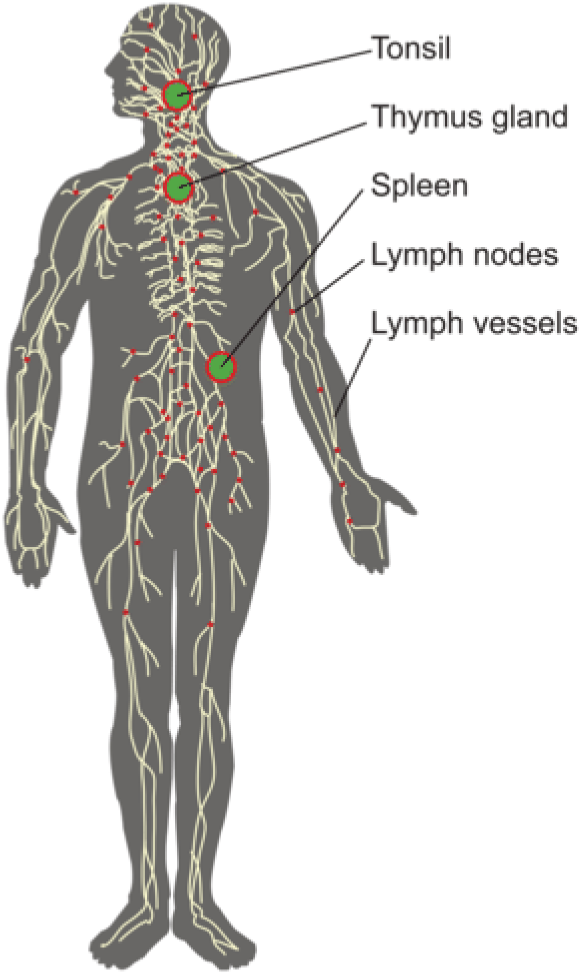
The immune response mainly involves the lymphatic system. The **lymphatic system** is a major part of the immune system. It produces leukocyte called **lymphocyte**. **Lymphocytes** are the key cell involved in the immune response. They recognize and help destroy particular pathogens in body fluids and cells. They also destroy certain cancer cells.

Structures of the Lymphatic System

Figure below shows the structures of the lymphatic system. They include organ, lymph vessel, **lymph**, and **lymph node**. Organs of the lymphatic system are the **bone marrow**, **thymus**, spleen, and tonsils.

- **Bone marrow** is found inside many bone. It produces lymphocytes.
- The **thymus** is located in the upper chest behind the breast bone. It stores and matures lymphocytes.
- The **spleen** is in the upper abdomen. It filters pathogens and worn out red blood cell from the blood, and then lymphocytes in the spleen destroy them.
- The **tonsils** are located on either side of the pharynx in the throat. They trap pathogens, which are destroyed by lymphocytes in the tonsils.



[Figure 2]

The lymphatic system consists of organs, vessels, and lymph.

Lymphatic Vessels and Lymph

Lymphatic vessels make up a body-wide circulatory system. The fluid they circulate is lymph. **Lymph** is a fluid that leaks out of capillaries into spaces between cells. As the lymph accumulates between cells, it diffuses into tiny lymphatic vessels. The lymph then moves through the lymphatic system from smaller to larger vessels. It finally drains back into the bloodstream in the chest. As lymph passes through the lymphatic vessels, pathogens are filtered out at small structures called **lymph nodes** (see **Figure** above). The filtered pathogens are destroyed by lymphocytes.

Lymphocytes

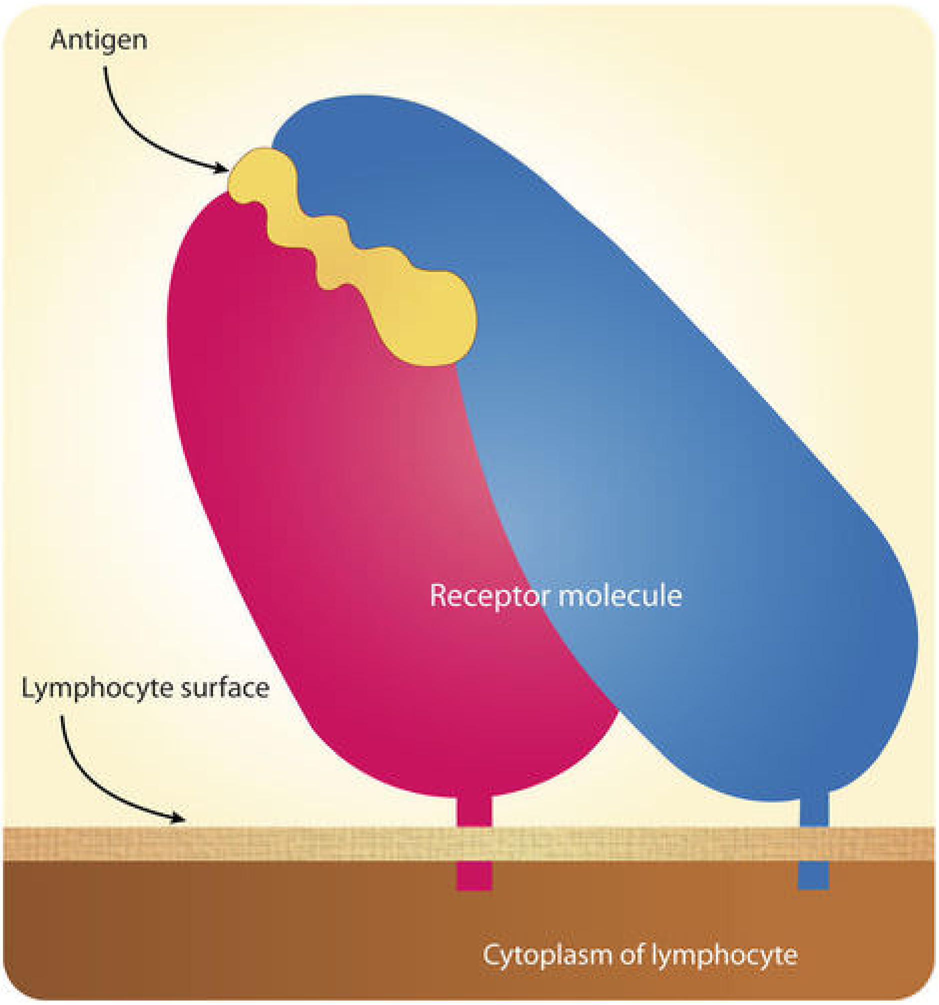
The human body has as many as two trillion lymphocytes, and lymphocytes make up about 25% of all leukocytes. The majority of lymphocytes are found in the lymphatic system, where they are most likely to encounter pathogens. The rest are found in the blood. There are two major types of lymphocytes, called **B cell** and **T cell.** These cells get their names from the organs in which they mature. B cells mature in bone marrow, and T cells mature in the thymus. Both B and T cells recognize and respond to particular pathogens.

Antigen Recognition

B cells and T cells actually recognize and respond to **antigen** on pathogens. **Antigens** are molecules that the immune system recognizes as foreign to the body. Antigens are also found on cancer cells and the cells of transplanted organs. They trigger the immune system to react against the cells that carry them. This is why a transplanted organ may be rejected by the recipient's immune system.

How do B and T cells recognize specific antigens? They have receptor molecules on their surface that bind only with particular antigens.

As shown in **Figure** below, the fit between an antigen and a matching receptor molecule is like a key in a lock.



[Figure 3]

An antigen fits the matching receptor molecule like a key in a lock.

Summary

- The body's third line of defense is the immune response. This involves the lymphatic system. This system filters pathogens from lymph and produces lymphocytes.
- Lymphocytes are the key cells in the immune response. They are leukocytes that become activated by a particular antigen. There are two major type of lymphocytes: B cells and T cells.

Review

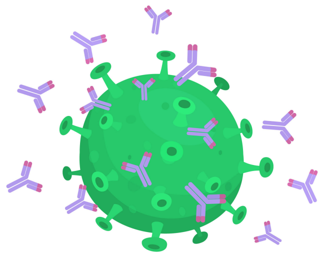
1. What is the lymphatic system?
2. List three organs of the lymphatic system and their functions.
3. What are lymph nodes? What is their function?
4. What are the two major types of lymphocytes?
5. What are antigens, and how do lymphocytes "recognize" them?

Report Content Errors

13.48 Humoral Response

FlexBooks 2.0 > Biology For High School Diploma > Humoral Response

Last Modified: Aug 01, 2018



[Figure 1]

What are those Y-shaped things floating around the cell?

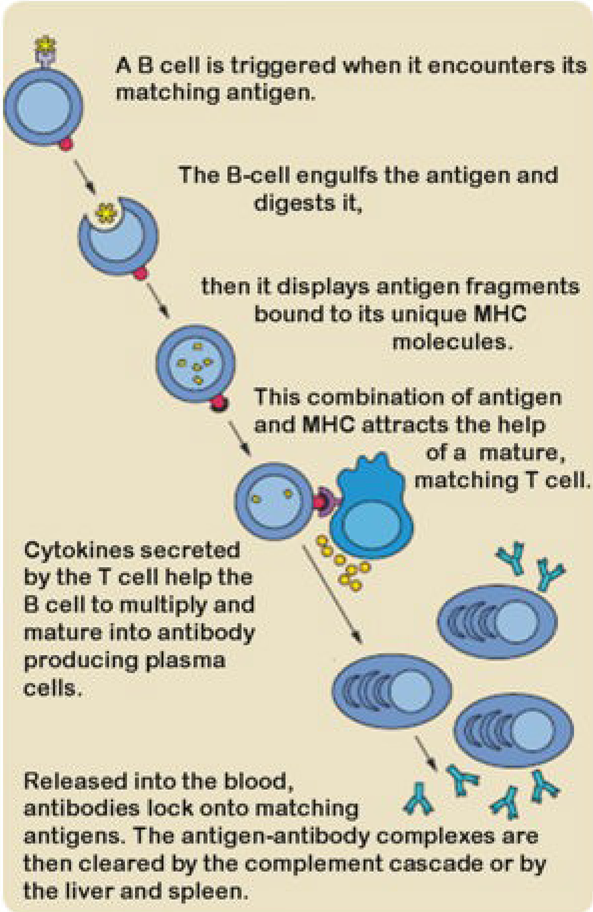
They are **antibody**, which are large protein. And they signal specific antigen for destruction. It does help that the antigens are usually attached to pathogen.

Humoral Immune Response

There are actually two types of immune responses: humoral and cell-mediated. The **humoral immune response** involves mainly **B cell** and takes place in blood and lymph.

B Cell Activation

B cells must be activated by an antigen before they can fight pathogens. This happens in the sequence of events shown in **Figure** below. First, a encounters its matching antigen and engulfs it. The B cell then displays fragments of the antigen on its surface. This attracts a **helper T cell**. The helper T cell binds to the B cell at the antigen site and releases **cytokine** that "tell" or signal the B cell to develop into a **plasma cell**.

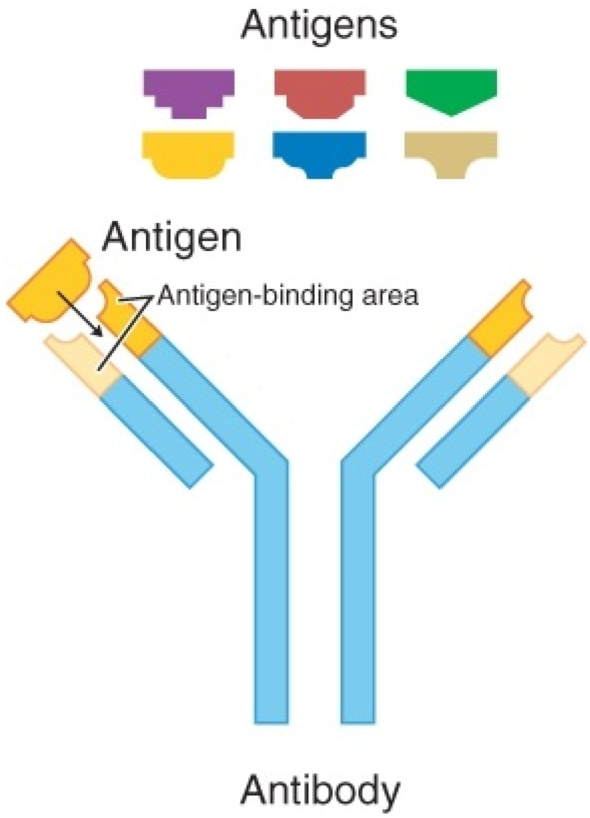


[Figure 2]

Activation of a B cell must occur before it can respond to pathogens. What role do T cells play in the activation process?

Plasma Cells and Antibody Production

Plasma cells are activated B cells that secrete antibodies. **Antibodies** are large, Y-shaped proteins that recognize and bind to antigens. Plasma cells are like antibody factories, producing many copies of a single type of antibody. The antibodies travel throughout the body in blood and lymph. Each antibody binds to just one kind of antigen. When it does, it forms an **antigen-antibody complex** (see **Figure** below). The complex flags the antigen-bearing cell for destruction by **phagocytosis**.

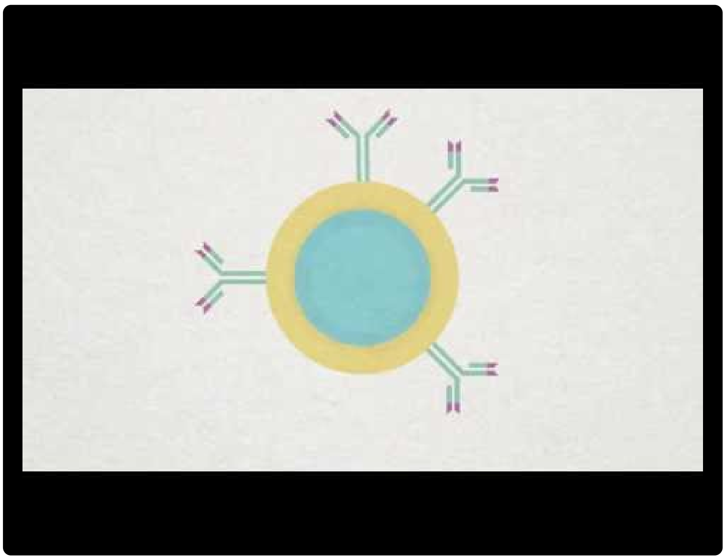


[Figure 3]

An antibody matches only one type of antigen.

Memory Cells

Most plasma cells live for just a few days, but some of them live much longer. They may even survive for the lifetime of the individual. Long-living plasma cells are called **memory cells.** They retain a "memory" of a specific pathogen long after an infection is over. They help launch a rapid response against the pathogen if it invades the body again in the future.



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Summary

- Activated B cells produce antibodies to a particular antigen.
- Memory B cells remain in the body after the immune response is over and provide immunity to pathogens bearing the antigen.

Review

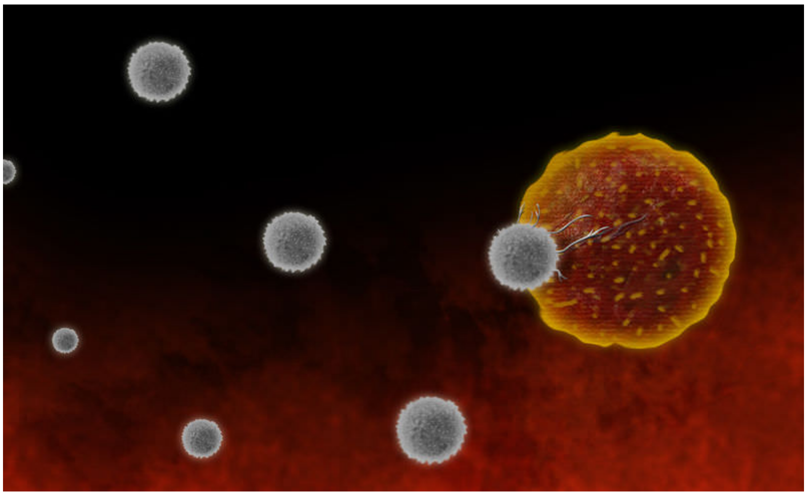
1. How do plasma cells help fight pathogens? Include the role of antibodies in your response.
2. If a disease destroyed a person's helper T cells, how might this affect the ability to launch an immune response?
3. What are memory cells? What is their role?

Report Content Errors

13.49 Cell-Mediated Response

FlexBooks 2.0 > Biology For High School Diploma > Cell-Mediated Response

Last Modified: Aug 01, 2018



[Figure 1]

Do cells really attack other cells?

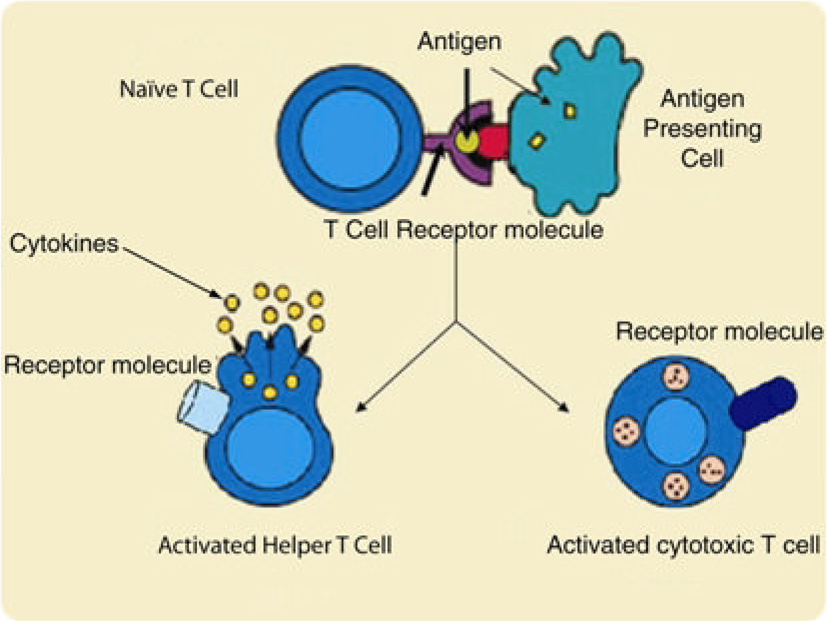
They sure do. Depicted here is a group of T cell attacking a cancer cell. When they can, the T cells search out and destroy "bad" cells.

Cell-Mediated Immune Response

In addition to the humoral response, the other type of immune response is the **cell-mediated immune response**, which involves mainly **T cells**. It leads to the destruction of cells that are infected with virus. Some cancer cells are also destroyed in this way. There are several different types of T cells involved in a cell-mediated immune response, including helper, cytotoxic, and **regulatory T cell**.

T Cell Activation

All three types of T cells must be activated by an antigen before they can fight an infection or cancer. activation is illustrated in **Figure** below. It begins when a B cell or nonspecific leukocyte engulfs a virus and displays its antigens. When the T cell encounters the matching antigen on a leukocyte, it becomes activated. What happens next depends on which type of T cell it is.



[Figure 2]

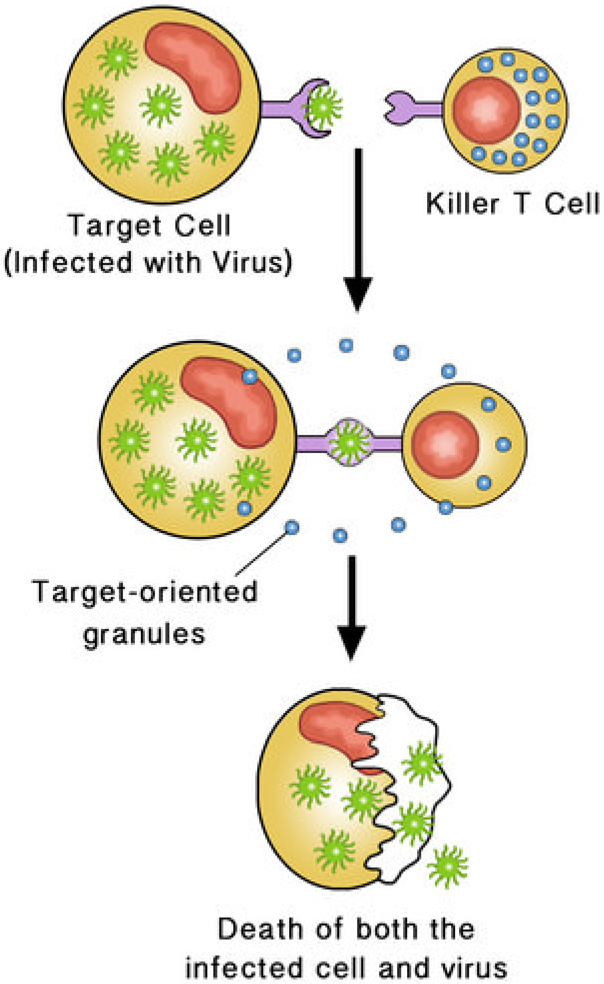
T cell activation requires another leukocyte to engulf a virus and display its antigen.

Helper T Cells

helper T cell are like the "managers" of the immune response. They secrete **cytokine**, which activate or control the activities of other lymphocyte. Most helper T cells die out once a pathogen has been cleared from the body, but a few remain as **memory cells**. These memory cells are ready to produce large numbers of antigen-specific helper T cells like themselves if they are exposed to the same antigen in the future.

Cytotoxic T Cells

cytotoxic T cell destroy virus-infected cells and some cancer cells. Once activated, a divides rapidly and produces an "army" of cells identical to itself. These cells travel throughout the body "searching" for more cells to destroy. **Figure** below shows how a cytotoxic T cell destroys a body cell infected with viruses. This T cell releases toxins that form pores in the membrane of the infected cell. This causes the cell to burst, destroying both the cell and the viruses inside it.



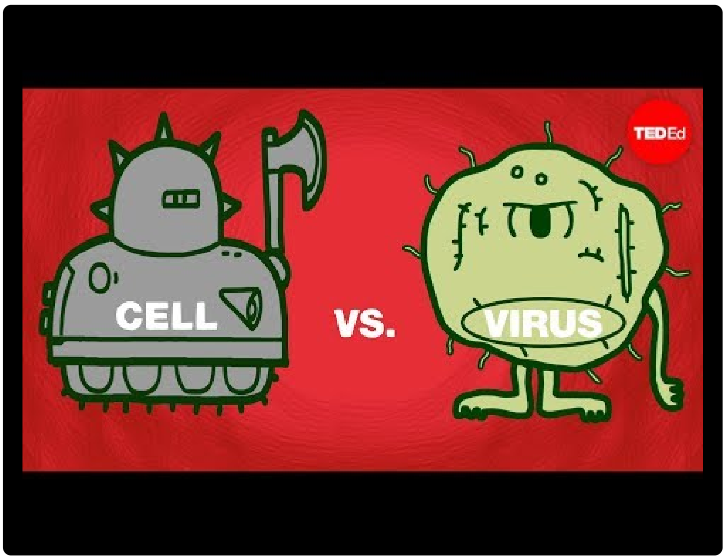
[Figure 3]

A cytotoxic T cell releases toxins that destroy an infected body cell and the viruses it contains.

After an infection has been brought under control, most cytotoxic T cells die off. However, a few remain as memory cells. If the same pathogen enters the body again, the memory cells mount a rapid immune response. They quickly produce many copies of cytotoxic T cells specific to the antigen of that pathogen.

Regulatory T Cells

Regulatory T cells are responsible for ending the cell-mediated immune response after an infection has been curbed. They also suppress T cells that mistakenly react against self antigens. What might happen if these T cells were not suppressed?



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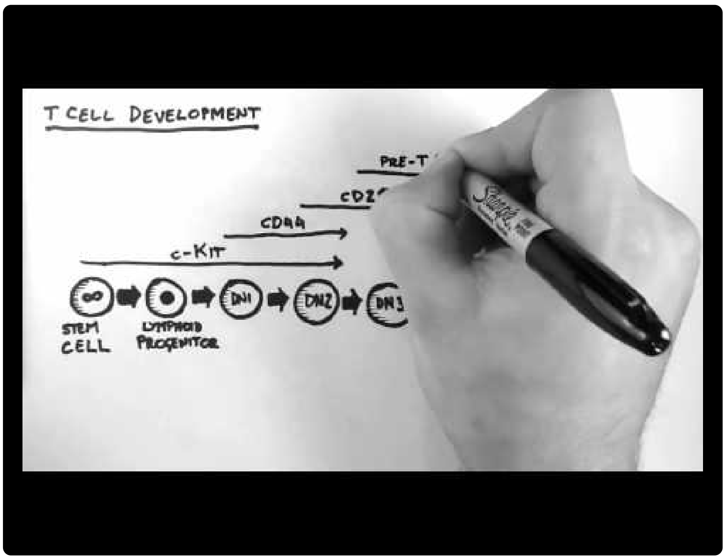
Summary

- Activated T cells destroy certain cancer cells and cells infected by viruses.
- Memory T cells remain in the body after the immune response and provide antigen-specific immunity to the virus.

Review

1. Describe one way that cytotoxic T cells destroy cells infected with viruses.
2. What are regulatory T cells?

Resources



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Report Content Errors

13.50 Immunity

FlexBooks 2.0 > Biology For High School Diploma > Immunity

Last Modified: Aug 06, 2018

[Figure 1]

Is giving shots to young children a good thing?

Many, if not most, children hated going to the doctor, as it often meant getting a shot. Why? The shot actually contained a weakened or dead pathogen. And putting some of that dead pathogen into you was a good thing.

Immunity

Memory B and T cell help protect the body from re-infection by pathogens that infected the body in the past. Being able to resist a pathogen in this way is called **immunity.** Immunity can be active or passive.

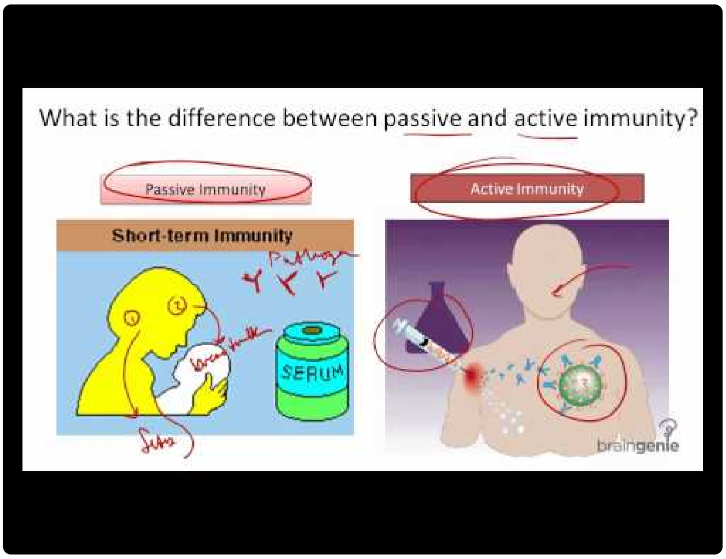
Active Immunity

active immunity results when an immune response to a pathogen produces memory cell. As long as the memory cells survive, the pathogen will be unable to cause a serious infection in the body. Some memory cells last for a lifetime and confer permanent immunity.

Active immunity can also result from **immunization**. **Immunization** is the deliberate exposure of a person to a **pathogen** in order to provoke an immune response and the formation of memory cells specific to that pathogen. The pathogen is often injected. However, only part of a pathogen, a weakened form of the pathogen, or a dead pathogen is typically used. This causes an immune response without making the immunized person sick. This is how you most likely became immune to measles, mumps, and chicken pox.

Passive Immunity

passive immunity results when **antibody** are transferred to a person who has never been exposed to the pathogen. Passive immunity lasts only as long as the antibodies survive in body fluids. This is usually between a few days and a few months. Passive immunity may be acquired by a fetus through its mother's blood. It may also be acquired by an infant though the mother's breast milk. Older children and adults can acquire passive immunity through the injection of antibodies.



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Further Reading

Autoimmune Disease

Summary

- Immunity is the ability to resist infection by a pathogen.
- Active immunity results from an immune response to a pathogen and the formation of memory cells.
- Passive immunity results from the transfer of antibodies to a person who has not been exposed to the pathogen.

Review

1. What is immunity? What role do memory cells play in immunity?
2. How is active immunity different from passive immunity? Why does active immunity last longer?

3. Explain how immunization prevents a disease such as measles, which is caused by a virus.

Report Content Errors

13.51 Allergies

FlexBooks 2.0 > Biology For High School Diploma > Allergies

Last Modified: Jul 04, 2019

[Figure 1]

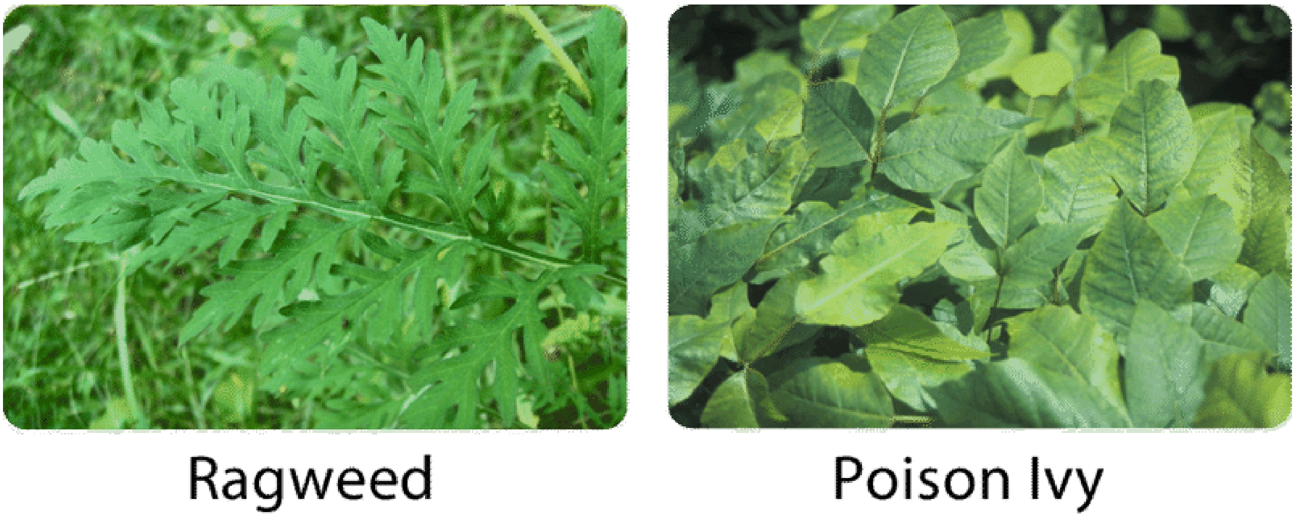
Have you ever started to sneeze and not known why?

A beautiful sea of flower. A nice sight, unless you have an allergic reaction. It is not uncommon to have reactions to pollen.

Allergies

Your immune system usually protects you from pathogen and keeps you well. However, like any other body system, the immune system itself can develop problems. Sometimes it responds to harmless foreign substances as though they were pathogens. Sometimes it attacks the body's own cell. Certain diseases can also attack and damage the immune system and interfere with its ability to defend the body.

An **allergy** is a disease in which the immune system makes an inflammatory response to a harmless **antigen**. Any antigen that causes an allergy is called an **allergen.** Allergens may be inhaled or ingested, or they may come into contact with the skin. Two common causes of allergies are shown in **Figure** below. inhaling ragweed pollen may cause coughing and sneezing. Skin contact with oils in poison ivy may cause an itchy rash. Other common causes of allergies include dust mites, mold, animal dander, insect stings, latex, and certain food and medications. Symptoms of a common allergy such as pollen can include sneezing, a runny nose, nasal congestion and itchy, watery eyes.



[Figure 2]

Ragweed and poison ivy are common causes of allergies. Are you allergic to these plants?

The symptoms of allergies can range from mild to severe. Mild allergy symptoms are often treated with **antihistamines**. These are drug that reduce or eliminate the effects of the histamine that cause allergy symptoms. Recall that histamines trigger the inflammatory response. The most severe allergic reaction is called **anaphylaxis**. This is a life-threatening response caused by a massive release of histamines. It requires emergency medical treatment.

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Summary

- Allergies occur when the immune system makes an inflammatory response to a harmless antigen.
- An antigen that causes an allergy is called an allergen.

Review

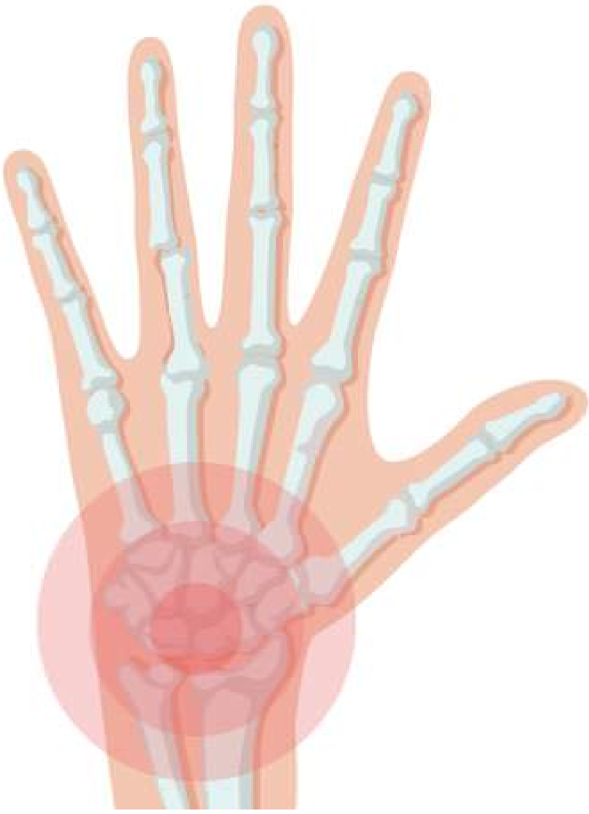
1. What is an allergen? Give two examples.
2. Define anaphylaxis. What causes the symptoms of anaphylaxis?
3. Sometimes people with an allergy get allergy shots. They are injected with tiny amounts of the allergen that triggers the allergic reaction. The shots are repeated at regular intervals, and the amount of allergen that is injected each time gradually increases. How do you think this might help an allergy? Do you think this approach just treats allergy symptoms or might it cure the allergy?

Report Content Errors

13.52 Autoimmune Disease

FlexBooks 2.0 > Biology For High School Diploma > Autoimmune Disease

Last Modified: Feb 29, 2020



[Figure 1]

joint pain. Not an uncommon problem as you grow older. Is it due to normal wear and tear on the joints? Possibly. But **rheumatoid arthritis** is an autoimmune disease, which means the body's immune system mistakenly attacks healthy tissue.

Autoimmune Diseases

Autoimmune diseases occur when the immune system fails to recognize the body's own molecules as "self," or belonging to the person. Instead, it attacks body cell as though they were dangerous pathogen. There are more than 80 known autoimmune diseases. Recall that **regulatory T cell** help regulate the immune system. When autoimmune disorders occur, these regulatory T cells fail in their function. This results in damage to various organ and tissues. The type of autoimmune disorder depends on the type of body tissue that is affected.

Some relatively common autoimmune diseases are listed in **Table** below. These diseases cannot be cured, although they can be treated to relieve symptoms and prevent some of the long-term damage they cause.

Name of Disease	Tissues Attacked by Immune System	Results of Immune System Attack
Rheumatoid arthritis	tissues inside joints	joint damage and pain
type 1 diabetes	insulin-producing cells of the pancreas	inability to produce insulin, high blood sugar
multiple sclerosis	myelin sheaths of central nervous system neuron	muscle weakness, pain, fatigue
Systemic lupus erythematosus	joints, heart, other organs	joint and organ damage and pain

Why does the immune system attack body cells? In some cases, it's because of exposure to **pathogens** that have **antigen** similar to the body's own molecules. When this happens, the immune system not only attacks the pathogens, it also attacks body cells with the similar molecules.

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Summary

- Autoimmune diseases occur when the immune system fails to distinguish self from non-self. As a result, the immune system attacks the body's own cells.

Review

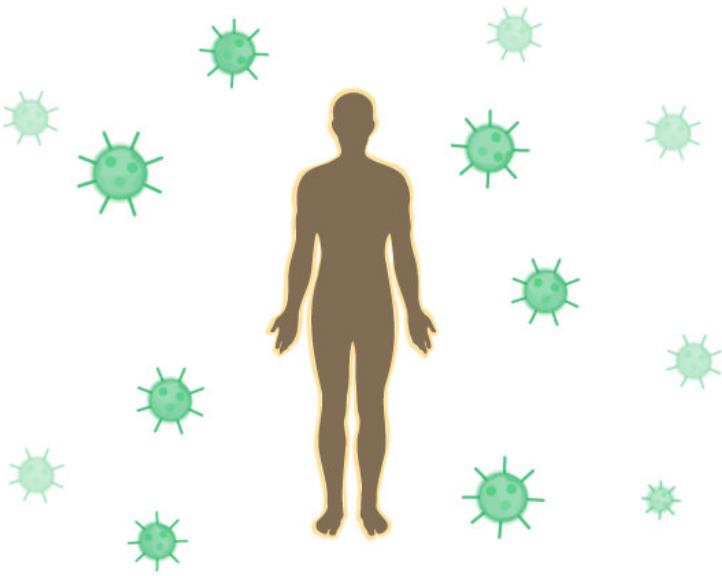
1. What is an autoimmune disease? Name an example.
2. Rheumatic fever is caused by a bacteria that has antigens similar to molecules in human heart tissues. When the immune system attacks the bacteria, it may also attack the heart. What type of immune system disease is rheumatic fever? Explain your answer.
3. Can autoimmune disease be cured?

Report Content Errors

13.53 Immunodeficiency

FlexBooks 2.0 > Biology For High School Diploma > Immunodeficiency

Last Modified: Jul 04, 2019



[Figure 1]

Which is stronger?

You or little tiny pathogen? Usually you are. Normally your body can put up a strong defense against enemy pathogens. But what if it can't? What happens if your immune system is "sick"?

Immunodeficiency

Immunodeficiency occurs when the immune system is not working properly. As a result, it cannot fight off pathogens that a normal immune system would be able to resist. Most commonly, immunodeficiency diseases occur when T or B cell (or both) do not work as well as they should, or when your body doesn't produce enough antibody.

Rarely, the problem is caused by a defective gene. Inherited immunodeficiency disorders that affect B cells include hypogammaglobulinemia, which usually leads to respiratory and gastrointestinal infections, and agammaglobulinemia, which results in severe infections early in life, and is often deadly.

More often, immunodeficiency is acquired during a person's lifetime. Immunodeficiency may occur for a variety of reasons:

- The immune system naturally becomes less effective as people get older. This is why older people are generally more susceptible to disease.
- The immune system may be damaged by other disorders, such as obesity or drug abuse.
- Certain medications can suppress the immune system. This is an intended effect of drug given to people with transplanted organ. In many cases, however, it is an unwanted side effect of drugs used to treat other diseases.
- Some pathogens attack and destroy cell of the immune system. An example is the virus known as **HIV**. It is the most common cause of immunodeficiency in the world today.

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Summary

- In an immunodeficiency disease, the immune system does not work normally. As a consequence, it cannot defend the body.

Review

1. What is immunodeficiency?
2. List three possible reasons for acquired immunodeficiency.

Report Content Errors

13.54 HIV AIDS

FlexBooks 2.0 > Biology For High School Diploma > HIV AIDS

Last Modified: Aug 06, 2018

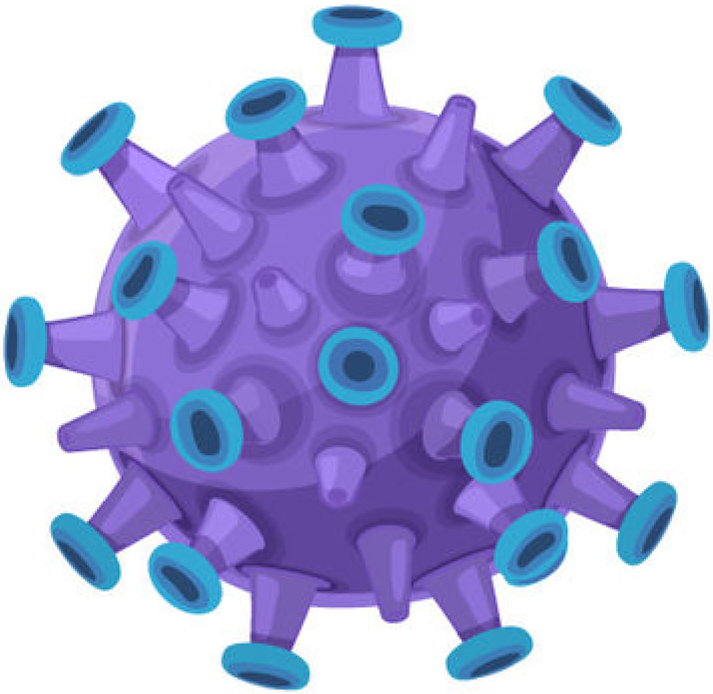
[Figure 1]

How long can a person live with HIV?

Years ago, a diagnosis of an HIV infection was a death sentence. Not today. With the proper medical treatment, an individual can live well over 10 or 20 or more productive years with an AIDS diagnosis. One of the most famous individuals with HIV is Earvin "Magic" Johnson, a retired professional basketball player. He was diagnosed in 1991. Over 20 years later, he is still doing well.

HIV and AIDS

human immunodeficiency virus (HIV) is a virus that attacks the **immune system**. An example of HIV is shown in **Figure** below. Many people infected with HIV eventually develop **acquired immune deficiency syndrome (AIDS).** This may not occur until many years after the virus first enters the body.

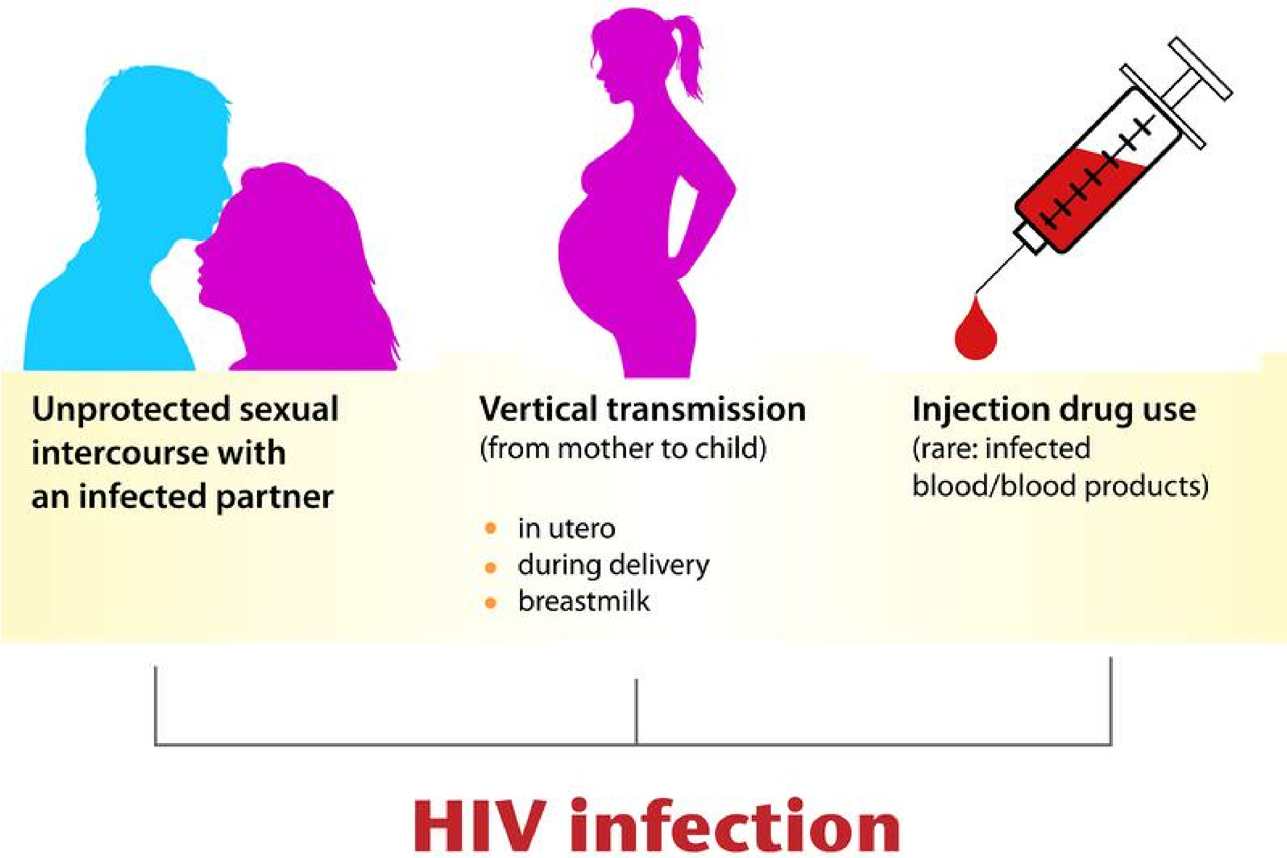


[Figure 2]

HIV is a virus that attacks cells of the immune system.

HIV Transmission

HIV is transmitted, or spread, through direct contact of **mucous membranes** or body fluids such as blood, semen, or breast milk. As shown in **Figure** below, transmission of the virus can occur through sexual contact or the use of contaminated hypodermic needle. It can also be transmitted through an infected mother's blood to her baby during late pregnancy or birth or through breast milk after birth. In the past, HIV was also transmitted through blood transfusions. Because donated blood is now screened for HIV, the virus is no longer transmitted this way. HIV is not spread through saliva, touching or in swimming pools.

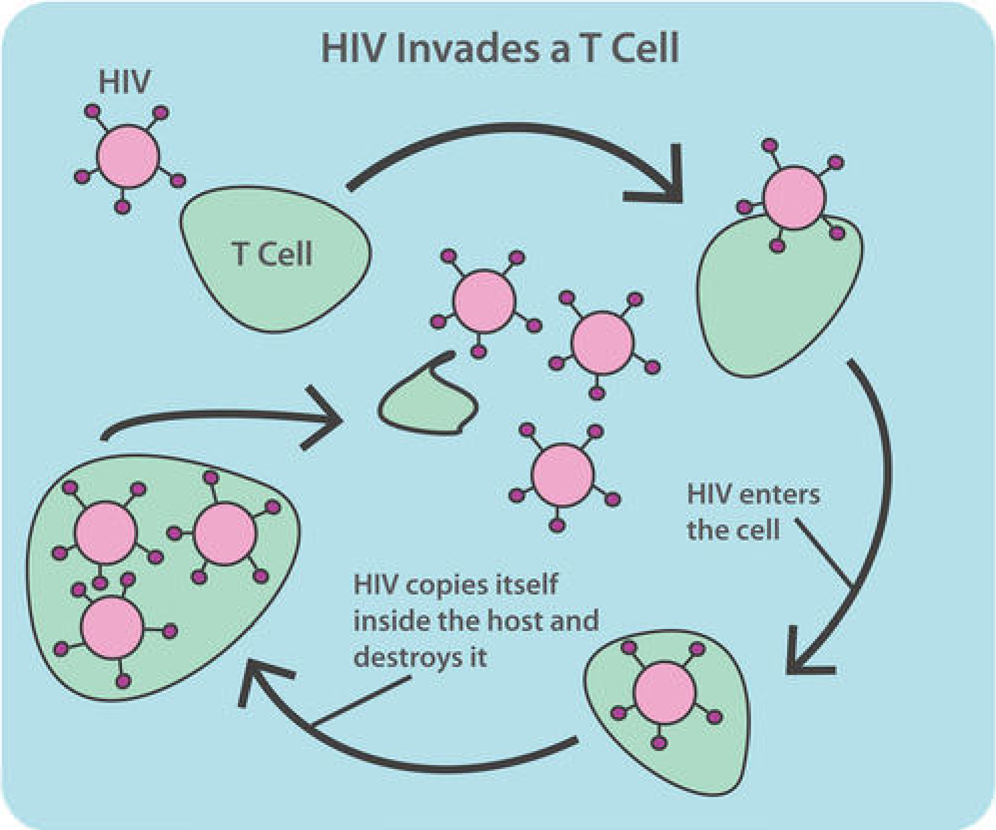


[Figure 3]

HIV may be transmitted in all of the ways shown here. Based on how HIV is transmitted, what can people do to protect themselves from becoming infected? What choices can they make to prevent infection?

HIV and the Immune System

HIV infects and destroys **helper T cell**. As shown in **Figure** below, the virus injects its own DNA into a and uses the T cell's "machinery" to make copies of itself. In the process the T cell is destroyed, and the virus copies go on to infect other helper T cells.



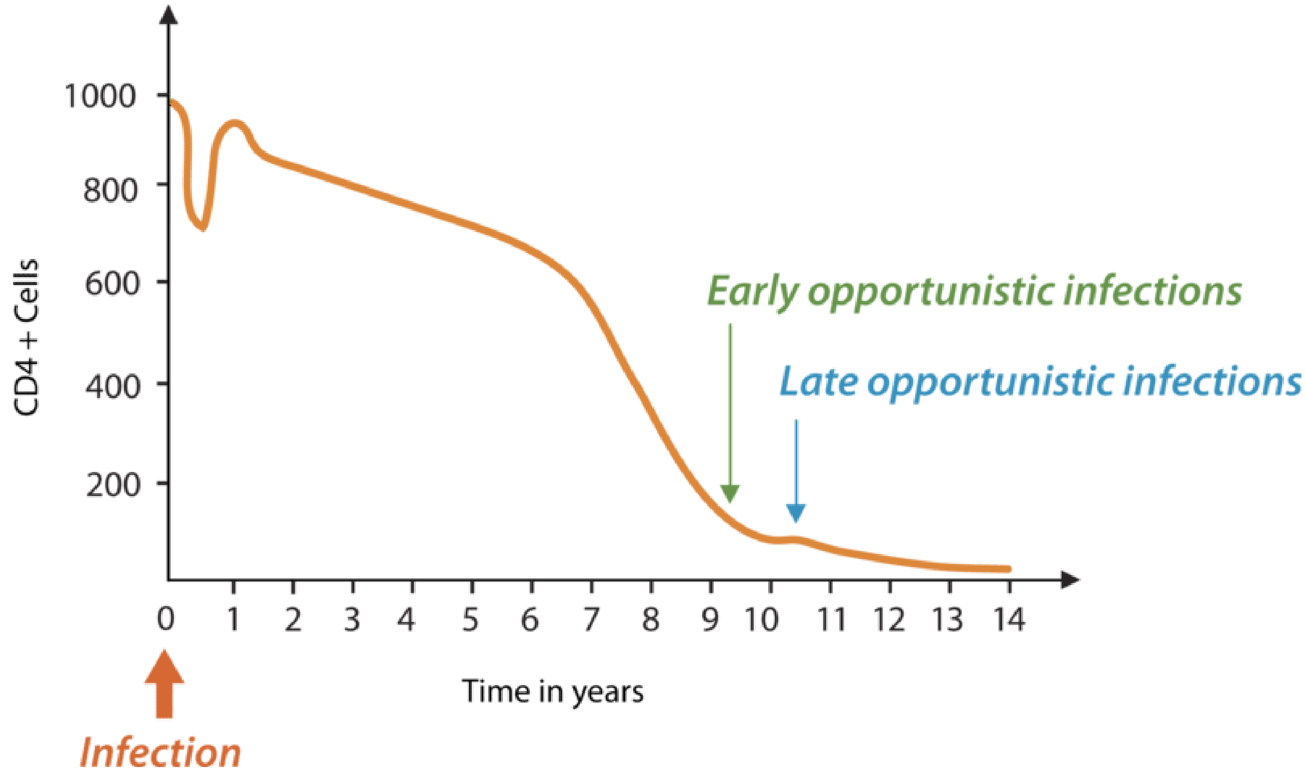
[Figure 4]

This diagram shows how HIV infects and destroys T cells.

HIV is able to evade the immune system and keep destroying . This occurs in two ways:

- The virus frequently mutates and changes its surface **antigen**. This prevents antigen-specific lymphocyte from developing that could destroy cell infected with the virus.
- The virus uses the plasma membranes of host cells to hide its own antigens. This prevents the host's immune system from detecting the antigens and destroying infected cells.

As time passes, the number of HIV copies keeps increasing, while the number of helper T cells keeps decreasing. The graph in **Figure** below shows how the number of T cells typically declines over a period of many years following the initial HIV infection. As the number of T cells decreases, so does the ability of the immune system to defend the body. As a result, an HIV-infected person develops frequent infections. Medicines can slow down the virus but not get rid of it, so there is no cure at present for HIV infections or AIDS. There also is no vaccine to immunize people against HIV infection, but scientists are working to develop one.

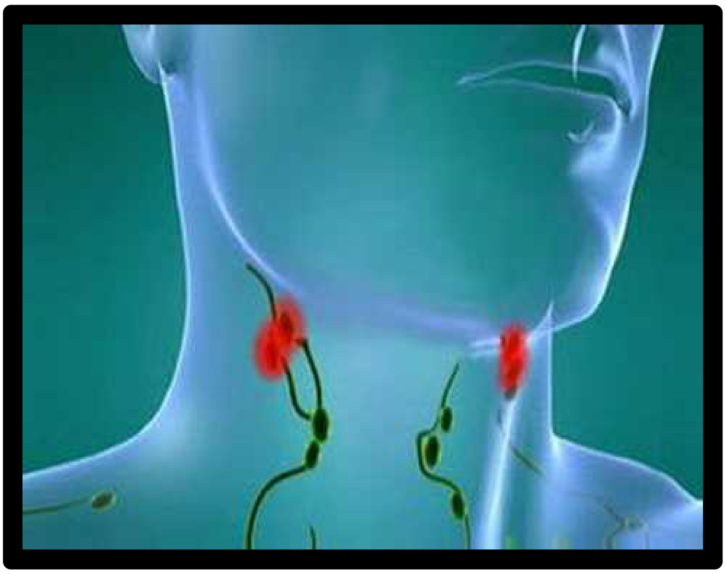


[Figure 5]

It typically takes several years after infection with HIV for the drop in T cells to cripple the immune system. What do you think explains the brief spike in T cells that occurs early in the HIV infection shown here?

AIDS

AIDS is not a single disease but a set of diseases. It results from years of damage to the immune system by HIV. It occurs when helper T cells fall to a very low level and **opportunistic disease** occur (see **Figure** above). **Opportunistic diseases** are infections and tumor that are rare except in people with immunodeficiency. The diseases take advantage of the opportunity presented by people whose immune systems can't fight back. Opportunistic diseases are usually the direct cause of death of people with AIDS.



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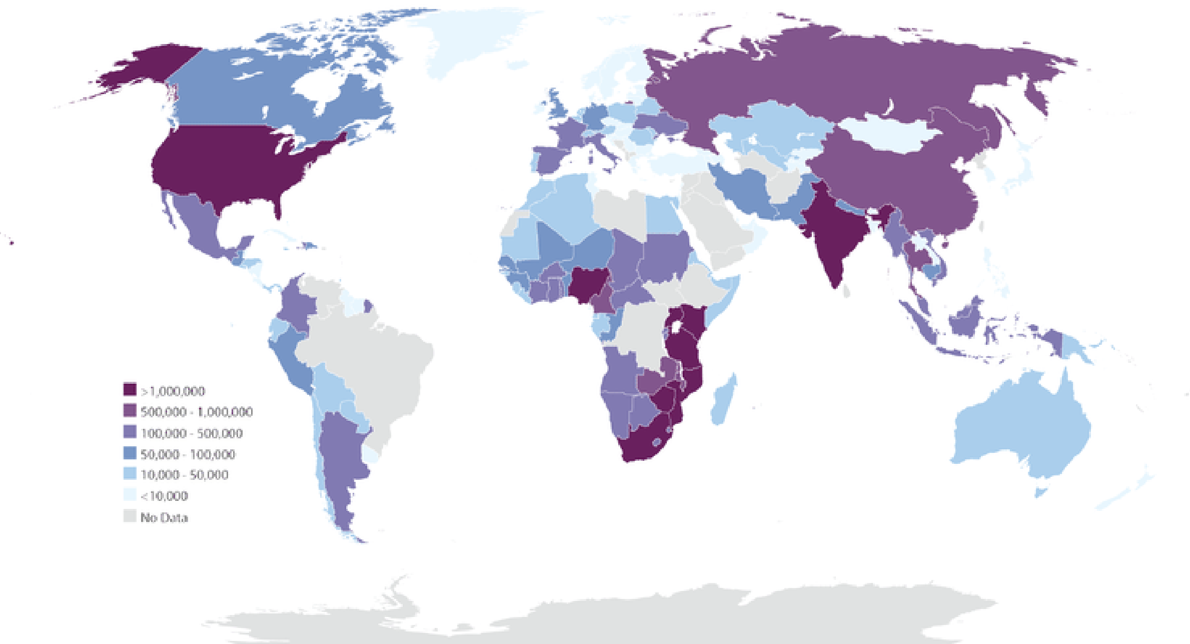
AIDS and HIV were first identified in 1981. Scientists think that the virus originally infected monkeys but then jumped to human population, probably sometime during the early to mid-1900s. This most likely occurred in West Africa, but the virus soon spread around the world (see **Figure** below). Since then, HIV has killed more than 25 million people worldwide. The hardest hit countries are in Africa, where medicines to slow down the virus are least available. The worldwide economic toll of HIV and AIDS has also been enormous.



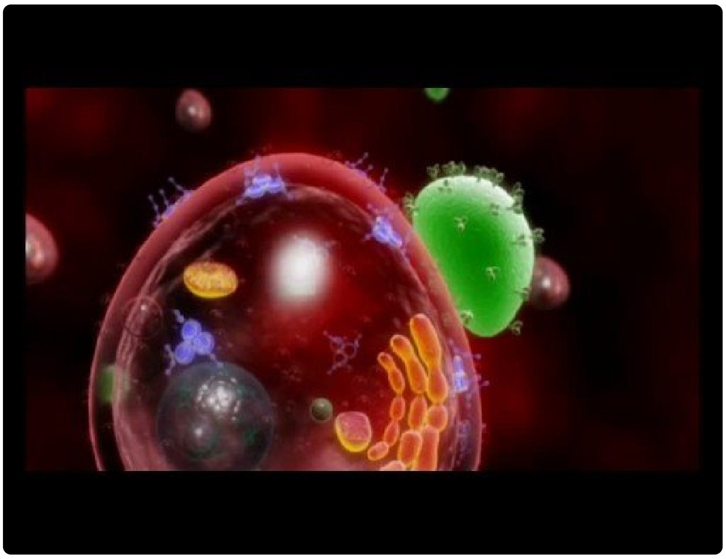
[Figure 6]

This map shows the number of people in different countries with HIV infections and AIDS in 2008. The rate of spread of the infection is higher Africa than in the U.S., yet the U.S. has a relatively large number of people with HIV infections and AIDS. Why might there be more survivors with HIV infections and AIDS in the U.S. than in Africa?

HIV Research: Beyond the Vaccine

Over the past 15 years, the number of people who die of AIDS each year in the United States has dropped by 70 percent. But AIDS remains a serious public health crisis among low-income African-Americans, particularly women. And in sub-Saharan Africa, the virus killed more than 1.6 million people in 2007 alone. Innovative research approaches could lead to new treatments and possibly a cure for AIDS. HIV/AIDS has been described as a disease of poverty. Individuals with poor access to health care are less likely to see a doctor early on in their HIV infection, and thus they may be more likely to transmit the infection. HIV is now the leading cause of death for African American women between 24 and 35 years old.

For patients who have access to drug, infection with the virus has ceased to be a death sentence. In 1995, combinations of drugs called **highly active anti-retroviral therapy (HAART)** were developed. For some patients, drugs can reduce the amount of virus to undetectable levels. But some amount of virus always hides in the body's immune cells and attacks again if the patient stops taking his or her medication. Researchers are working on developing a drug to wipe out this hidden virus, which could mean the end of AIDS.



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Further Reading

Immunodeficiency

Summary

- HIV is a virus that attacks cells of the immune system and eventually causes AIDS.
- AIDS is the chief cause of immunodeficiency in the world today.

Review

1. What is the relationship between HIV and AIDS?

2. Identify two ways that HIV can be transmitted.
3. What cells are affected by HIV?
4. What happens to the number of HIV copies and the helper T cells over time in an infected individual?
5. Draw a graph to show the progression of an untreated HIV infection. Include a line that shows how the number of HIV copies changes over time. Include another line that shows how the number of helper T cells changes over time.
6. What are opportunistic diseases?

Report Content Errors

13.55 Carcinogens and Cancer

FlexBooks 2.0 > Biology For High School Diploma > Carcinogens and Cancer

Last Modified: Jul 04, 2019

[Figure 1]

What's the worst thing you can do to hurt your health?

Besides pathogen, many other dangers in the environment may negatively affect human health. For example, air pollution can cause lung **cancer**. It can also make asthma and other diseases worse. bioterrorism is another potential threat in the environment. It may poison large numbers of people or cause epidemic of deadly diseases. But the worst thing you can do to yourself is smoke cigarettes.

Carcinogens and Cancer

A **carcinogen** is anything that can cause cancer. **Cancer** is a disease in which cell divide out of control. Most carcinogens cause cancer by producing mutation in DNA.

Types of Carcinogens

There are several different types of carcinogens. They include pathogens, radiation, and chemicals. Some carcinogens occur naturally. Others are produced by human actions.

- virus cause about 15 percent of all human cancers. For example, the virus called hepatitis B causes liver cancer.
- UV radiation is the leading cause of skin cancer. The radioactive gas known as **radon** causes lung cancer.
- Tobacco smoke contains dozens of carcinogens, including nicotine and formaldehyde. Exposure to tobacco smoke is the leading cause of lung cancer.

- Some chemicals that were previously added to foods, such as certain dyes, are now known to cause cancer. Cooking foods at very high temperatures also causes carcinogens to form (see **Figure** below).

[Figure 2]

Barbecued foods are cooked at very high temperatures. This may cause carcinogens to form.

How Cancer Occurs

Mutations that lead to cancer usually occur in gene that control the cell cycle. These include **tumor-suppressor gene** and **proto-oncogene**.

- **Tumor-suppressor genes** normally prevent cells with damaged DNA from dividing. Mutations in these genes prevent them from functioning normally. As a result, cells with damaged DNA are allowed to divide.
- **Proto-oncogenes** normally help control cell division. Mutations in these genes turn them into **oncogene**. **Oncogenes** promote the division of cells with damaged DNA.

Cells that divide uncontrollably may form a **tumor**, or abnormal mass of cells. Tumors may be benign or malignant. **benign tumor** remain localized and generally do not harm health. **malignant tumor** are cancerous. There are no limits to their growth, so they can invade and damage neighboring tissue. Cells from malignant tumors may also break away from the tumor and enter the bloodstream. They are carried to other parts of the body, where new tumors may form. The most common and the most deadly cancers for U.S. adults are listed in **Table** below.

Gender	Most Common Types of Cancer after Skin Cancer (% of all cancers)	Most Common Causes of Cancer Deaths (% of all cancer deaths)
Males	prostate cancer (33%), lung cancer (13%)	lung cancer (31%), prostate cancer (10%)
Females	breast cancer (32%), lung cancer (12%)	lung cancer (27%), breast cancer (15%)

More cancer deaths in adult males and females are due to lung cancer than any other type of cancer. Lung cancer is most often caused by exposure to tobacco smoke. What might explain why lung cancer causes the most cancer deaths when it isn't the most common type of cancer?

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Cancer Treatment and Prevention

Most cancers can be treated, and some can be cured. The general goal of treatment is to remove the tumor without damaging other cells. A cancer patient is typically treated in more than one way. Possible treatments include surgery, drug (**chemotherapy**), and radiation. Early diagnosis and treatment of cancer lead to the best chance for survival. That's why it's important to know the following warning signs of cancer:

- change in bowel or bladder habits
- sore that does not heal
- unusual bleeding or discharge
- lump in the breast or elsewhere
- chronic indigestion or difficulty swallowing
- obvious changes in a wart or mole
- persistent coughing or hoarseness

Having one or more warning signs does not mean you have cancer, but you should see a doctor to be sure. Getting routine tests for particular cancers can also help detect cancers early, when chances of a cure are greatest. For example, getting the skin checked regularly by a dermatologist is important for early detection of skin cancer (see **Figure** below).

[Figure 3]

Regular checkups with a dermatologist can detect skin cancers early. Why is early detection important?

You can take steps to reduce your own risk of cancer. For example, you can avoid exposure to carcinogens such as tobacco smoke and UV light. You can also follow a healthy lifestyle. Being active, eating a low-fat diet, and maintaining a normal weight can help reduce your risk of cancer.

Summary

- A carcinogen is anything that causes cancer.
- Most carcinogens produce mutations in genes that control the cell cycle.

Review

1. What is a carcinogen? What is cancer?
2. How do most carcinogens cause cancer? Give two examples of carcinogens.
3. Describe tumor-suppressor genes and describe how they cause cancer.
4. Identify three ways cancer can be treated.
5. List four warning signs of cancer.
6. What might explain why lung cancer causes the most cancer deaths when it isn't the most common type of cancer?

Report Content Errors

13.56 Air Pollution and Illness

FlexBooks 2.0 > Biology For High School Diploma > Air Pollution and Illness

Last Modified: Jul 04, 2019

[Figure 1]

Is some air actually bad for you?

This question shouldn't even need an answer. Yes, some air can be harmful.

Air Pollution and Illness

Almost 5 million people die each year because of **air pollution**. In fact, polluted air causes more deaths than traffic accidents. Air pollution harms the respiratory and circulatory systems. Both outdoor and indoor air can be polluted.

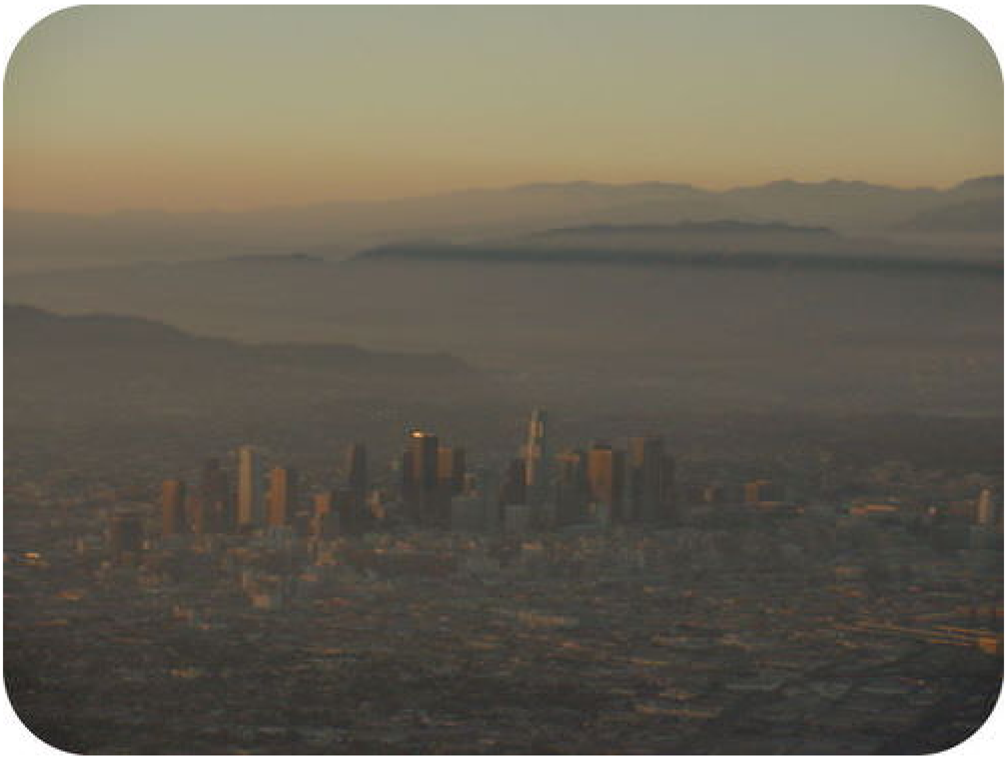
Outdoor Air Pollution

The **Air Quality Index (AQI)** is an assessment of the pollutants in the outdoor air based on their human health effects. The health risks associated with different values of AQI are shown in **Figure** below. When AQI is high, you should limit the time you spend outdoors. Avoiding exposure to air pollution can help limit its impact on your health. People with certain health problems, including asthma, are very sensitive to the effects of air pollution. They need to be especially careful to avoid it.

[Figure 2]

Air quality is especially important for sensitive people. They include people with asthma, other respiratory illnesses, and cardiovascular diseases.

AQI generally refers to the levels of ground-level **ozone** and **particulates**. **Ozone** is a gas that forms close to the ground when air pollutants are heated by sunlight. It is one of the main components of **smog** (see **Figure** below). Smog also contains particulates. **Particulates** are tiny particles of solids or liquids suspended in the air. They are produced mainly by the burning of fossil fuel. The particles settle in airways and the lung, where they cause damage.



[Figure 3]

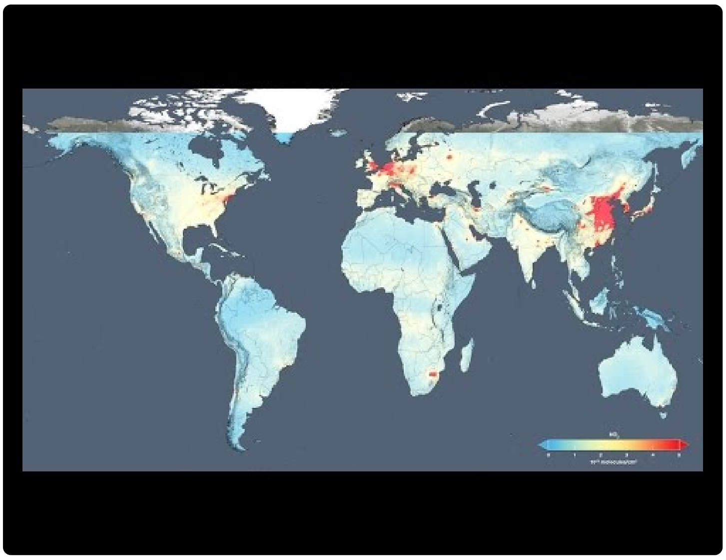
Smog clouds the city of Los Angeles, California. Visible air pollution in the form of smog is a sign that the air is unhealthy.

Indoor Air Pollution

Indoor air may be even more polluted than outdoor air. It may contain harmful substances such as mold, bacterium, and radon. It may also contain **carbon monoxide**. **Carbon monoxide** is a gas produced by furnaces and other devices that burn fuel. If it is inhaled, it replaces oxygen in the blood and quickly leads to death. Carbon monoxide is colorless and odorless, but it can be detected with a carbon monoxide detector like the one in **Figure** below.

[Figure 4]

A carbon monoxide detector warns you if the level of the gas is too high.



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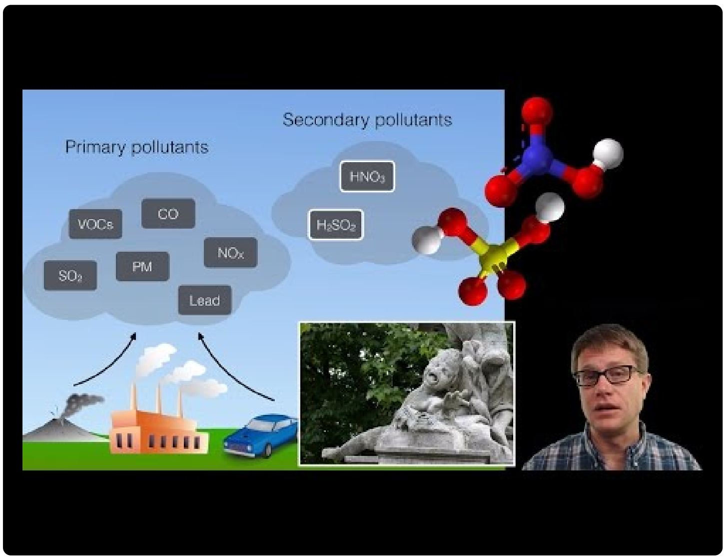

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Summary

- Both outdoor and indoor air may contain pollutants that can cause human illness and death.

Review

1. How can you use the Air Quality Index to protect your health?
2. Explain why ground-level ozone is usually a worse problem in the summer than in the winter in North America.
3. Compare and contrast pollutants in outdoor and indoor air, including their effects on human health.

Report Content Errors

13.57 Bioterrorism

FlexBooks 2.0 > Biology For High School Diploma > Bioterrorism

Last Modified: Jul 04, 2019

[Figure 1]

"The world has definitely changed." This statement is common at times. What might it refer to?

Bioterrorism is a threat against civilized people worldwide. To be prepared, all levels of government have developed and conducted terrorism drills. These include protecting responders from harmful biological substances.

Bioterrorism

Bioterrorism is the intentional release or spread of agents of disease. The agents may be virus, bacterium, or toxins produced by bacteria. The agents may spread through the air, food, or water; or they may come into direct contact with the skin. Two of the best known bioterrorism incidents in the U.S. occurred early in this century:

1. In 2001, letters containing **anthrax** spores were mailed to several news offices and two U.S. Senate offices. A total of 22 people were infected, and 5 of them died of anthrax.
2. In 2003, a deadly toxin called **ricin** was detected in a letter addressed to the White House. The letter was intercepted at a mail-handling facility off White House grounds. Fortunately, the ricin toxin did not cause any illnesses or deaths.

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Summary

- Bioterrorism is the intentional release or spread of agents of disease.

Review

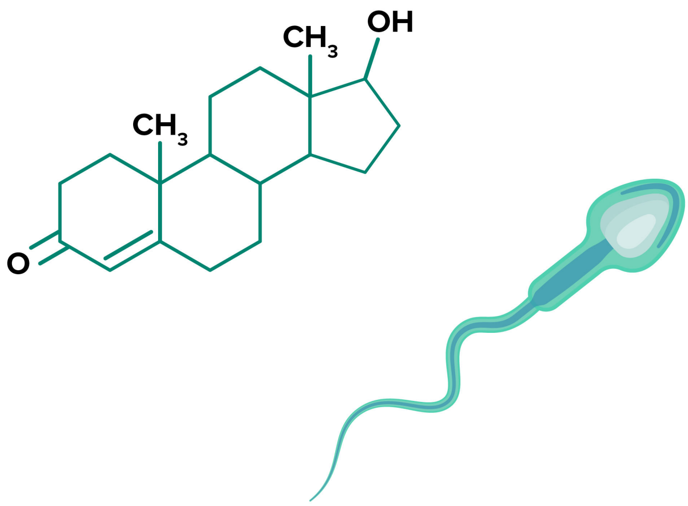
1. Define bioterrorism.
2. Research additional recent acts of bioterrorism.

Report Content Errors

13.58 Male Reproductive Organs

FlexBooks 2.0 > Biology For High School Diploma > Male Reproductive Organs

Last Modified: Aug 01, 2018



[Figure 1]

Would you believe the male reproductive structures are over 100 feet long?

The male **reproductive system** has two goals: to produce and deliver **sperm** and to secrete **testosterone**. Might seem simple. But there are a number of complicated processes and structures - including over 100 feet of tubules - that go into these simple goals.

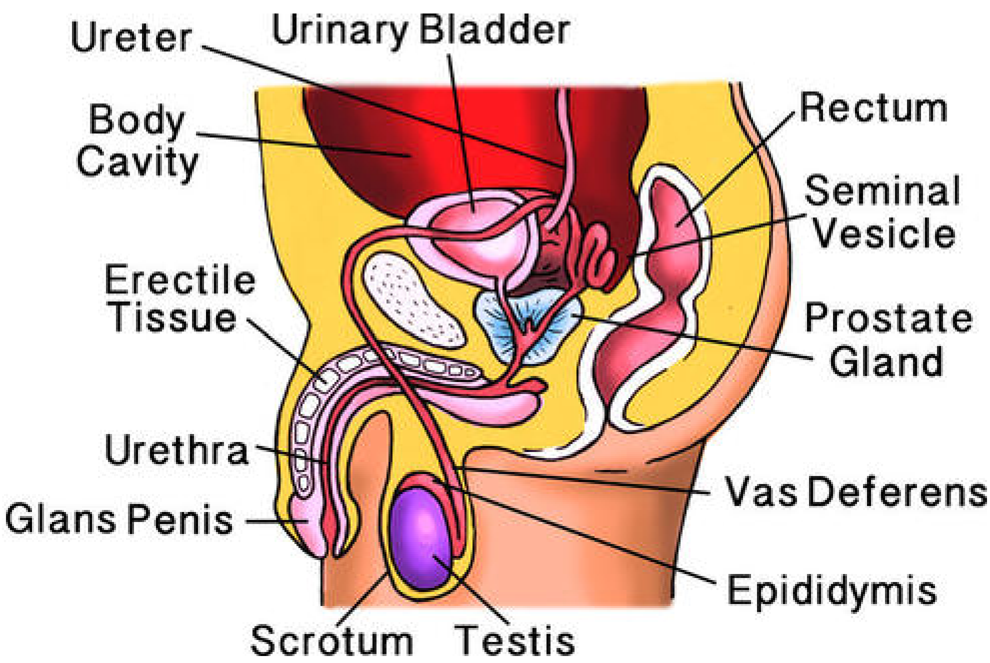
The male reproductive system has two main functions: (1) to produce sperm, the male gamete, and (2) to release the male sex hormone, testosterone, into the body.

Male Reproductive Structures

The reproductive system in both males and females consists of structures that produce reproductive cell, or gametes, and secrete sex hormones. A gamete is a haploid cell that combines with another haploid gamete during fertilization. Recall that haploid cells have one complete set of chromosome; in humans that would be 22 autosome and one sex chromosome.

Sex hormones are chemical messengers that control sexual development and reproduction. The male reproductive system consists of structures that produce male gametes called sperm and secrete the male sex hormone testosterone.

The main structures of the male **reproductive system** are shown in **Figure** below. Locate them in the figure as you read about them below.



[Figure 2]

Male Reproductive Structures. Organs of the male reproductive system include the penis, testes, and epididymis. Several ducts and glands are also part of the system. Do you know the reproductive functions of any of these structures?

Penis

The **penis** is an external genital organ with a long shaft and enlarged tip called the glans penis. The shaft of the penis contains erectile tissue that can fill with blood and cause an erection. When this occurs, the penis gets bigger and stiffer. The **urethra** passes through the penis. **Sperm** pass out of the body through the urethra. (During urination, the urethra carries urine from the bladder.)

Testes

The two **testis** (singular, testis) are located below the penis. They hang between the thighs in a sac of skin called the **scrotum**. Each testis contains more than 30 meters (over 90 feet) of tiny, tightly packed tubules called **seminiferous tubule**. These tubules are the functional units of the testes. They produce sperm and secrete **testosterone**.

Epididymis

The seminiferous tubules within each testis join to form the **epididymis**. The **epididymis** (plural, epididymis) is a coiled tube about 6 meters (20 feet) long lying atop the testis inside the scrotum. The functions of the epididymis are to mature and store sperm until they leave the body.

Ducts and Glands

In addition to these organs, the male reproductive system consists of a series of ducts and glands. Ducts include the **vas deferens** and ejaculatory ducts. They transport sperm from the epididymis to the urethra in the penis. Glands include the **seminal vesicle** and **prostate gland**. They secrete substances that become part of **semen**.

Semen

Semen is the fluid that carries sperm through the urethra and out of the body. In addition to sperm, it contains secretions from the glands. The secretions control pH and provide sperm with nutrient for energy.

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Summary

- The male reproductive system consists of structures that produce sperm and secrete testosterone.
- Male reproductive structures include the penis, testes, and epididymis.

Review

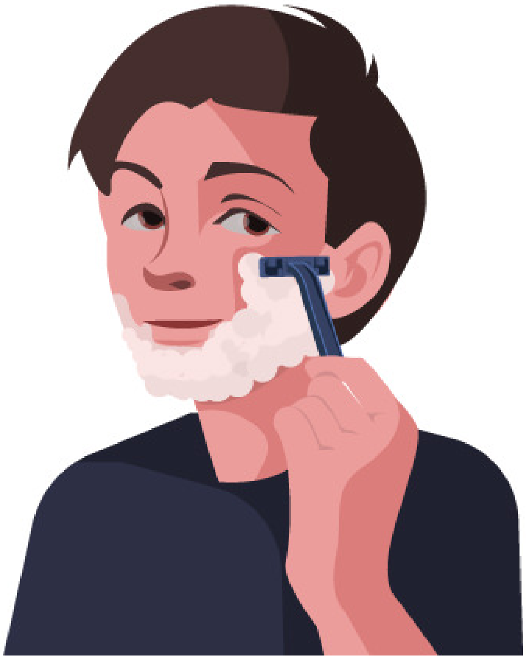
1. What is a gamete?
2. What are sex hormones?
3. What are the two major roles of the male reproductive system?
4. Name two male reproductive organs and identify their functions.

Report Content Errors

13.59 Male Reproductive Development

FlexBooks 2.0 > Biology For High School Diploma > Male Reproductive Development

Last Modified: Aug 01, 2018



[Figure 1]

What changes happen during puberty?

A lot changes during this time. A boy has to start shaving, his voice deepens, he gets taller, as well as a few other changes.

Sexual Development in Males

The only obvious difference between boys and girls at birth is their reproductive organ. However, even the reproductive organs start out the same in both sexes.

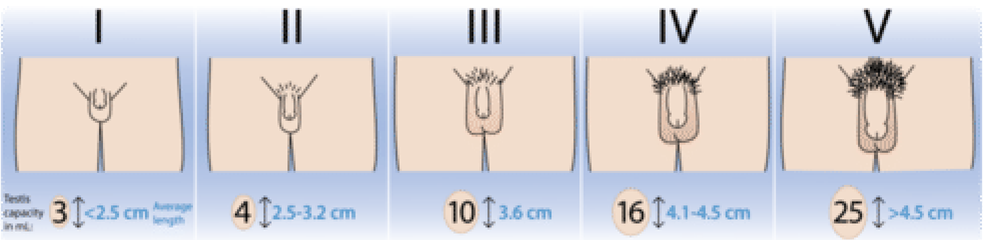
Development Before Birth

In the first several weeks after fertilization, males and females are essentially the same except for their chromosome. Females have two **X chromosomes** (XX), and males have an X and a **Y chromosome** (XY). Then, during the second month after fertilization, gene on the Y chromosome of males cause the secretion of **testosterone**. **Testosterone** stimulates the reproductive organs to develop into male organs. (Without testosterone, the reproductive organs always develop into female organs.) Although boys have male reproductive organs at birth, the organs are immature and not yet able to produce sperm or secrete testosterone.

Puberty and Its Changes

The reproductive organs grow very slowly during childhood and do not mature until **puberty**. **Puberty** is the period during which humans become sexually mature. In the U.S., boys generally begin puberty at about age 12 and complete it at about age 18.

What causes puberty to begin? The hypothalamus in the brain "tells" the pituitary gland to secrete hormone that target the testis. The main pituitary hormone involved is **luteinizing hormone (LH)**. It stimulates the testes to secrete testosterone. Testosterone, in turn, promotes protein synthesis and growth. It brings about most of the physical changes of puberty, some of which are shown in **Figure** below. In addition to the changes shown below, during puberty male facial hair begins to grow, the shoulders broaden, and the male voice deepens.



[Figure 2]

Some of the changes that occur in boys during puberty are shown in this figure. Pubic hair grows, and the penis and testes both become larger.

Adolescent Growth Spurt

Another obvious change that occurs during puberty is rapid growth. This is called the **adolescent growth spurt**. In boys, it is controlled by testosterone. The rate of growth usually starts to increase relatively early in puberty. At its peak rate, growth in height is about 10 centimeters (almost 4 inches) per year in the average male. Growth generally remains rapid for several years. Growth and development of muscles occur toward the end of the growth spurt in height. Muscles may continue to develop and gain strength after growth in height is finished.

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Summary

- The male reproductive system forms before birth but does not become capable of reproduction until it matures during puberty.
- Puberty lasts from about ages 12 to 18 years and is controlled by hormones.

Review

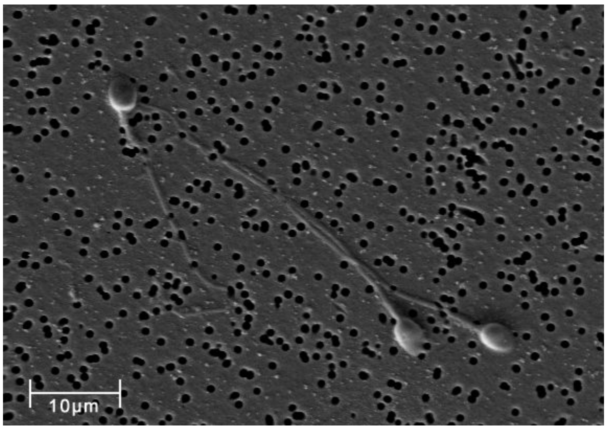
1. What happens to a developing baby that lacks testosterone?
2. List three physical changes that occur in males during puberty.
3. Explain how and why boys change so much during puberty.

Report Content Errors

13.60 Sperm

FlexBooks 2.0 > Biology For High School Diploma > Sperm

Last Modified: May 16, 2021



[Figure 1]

How many sperm does it take to fertilize an egg?

85 million sperm per day are produced...per testicle. That's 170,000,000 every day. This means that a single male may produce more than a quadrillion (1,000,000,000,000) sperm cell in his lifetime! But it only takes one to fertilize an egg.

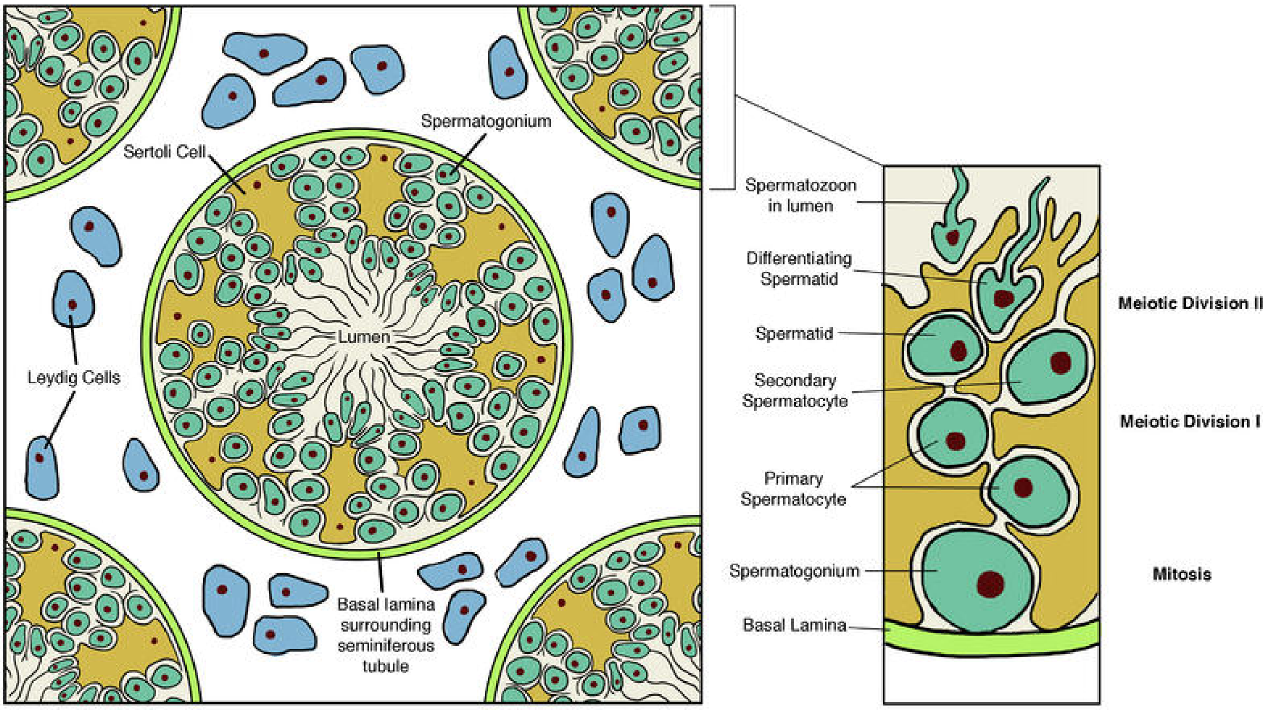
Production and Delivery of Sperm

A sexually mature male produces an astounding number of **sperm**—typically, hundreds of millions each day! Sperm production usually continues uninterrupted until death, although the number and quality of sperm decline during later adulthood.

Spermatogenesis

The process of producing mature sperm is called **spermatogenesis**. Sperm are produced in the **seminiferous tubule** of the testis and become mature in the **epididymis**. The entire process takes about 9 to 10 weeks.

If you look inside the seminiferous tubule shown in **Figure** below, you can see cells in various stages of spermatogenesis. The tubule is lined with **spermatogonium**, which are diploid, sperm-producing cells. Surrounding the spermatogonia are other cells. Some of these other cells secrete substances to nourish sperm, and some secrete testosterone, which is needed for sperm production.



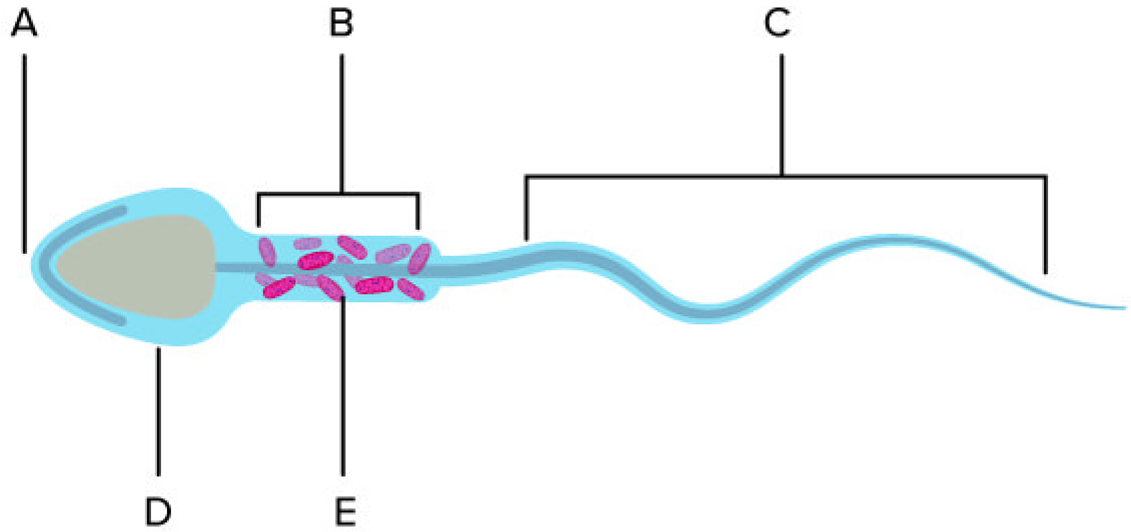
[Figure 2]

Seminiferous Tubule. Cross section of a testis and seminiferous tubules.

Spermatogonia lining the seminiferous tubule undergo mitosis to form **primary spermatocyte**, which are also diploid. The primary spermatocytes undergo the first meiotic division to form **secondary spermatocyte**, which are haploid. Spermatocytes make up the next layer of cells inside the seminiferous tubule. Finally, the secondary spermatocytes complete meiosis to form **spermatid**. Spermatids make up a third layer of cells in the tubule.

Sperm Maturation

After spermatids form, they move into the epididymis to mature into sperm, like the one shown in **Figure** below. The spermatids grow a tail and lose excess cytoplasm from the head. When a sperm is mature, the tail can rotate like a propeller, so the sperm can propel itself forward. mitochondrion in the connecting piece produce the energy (ATP) needed for movement. The head of the mature sperm consists mainly of the nucleus, which carries copies of the father's chromosome. The part of the head called the **acrosome** produces enzyme that help the sperm head penetrate an egg.

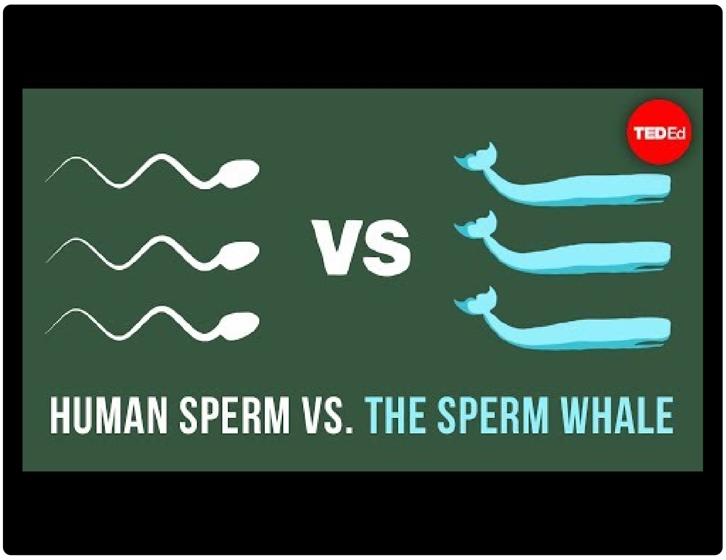


[Figure 3]

Mature Sperm Cell. A mature sperm cell has several structures that help it reach and penetrate an egg. These structures include the tail, mitochondria, and acrosome. How does each structure contribute to the sperm's function? (a) acrosome, (b) connecting piece, (c) tail, (d) head, (e) mitochondria.

Ejaculation

Sperm are released from the body during **ejaculation**. Ejaculation occurs when muscle contractions propel sperm from the epididymis. The sperm are forced through the ducts and out of the body through the urethra. As sperm travel through the ducts, they mix with fluids from the glands to form semen. Hundreds of millions of sperm are released with each ejaculation.



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Summary

- Sperm are produced in the testes in the process of spermatogenesis.
- Sperm mature in the epididymis before being ejaculated from the body through the penis.

Review

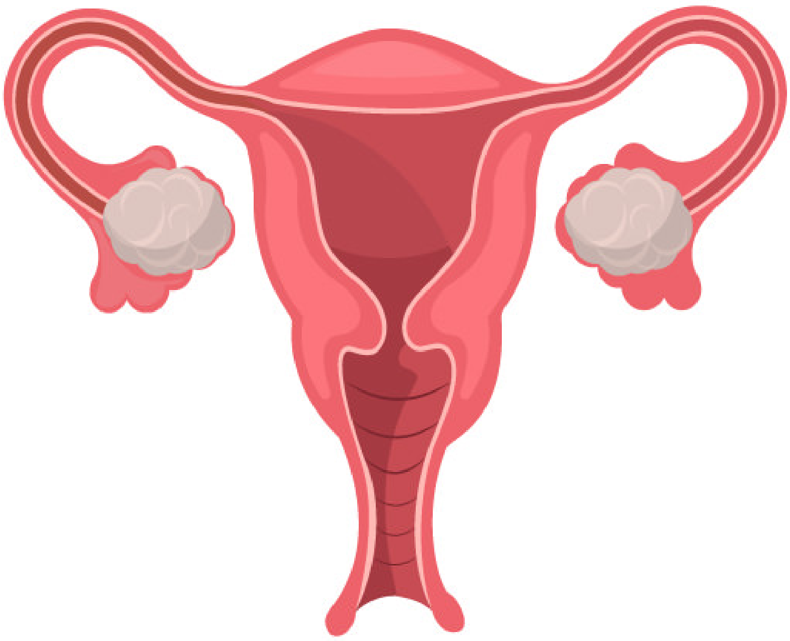
1. Outline the process of spermatogenesis. Name the cells involved in the process?
2. Where do sperm mature and how do they leave the body?
3. If a man did not have functioning epididymis, predict how his sperm would be affected. How would this influence his ability to reproduce?
4. How does each mature sperm structure contribute to the sperm's function?

Report Content Errors

13.61 Female Reproductive Organs

FlexBooks 2.0 > Biology For High School Diploma > Female Reproductive Organs

Last Modified: Aug 01, 2018



[Figure 1]

Think producing millions of sperm each day is complicated?

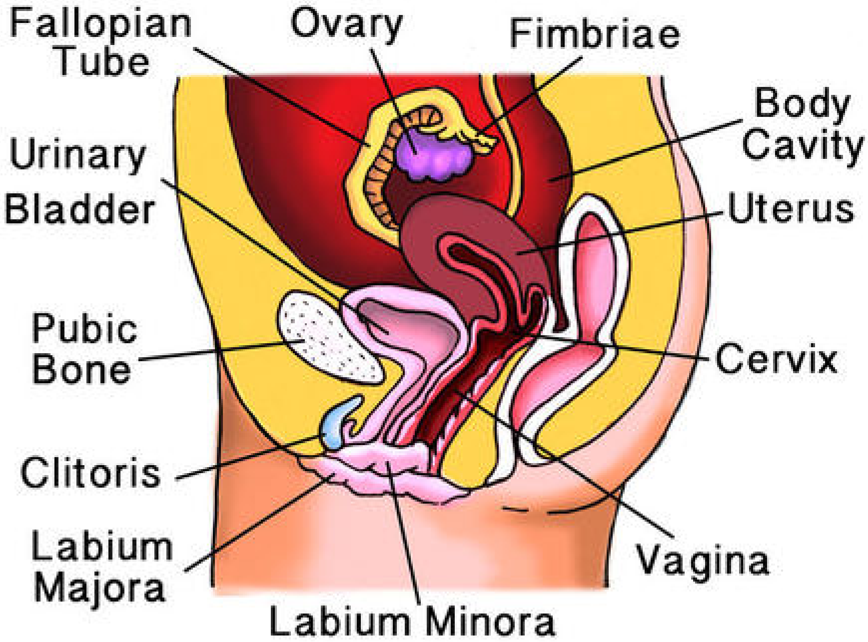
If producing millions of sperm each day, as in the male reproductive system, is complicated, that is nothing compared to what must occur in the female reproductive system. This system is controlled by an intricate dance of hormone, cycles, and events.

Female Reproductive Structures

The female reproductive system consists of structures that produce female gamete called egg and secrete the female sex hormone **estrogen**. The female reproductive system has several other functions as well:

1. It receives sperm during sexual intercourse.
2. It supports the development of a fetus.
3. It delivers a baby during birth.
4. It breast feeds a baby after birth.

The main structures of the female reproductive system are shown in **Figure** below. Most of the structures are inside the pelvic region of the body. Locate the structures in the figure as you read about them below.



[Figure 2]

Female Reproductive Structures. Organs of the female reproductive system include the vagina, uterus, ovaries, and fallopian tubes.

External Structures

The external female reproductive structures are referred to collectively as the **vulva**. They include the **labium** (singular, **labium**), which are the "lips" of the vulva. The labia protect the **vagina** and urethra, both of which have openings in the vulva.

Vagina

The **vagina** is a tube-like structure about 9 centimeters (3.5 inches) long. It begins at the vulva and extends upward to the **uterus**. It has muscular walls lined with mucous membranes. The vagina has two major reproductive functions. It receives sperm during sexual intercourse, and it provides a passageway for a baby to leave the mother's body during birth.

Uterus

The **uterus** is a muscular organ shaped like an upside-down pear. It has a thick lining of tissue called the **endometrium**. The lower, narrower end of the uterus is known as the **cervix**. The uterus is where a fetus grows and develops until birth. During pregnancy, the uterus can expand greatly to make room for the baby as it grows. During birth, contractions of the muscular walls of the uterus push the baby through the cervix and out of the body.

Ovaries

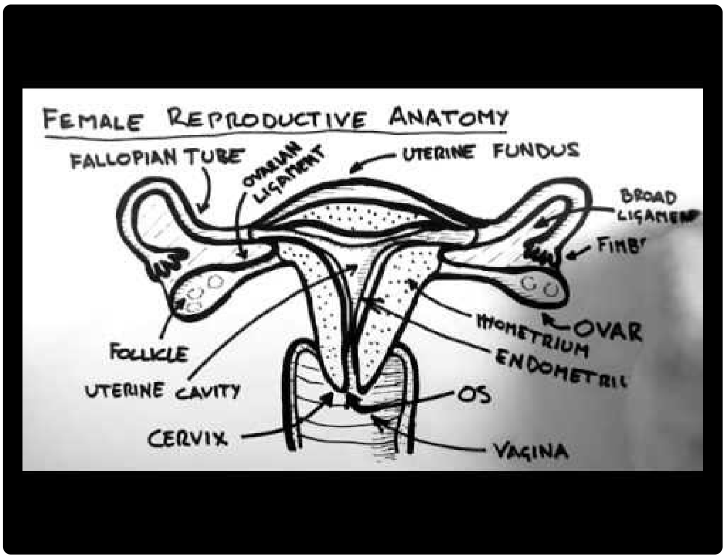
The two **ovary** are small, egg-shaped organs that lie on either side of the uterus. They produce eggs and secrete estrogen. Each egg is located inside a structure called a **follicle**. cell in the follicle protect the egg and help it mature.

Fallopian Tubes

Extending from the upper corners of the uterus are the two **fallopian tube**. Each tube reaches (but is not attached to) one of the ovaries. The ovary end of the tube has a fringelike structure that moves in waves. The motion sweeps eggs from the ovary into the tube.

Breasts

The **breasts** are not directly involved in reproduction, but they nourish a baby after birth. Each breast contains **mammary gland**, which secrete milk. The milk drains into ducts leading to the nipple. A suckling baby squeezes the milk out of the ducts and through the nipple.



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Summary

- The female reproductive system consists of structures that produce eggs and secrete female sex hormones. They also provide a site for fertilization and enable the development and birth of a fetus.
- Female reproductive structures include the vagina, uterus, ovaries, and fallopian tubes.

Review

1. List three general functions of the female reproductive system.
2. Describe the uterus, and state its role in reproduction.
3. What are the roles of the ovaries and the follicles?
4. What are the fallopian tubes?

Report Content Errors

13.62 Female Reproductive Development

FlexBooks 2.0 > Biology For High School Diploma > Female Reproductive Development

Last Modified: May 04, 2020

[Figure 1]

What changes happen during puberty?

A lot changes during this time, including changes to reproductive organ and other physical changes.

Sexual Development in Females

Female reproductive organs form before birth. However, as in males, the organs do not mature until puberty.

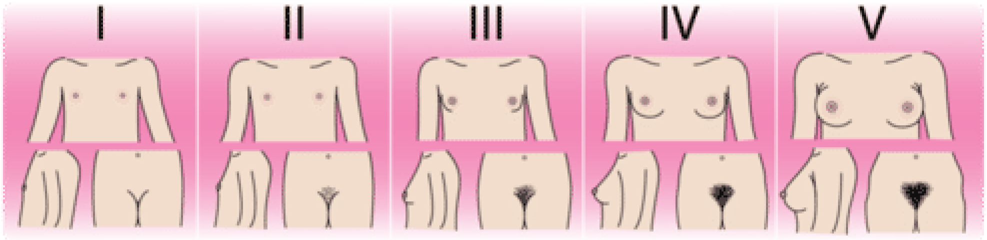
Development Before Birth

Unlike males, females are not influenced by the male sex hormone testosterone during embryonic development. This is because they lack a Y chromosome. As a result, females do not develop male reproductive organs. By the third month of fetal development, most of the internal female organs have formed. Immature egg also form in the ovary before birth. Whereas a mature male produces sperm throughout his life, a female produces all the eggs she will ever make before birth.

Changes of Puberty

Like baby boys, baby girls are born with all their reproductive organs present but immature and unable to function. Female reproductive organs also grow very little until puberty. Girls begin puberty a year or two earlier than boys, at an average age of 10 years. Girls also complete puberty sooner than boys, in about 4 years instead of 6.

Puberty in girls starts when the hypothalamus “tells” the pituitary gland to secrete hormone that target the ovaries. Two pituitary hormones are involved: **luteinizing hormone (LH)** and **follicle-stimulating hormone (FSH)**. These hormones stimulate the ovary to produce **estrogen**. Estrogen, in turn, promotes growth and other physical changes of puberty. It stimulates growth and development of the internal reproductive organs, breasts, and pubic hair (see **Figure** below).



[Figure 2]

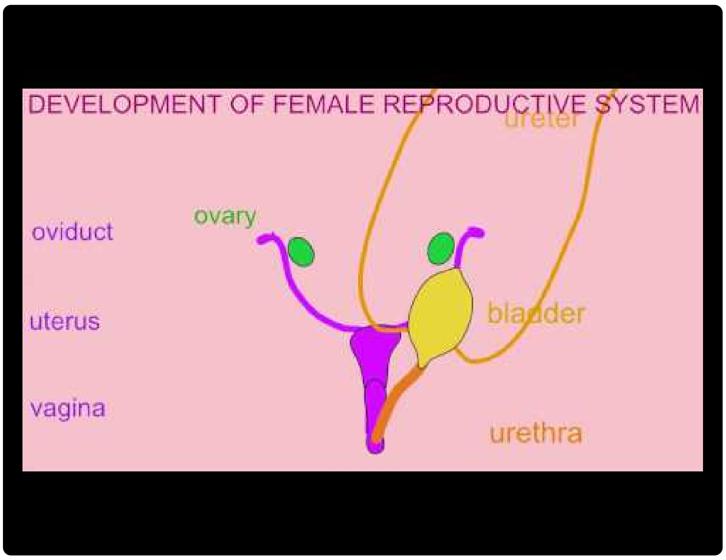
Changes in Females During Puberty. Two obvious changes of puberty in girls are growth and development of the breasts and pubic hair. The stages begin around age 10 and are completed by about age 14.

Adolescent Growth Spurt

Like boys, girls also go through an **adolescent growth spurt**. However, girls typically start their growth spurt a year or two earlier than boys (and therefore a couple of centimeters shorter, on average). Girls also have a shorter growth spurt. For example, they typically reach their adult height by about age 15. In addition, girls generally do not grow as fast as boys do during the growth spurt, even at their peak rate of growth. As a result, females are about 10 centimeters (about 4 inches) shorter, on average, than males by the time they reach their final height.

Menarche

One of the most significant changes in females during puberty is **menarche**. **Menarche** is the beginning of **menstruation**, or monthly periods as the ovaries begin the cyclic release of an egg. In U.S. girls, the average age of menarche is 12.5 years, although there is a lot of variation in this age. The variation may be due to a combination of genetic factors and environmental factors, such as diet.



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Summary

- Female reproductive organs form before birth. However, they do not mature until puberty.

Review

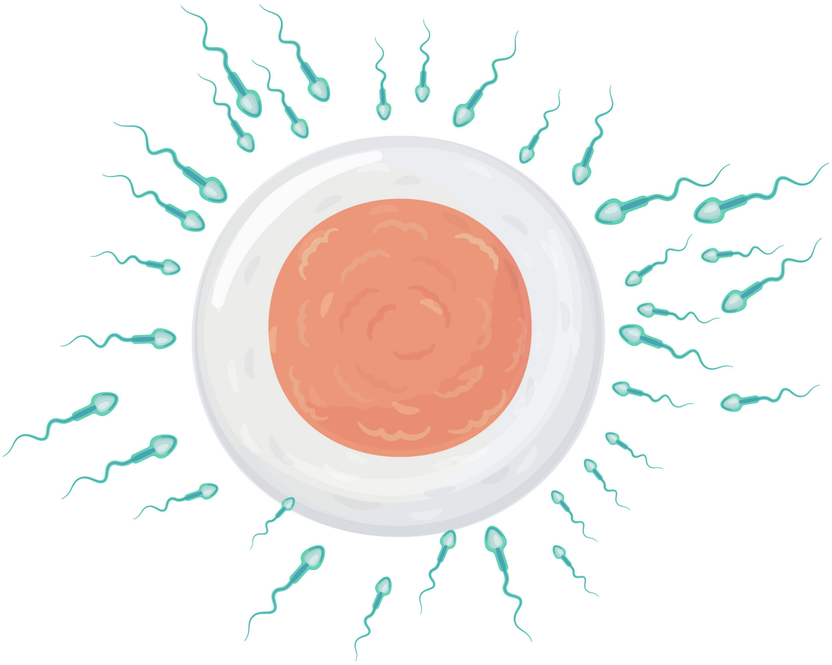
1. State two ways that puberty differs in girls and boys.
2. Define menstruation. What is the first menstrual period called?
3. Males and females are quite similar in height when they begin the adolescent growth spurt. Why are females about 10 centimeters shorter than males by adulthood?

Report Content Errors

13.63 Egg Cells

FlexBooks 2.0 > Biology For High School Diploma > Egg Cells

Last Modified: May 16, 2021



[Figure 1]

What's amazing about these cells?

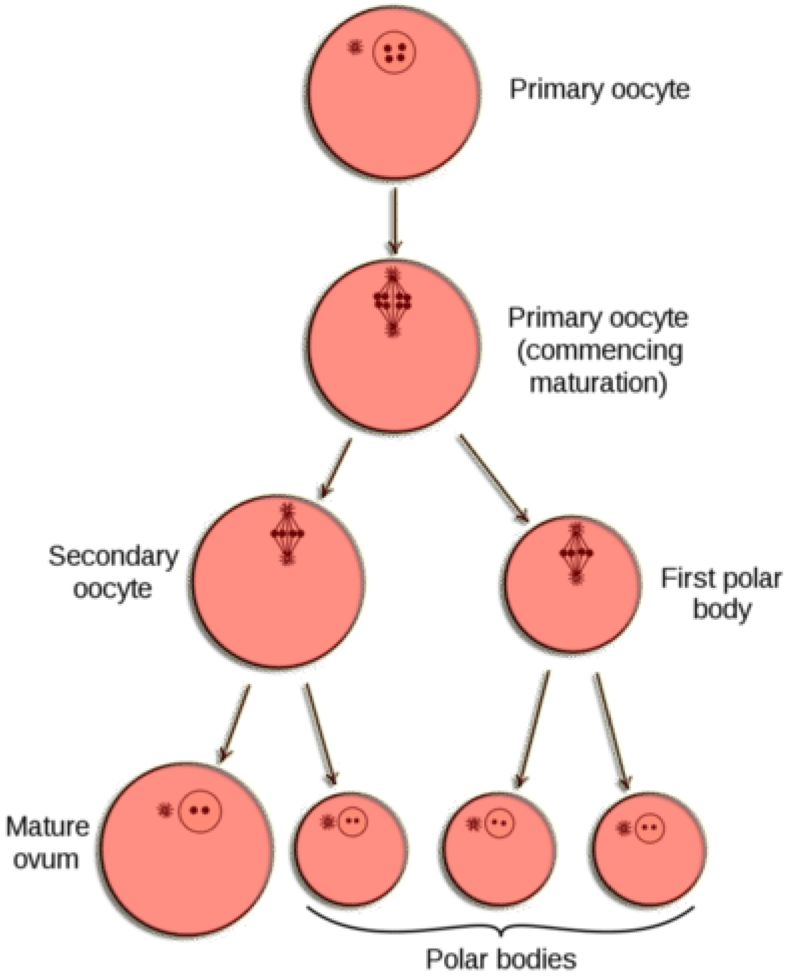
Many things. A human egg cell. Just add sperm and you have the necessary ingredients for a new baby. What's amazing about these cells is that they are all produced before the girl is even born. Before the girl is even born, plans for the next generation have begun. And that is the start of an amazing process.

Egg Production

At birth, a female's ovary contain all the eggs she will ever produce. However, the eggs do not start to mature until she enters puberty. After menarche, one egg typically matures each month until a woman reaches middle adulthood.

Oogenesis

The process of producing eggs in the ovary is called **oogenesis**. Eggs, like sperm, are haploid cells, and their production occurs in several steps that involve different types of cells, as shown in **Figure** below. You can follow the process of oogenesis in the figure as you read about it below.



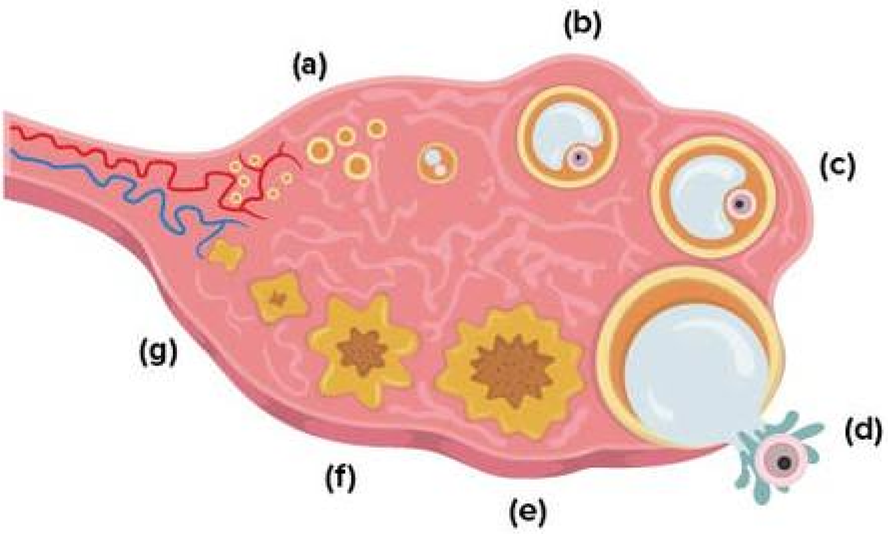
[Figure 2]

Oogenesis. Oogenesis begins before birth but is not finished until after puberty. A mature egg forms only if a secondary oocyte is fertilized by a sperm.

Oogenesis begins long before birth when an **oogonium** with the diploid number of chromosome undergoes mitosis. It produces a diploid daughter cell called a **primary oocyte**. The primary oocyte, in turn, starts to go through the first cell division of meiosis (meiosis I). However, it does not complete meiosis until much later. The primary oocyte remains in a resting state, nestled in a tiny, immature **follicle** until puberty.

Maturation of a Follicle

Beginning in puberty, each month one of the follicles and its primary oocyte starts to mature (also see **Figure** below). The primary oocyte resumes meiosis and divides to form a **secondary oocyte** and a smaller cell, called a **polar body**. Both the secondary oocyte and polar body are haploid cells. The secondary oocyte has most of the cytoplasm from the original cell and is much larger than the polar body.

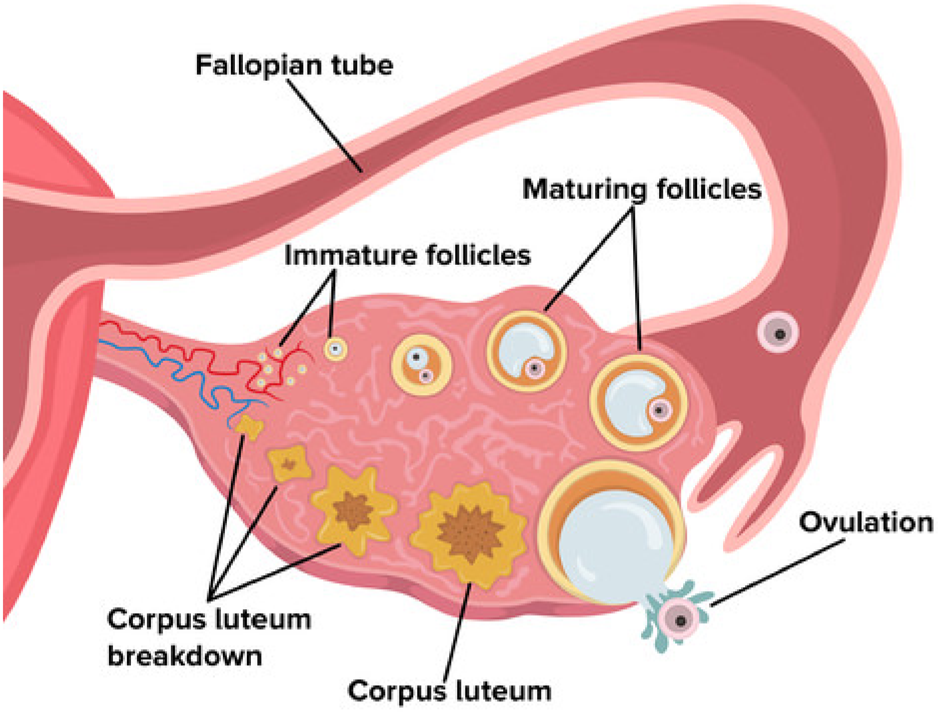


[Figure 3]

Maturation of a Follicle and Ovulation. A follicle matures and its primary oocyte (follicle) resumes meiosis to form a secondary oocyte in the secondary follicle. The follicle ruptures and the oocyte leaves the ovary during ovulation. What happens to the ruptured follicle then? (a) primary follicle, (b) secondary follicle, (c) vesicular follicle, (d) ovulation, (e) corpus luteum forms, (f) regression, (g) corpus albicans.

Ovulation and Fertilization

After 12–14 days, when the follicle is mature, it bursts open, releasing the secondary oocyte from the ovary. This event is called **ovulation** (see **Figure** above). The follicle, now called a **corpus luteum**, starts to degenerate, or break down. After the secondary oocyte leaves the ovary, it is swept into the nearby fallopian tube by the waving, fringelike end (see **Figure** below).



[Figure 4]

Egg Entering Fallopian Tube. After ovulation, the fringelike end of the fallopian tube sweeps the oocyte inside of the tube, where it begins its journey to the uterus.

If the secondary oocyte is fertilized by a sperm as it is passing through the fallopian tube, it completes meiosis and forms a mature egg and another polar body. (The polar bodies break down and disappear.) If the secondary oocyte is not fertilized, it passes into the uterus as an immature egg and soon disintegrates.

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Summary

- Immature eggs form in the ovaries before birth.
- Each month, starting in puberty, one egg matures and is released from the ovary.
- Release of an egg is called ovulation.

Review

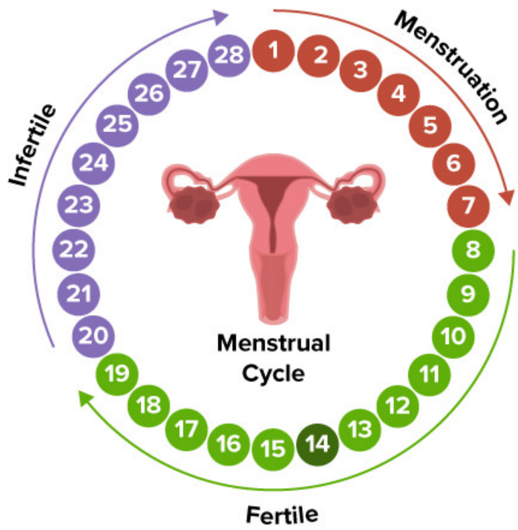
1. When does a female begin to produce her eggs?
2. What is a polar body?
3. Describe ovulation.
4. Predict how blockage of both fallopian tubes would affect a woman's ability to reproduce naturally. Explain your answer.
5. Create a flow chart showing the steps in which an oogonium develops into a mature egg.

Report Content Errors

13.64 Menstrual Cycle

FlexBooks 2.0 > Biology For High School Diploma > Menstrual Cycle

Last Modified: Feb 26, 2022



[Figure 1]

What's the most important part of the female menstrual cycle?

A menstrual cycle calendar. A lot of things to keep track of. And for a few very important reasons, it is important to know when a woman is ovulating. But what's the *most* important part of the female menstrual cycle? That depends on who you ask.

Menstrual Cycle

ovulation, the release of an egg from an ovary, is part of the **menstrual cycle**, which typically occurs each month in a sexually mature female unless she is pregnant. Another part of the cycle is the monthly period, or **menstruation**. **Menstruation** is the process in which the **endometrium** of the uterus is shed from the body. The menstrual cycle is controlled by hormone from the hypothalamus, pituitary gland, and ovaries.

Phases of the Menstrual Cycle

The menstrual cycle occurs in several phases, beginning with menstruation. During menstruation, artery that supply the endometrium of the uterus constrict. As a result, the endometrium breaks down and detaches from the uterus. It passes out of the body through the vagina over a period of several days.

After menstruation, the endometrium begins to build up again. At the same time, a **follicle** starts maturing in an ovary. Ovulation occurs around day 14 of the cycle. After it occurs, the endometrium continues to build up in preparation for a fertilized egg. What happens next depends on whether the egg is fertilized.

If the egg is fertilized, the endometrium will be maintained and help nourish the egg. The ruptured follicle, now called the **corpus luteum**, will secrete the hormone **progesterone**. This hormone keeps the endometrium from breaking down. If the egg is not fertilized, the corpus luteum will break down and disappear. Without progesterone, the endometrium will also break down and be shed. A new menstrual cycle thus begins.

Menopause

For most women, menstrual cycles continue until their mid- or late- forties. Then women go through **menopause**, a period during which their menstrual cycles slow down and eventually stop, generally by their early fifties. After menopause, women can no longer reproduce naturally because their ovaries no longer produce eggs.

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Summary

- The menstrual cycle includes events that take place in the ovary, such as ovulation.
- The menstrual cycle also includes changes in the uterus, including menstruation.
- Menopause occurs when menstruation stops occurring, usually in middle adulthood.

Review

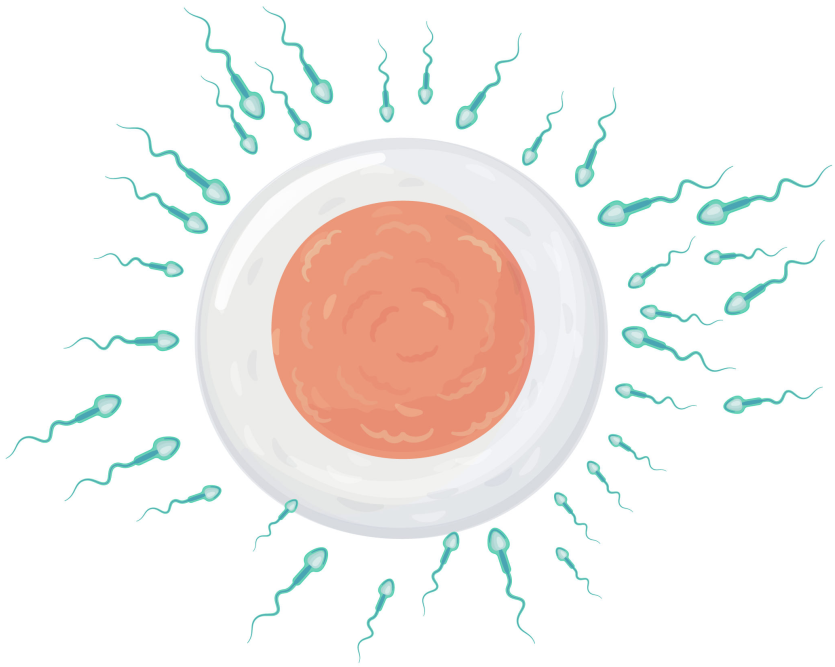
1. Define menstruation.
2. What is menopause? When does it occur?
3. What is the corpus luteum?
4. Compare and contrast what happens in the menstrual cycle when the egg is fertilized with what happens when the egg is not fertilized.
5. Make a cycle diagram to represent the main events of the menstrual cycle in both the ovaries and the uterus, including the days when they occur.

Report Content Errors

13.65 Fertilization

FlexBooks 2.0 > Biology For High School Diploma > Fertilization

Last Modified: Jul 04, 2019



[Figure 1]

How far does a sperm have to swim?

sperm swimming to an egg. If fertilization occurs, the egg will have all the "instructions" to grow into a new organism. That one cell will become two, then four, then eight, then sixteen, and on and on and on. And after about 9 months, that one cell will have become a new baby. But it all starts with the sperm swimming to the egg. A sperm cell is about two thousandths of an inch long. And although they are small, they can swim roughly 8 inches in an hour. To reach an egg, they will ultimately they have to swim around 192,000 times their own length.

Cleavage and Implantation

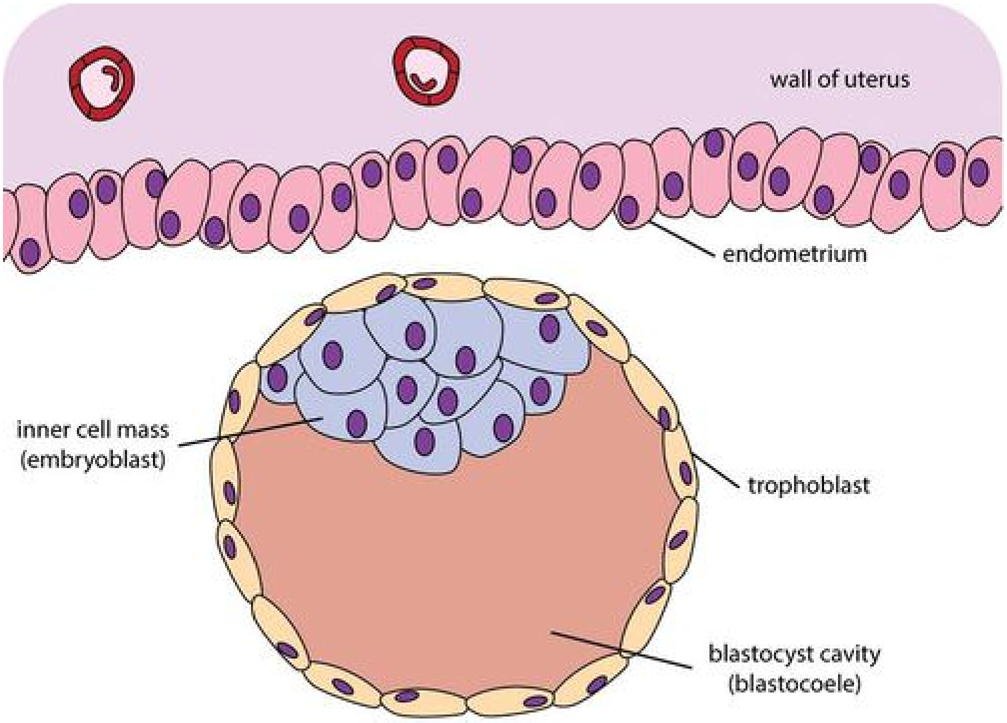
A day or two after an ovary releases an egg, the egg may unite with a sperm. Sperm are deposited in the vagina during sexual intercourse. They propel themselves through the **uterus** and enter a **fallopian tube**. This is where **fertilization** usually takes place.

When a sperm penetrates the egg, it triggers the egg to complete meiosis. The sperm also undergoes changes. Its tail falls off, and its nucleus fuses with the nucleus of the egg. The resulting cell, called a **zygote**, contains all the chromosome needed for a new human organism. Half the chromosomes come from the egg and half from the sperm.

Morula and Blastocyst Stages

The zygote spends the next few days traveling down the fallopian tube toward the uterus, where it will take up residence. As it travels, it divides by mitosis several times to form a ball of cells called a **morula**. The cell divisions are called **cleavage**. They increase the number of cells but not the overall size of the new organism. As more cell divisions occur, a fluid-filled cavity forms inside the ball of cells. At this stage, the ball of cells is called a **blastocyst**.

The cells of the blastocyst form an inner cell mass and an outer cell layer, as shown in **Figure** below. The inner cell mass is called the **embryoblast**. These cells will soon develop into an embryo. The outer cell layer is called the **trophoblast**. These cells will develop into other structures needed to support and nourish the embryo.



[Figure 2]

Blastocyst. The blastocyst consists of an outer layer of cells called the trophoblast and an inner cell mass called the embryoblast. The blastocyst fluid-filled cavity is also known as the blastocoel or blastocoele.

Implantation

The blastocyst continues down the fallopian tube and reaches the uterus about 4 or 5 days after fertilization. When the outer cells of the blastocyst contact cells of the endometrium lining the uterus, the blastocyst embeds in the endometrium. The process of embedding is called **implantation**. It generally occurs about a week after fertilization.

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Summary

- Fertilization is the union of a sperm and egg, resulting in the formation of a zygote.
- The zygote undergoes many cell divisions before it implants in the lining of the uterus.

Review

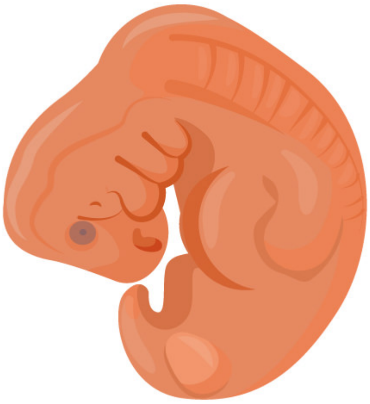
1. What happens during fertilization? Where does it usually take place?
2. What is implantation? When does it occur?
3. Describe a morula and blastocyst.

Report Content Errors

13.66 Embryo Growth

FlexBooks 2.0 > Biology For High School Diploma > Embryo Growth

Last Modified: Jul 04, 2019



[Figure 1]

At one time, did we really all look alike?

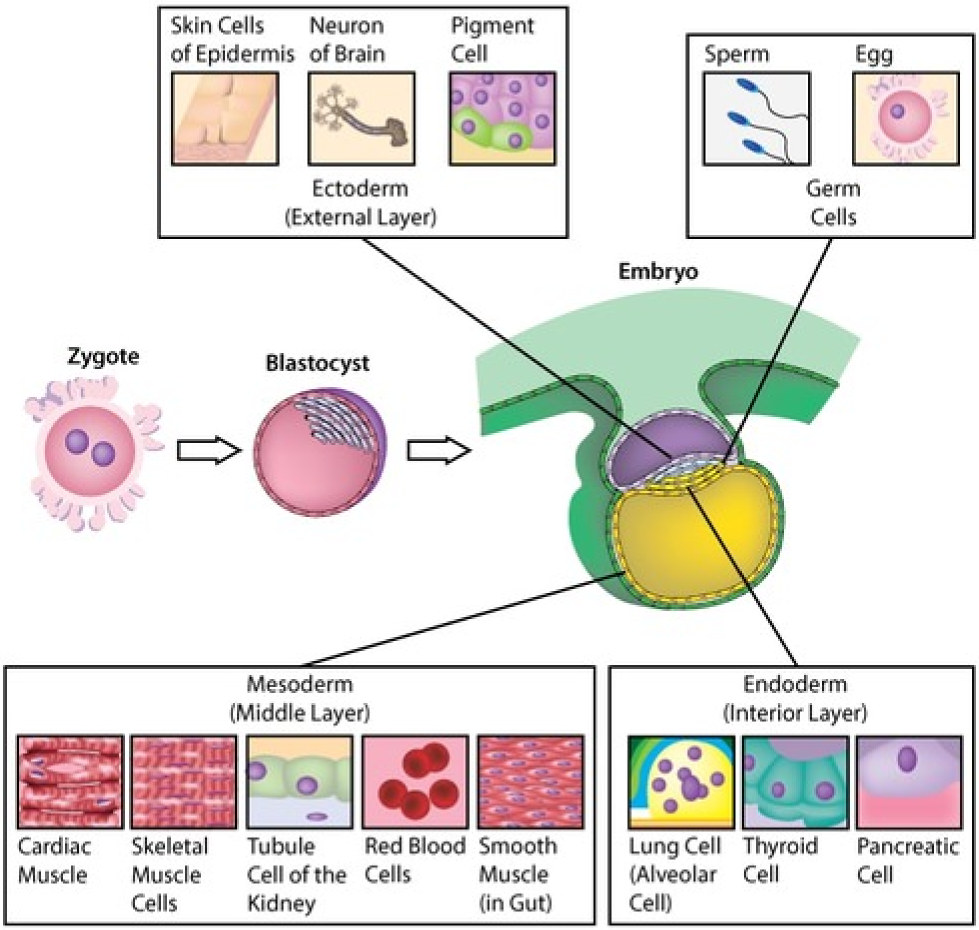
We all start as a single cell and soon grow into an **embryo**. Notice the remarkable details beginning to form. The eyes, backbone, and limb buds are obvious. Think about the amazing complexity that must be going on inside the embryo, and the tremendous amount of growth and development still to come. So, yes, at one time we all looked similar.

Growth and Development of the Embryo

After implantation occurs, the **blastocyst** is called an **embryo**. The embryonic stage lasts through the eighth week following fertilization. During this time, the embryo grows in size and becomes more complex. It develops specialized cells and tissue and starts to form most organ.

Formation of Cell Layers

During the second week after fertilization, cells in the embryo migrate to form three distinct cell layers, called the **ectoderm, mesoderm**, and **endoderm**. Each layer will soon develop into different types of cells and tissues, as shown in **Figure** below.

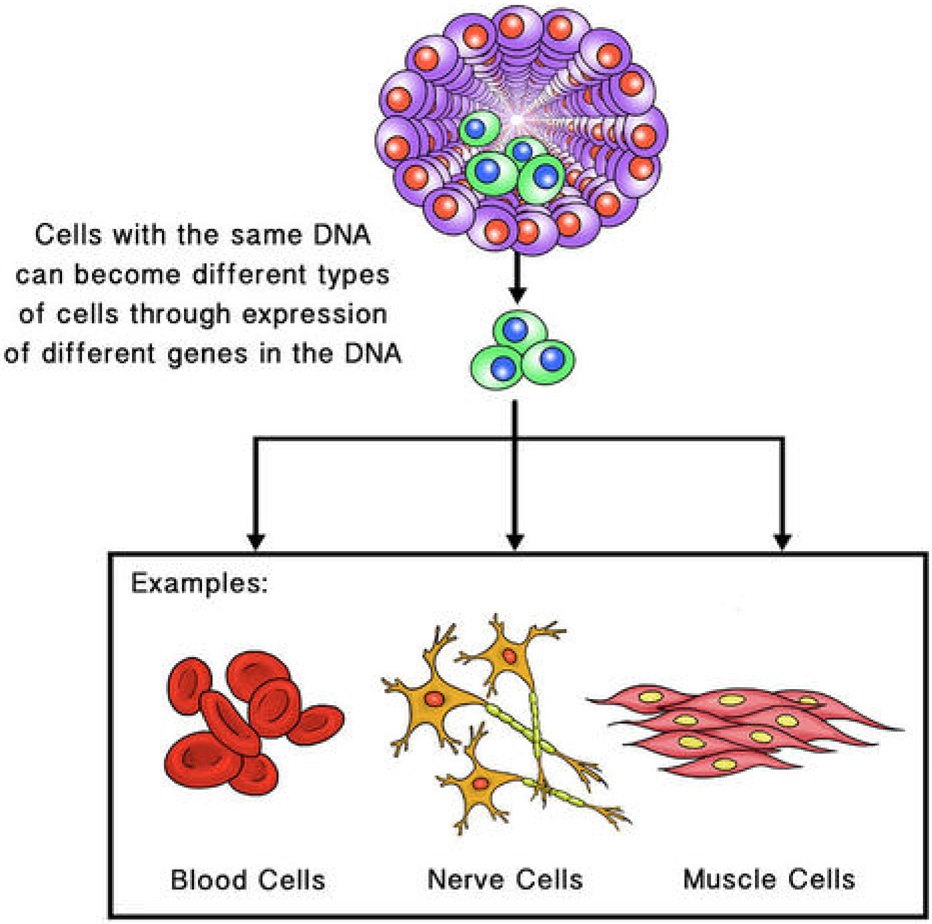


[Figure 2]

Cell Layers of the Embryo. The migration of cells into three layers occurs in the 2-week-old embryo. What organs eventually develop from the ectoderm cell layer? Which cell layer develops into muscle tissues?

Differentiation of Cells

A **zygote** is a single cell. How does a single cell develop into many different types of cells? During the third week after fertilization, the embryo begins to undergo cellular **differentiation**. **Differentiation** is the process by which unspecialized cells become specialized. As illustrated in **Figure** below, differentiation occurs as certain gene are expressed ("switched on") while other genes are switched off. Because of this process, cells develop unique structures and abilities that suit them for their specialized functions.

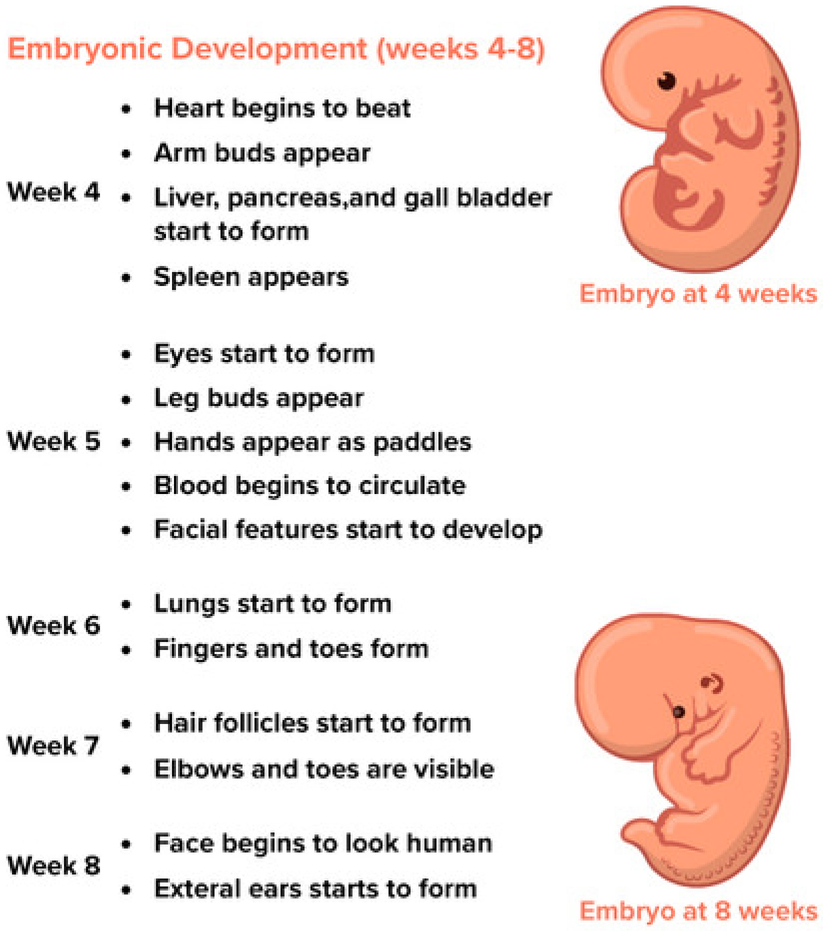


[Figure 3]

Cellular differentiation occurs in the 3-week-old embryo.

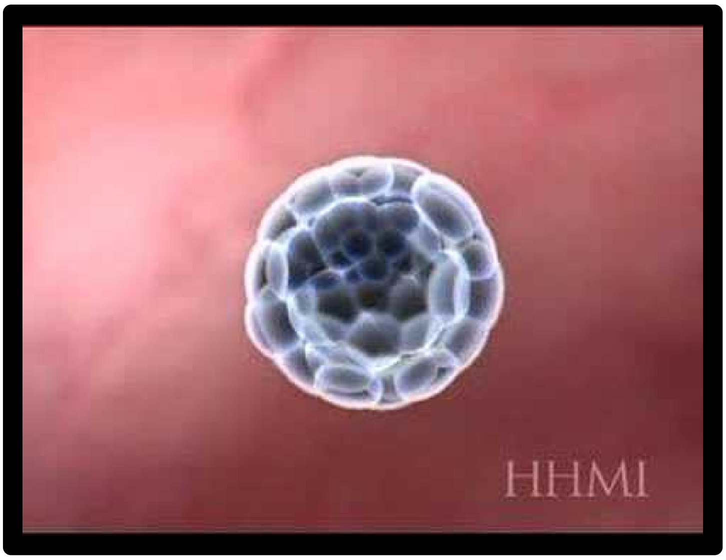
Organ Formation

After cells differentiate, all the major organs begin to form during the remaining weeks of embryonic development. A few of the developments that occur in the embryo during weeks 4 through 8 are listed in **Figure** below. As the embryo develops, it also grows in size. By the eighth week of development, the embryo is about 30 millimeters (just over 1 inch) in length. It may also have begun to move.



[Figure 4]

Embryonic Development (Weeks 4–8). Most organs develop in the embryo during weeks 4 through 8. If the embryo is exposed to toxins during this period, the effects are likely to be very damaging. Can you explain why? (Note: the drawings of the embryos are not to scale.)



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Summary

- The embryonic stage begins with implantation.
- An embryo forms three distinct cell layers, and each layer develops into different types of cells and organs.

Review

1. Explain how the embryo forms specialized cells.
2. What organs eventually develop from the ectoderm cell layer?
3. Which cell layer develops into muscle tissues?
4. If the embryo is exposed to toxins during weeks 4 through 8, the effects are likely to be very damaging. Can you explain why?

13.67 Prenatal Development

FlexBooks 2.0 > Biology For High School Diploma > Prenatal Development

Last Modified: Jul 04, 2019

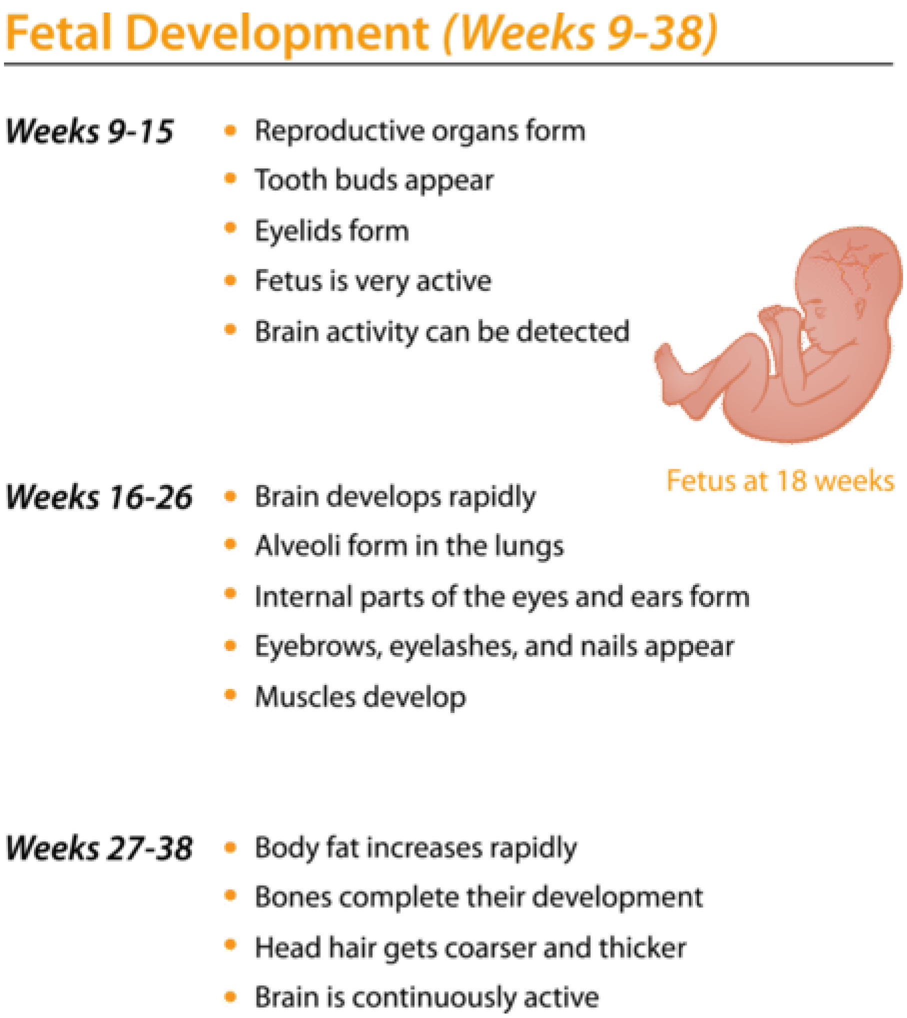
[Figure 1]

What characterizes this fetus as human?

The human **fetus**. Notice the details in the face and hands. Compare this to the human embryo, and the amount of growth and development is truly remarkable.

Growth and Development of the Fetus

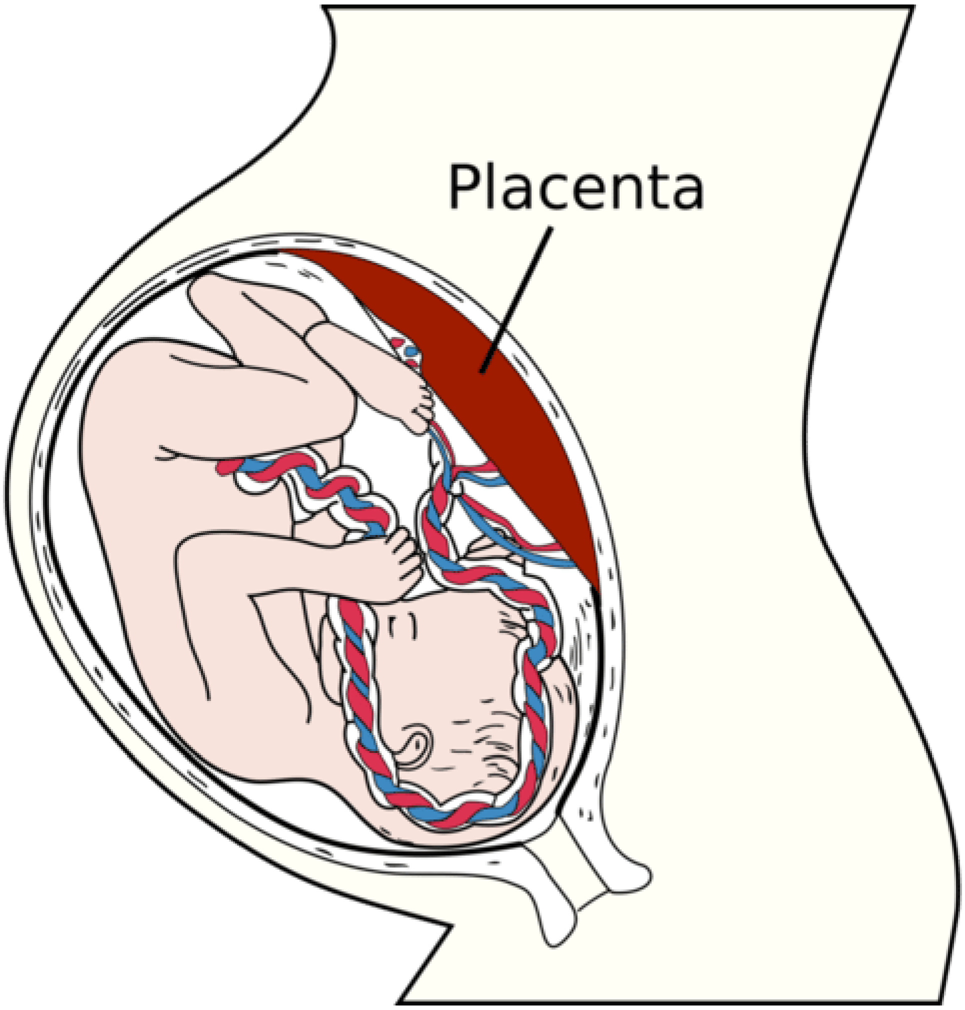
From the end of the eighth week until birth, the developing human organism is referred to as a **fetus**. Birth typically occurs at about 38 weeks after fertilization, so the fetal period generally lasts about 30 weeks. During this time, as outlined in **Figure** below, the organ complete their development. The fetus also grows rapidly in length and weight.



[Figure 2]

Fetal Development (Weeks 9–38). Organ development is completed and body size increases dramatically during weeks 9–38.

By the 38th week, the fetus is fully developed and ready to be born (see **Figure** below). A 38-week fetus normally ranges from 36 to 51 centimeters (14–20 inches) in length and weighs between 2.7 and 4.6 kilograms (about 6–10 pounds).



[Figure 3]

A 38-week-old fetus has completed development and will soon be born.

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https://flexbooks.ck12.org/flx/render/embeddedobject/177209

Summary

- The fetal stage begins about two months after fertilization and continues until birth.
- During this stage, organs continue to develop, and the fetus grows in size.

Review

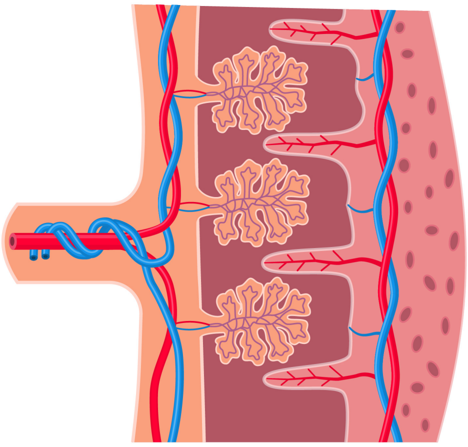
1. Make a flow chart of embryonic and fetal development.
2. Why would an embryo be more susceptible than a fetus to damage by toxins?

Report Content Errors

13.68 The Placenta

FlexBooks 2.0 > Biology For High School Diploma > The Placenta

Last Modified: Aug 24, 2020



[Figure 1]

How does a developing baby breathe?

Or eat? From mom, of course. Shown is a detailed representation of the **placenta**. And this is where all these interactions occur.

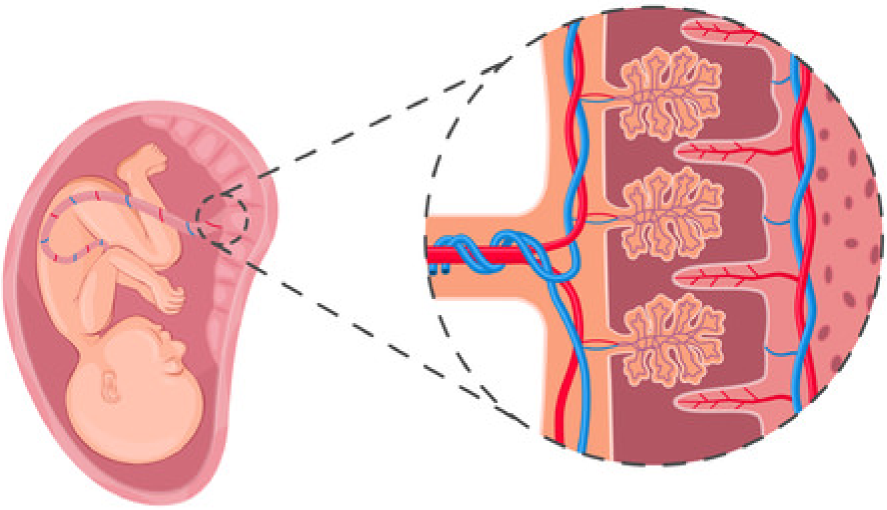
Placenta and Related Structures

The fetus could not grow and develop without oxygen and nutrient from the mother. Wastes from the fetus must also be removed in order for it to survive. The exchange of these substances between the mother and fetus occurs through the placenta.

Placenta

The **placenta** is a temporary organ that begins to form from the **trophoblast** layer of cell shortly after **implantation**. The placenta continues to develop and grow to meet the needs of the growing fetus. A fully developed placenta is made up of a large mass of blood vessel from both the mother and fetus. The maternal and fetal vessels are close together but separated by tiny spaces. This allows the mother's and fetus's blood to exchange substances across their capillary walls without the blood actually mixing.

The fetus is connected to the placenta through the **umbilical cord**, a tube that contains two artery and a vein. Blood from the fetus enters the placenta through the umbilical arteries, exchanges gases and other substances with the mother's blood, and travels back to the fetus through the umbilical vein.



[Figure 2]

The fetus and the placenta. Notice the fetus is attached to the placenta by the umbilical cord, made of two arteries and one vein.

Amniotic Sac and Fluid

Attached to the placenta is the **amniotic sac**, an enclosed membrane that surrounds and protects the fetus. It contains **amniotic fluid**, which consists of water and dissolved substances. The fluid allows the fetus to move freely until it grows to fill most of the available space. The fluid also cushions the fetus and helps protect it from injury.

https://flexbooks.ck12.org/flx/render/embeddedobject/284277

Summary

- The placenta allows nutrients and wastes to be exchanged between the mother and fetus.
- The fetus is connected to the placenta through the umbilical cord.

Review

1. What makes up a placenta?
2. Describe the role of the placenta in fetal development.
3. What is the umbilical cord? What occurs in the umbilical cord?

Report Content Errors

13.69 Pregnancy

FlexBooks 2.0 > Biology For High School Diploma > Pregnancy

Last Modified: May 21, 2021

[Figure 1]

Why is it called labor?

So...the mother carries the developing baby for nine months. We know about the tremendous growth and development of the embryo and fetus. Then comes labor.

Pregnancy and Childbirth

Pregnancy is the carrying of one or more offspring from fertilization until birth. It is the development of an embryo and fetus from the expectant mother's point of view.

The Mother's Role

The pregnant mother plays a critical role in the development of the embryo and fetus. She must avoid toxic substances such as alcohol, which can damage the developing offspring. She must also provide all the nutrient and other substances needed for normal growth and development. Most nutrients are needed in greater amounts by a pregnant woman, but some are especially important, including **folic acid** (vitamin B_9), calcium, iron, and omega-3 fatty acid.

Childbirth

Near the time of birth, the **amniotic sac** breaks in a gush of fluid. Often when this occurs, women say that their "water broke." **Labor** usually begins within a day of this event. Labor involves **contractions** of the muscular walls of the uterus, which cause the **cervix** to dilate. With the mother's help, the contractions eventually push the fetus out of the uterus and through the vagina. After birth, the **umbilical cord** is cut. The baby can breathe air now that it is no longer in amniotic fluid.

Summary

- A pregnant woman should avoid toxins and take in adequate nutrients for normal fetal growth and development.
- During childbirth, contractions of the uterus push the child out of the body.

Review

1. What causes the fetus to be pushed out of the uterus during birth?
2. Why is the umbilical cord cut before a newborn has started to breathe on its own?

Report Content Errors

13.70 Birth to Adulthood

FlexBooks 2.0 > Biology For High School Diploma > Birth to Adulthood

Last Modified: May 21, 2021

[Figure 1]

What's the main difference between an adorable little baby and a teenager?

This quiet little baby will soon grow into someone who talks and expresses feelings and attitudes. What's the main difference between an adorable little baby and a teenager? Plenty.

From Birth to Adulthood

For the first year after birth, a baby is called an **infant**. **childhood** begins at age two and continues until **adolescence**. **Adolescence** is the last stage of life before adulthood.

Infancy

infancy is the first year of life after birth. Infants are born with a surprising range of abilities. For example, they have well-developed senses of touch, hearing, and smell. They can also communicate their needs by crying. During their first year, they develop many other abilities, including those described below.

By 6 weeks after birth, infants typically start smiling (see **Figure** below) and making vocal sounds. By 6 months, infants are babbling. They have also learned to sit and are starting to crawl. The **deciduous teeth** (baby teeth) have started to come in. By 12 months, infants may be saying their first words. They usually can stand with help and may even have started to walk.

[Figure 2]

A baby's first smile is an early milestone in infant development.

Infancy is the period of most rapid growth after birth. Growth is even faster during infancy than it is during **puberty**. By the end of the first year, the average baby is twice as long as it was at birth and three times as heavy.

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Childhood

A **toddler** is a child aged 1 to 3 years. Children of this age are learning to walk, or "toddle." Growth is still relatively rapid during the toddler years but it has begun to slow down. During the next three years, children achieve many more milestones.

- By age 4, most children can run, climb stairs, and scribble with a crayon. They know many words and use simple sentences. The majority are also toilet trained.
- By age five, children are able to carry on conversations, recognize letters and words, and use a pencil to trace letters. They can usually tie their own shoelaces and may be learning to ride a bicycle, swing a bat, kick a ball and play other games (**Figure** below).
- By age 6, most children begin losing their deciduous teeth, and their permanent teeth start coming in. They speak fluently and are learning to read and write. They spend more time with peers and develop friendships.

[Figure 3]

Five year olds can usually play various games.

Older children continue to grow slowly until they start the adolescent growth spurt during puberty. They also continue to develop mentally, emotionally, and socially. Think about all the ways you have changed since you were as young as the child in **Figure** above. What milestones of development did you achieve during these childhood years?

Puberty

Puberty is the stage of life when a child becomes sexually mature. Puberty begins when the pituitary gland tells the testis to secrete testosterone in boys, and in girls the pituitary gland signals the ovary to secrete estrogen. Changes that occur during puberty are discussed in the *Male Reproductive Development* and *Female Reproductive Development* concepts.

Adolescence

Adolescence is the period of transition between the beginning of puberty and adulthood. Adolescence is also a time of significant mental, emotional, and social changes. For example:

- Adolescents generally develop the ability to think abstractly.
- Adolescents may have mood swings because of surging **hormone**.
- Adolescents usually try to be more independent from their parents.
- Adolescents typically spend much of their time with peers.
- Adolescents may start to develop intimate relationships.

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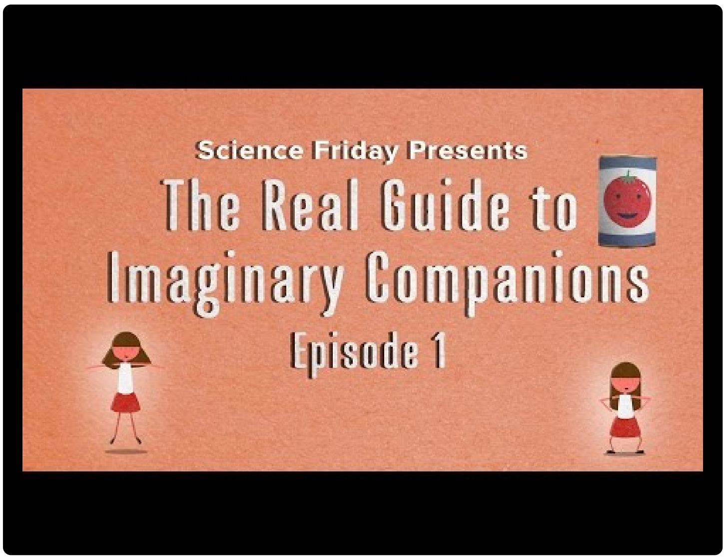
Science Friday: The Real Guide to Imaginary Companions

Children often have imaginary friends of various shapes and sizes. In this two-part video series by science Friday, psychologists Marjorie Taylor and Tracy Gleason discuss why kids create these companions, and the roles that these companions play in development.



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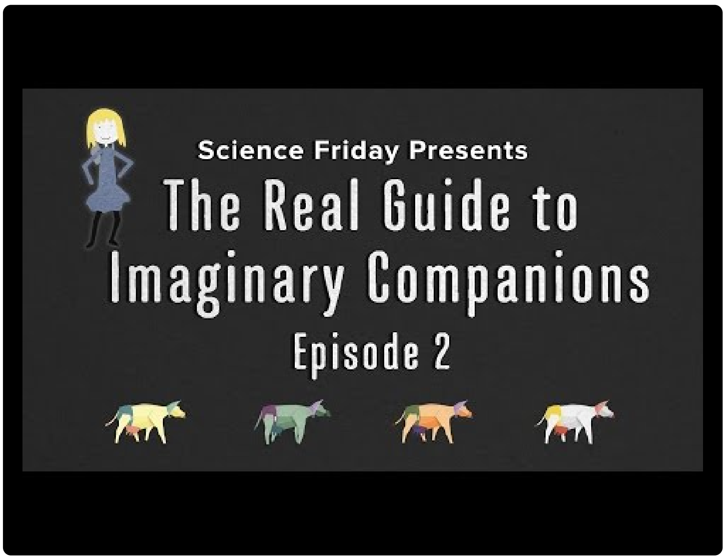

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Summary

- Growth and development are most rapid during infancy and slower throughout the rest of childhood until adolescence.
- Adolescence involves mental, emotional, and social changes in addition to the physical changes of puberty.

Review

1. Distinguish infancy from childhood.
2. What is a toddler?
3. List two abilities of an infant.
4. Describe three changes associated with adolescence.
5. Think about all the ways you have changed since you were a five year old child. List milestones of development you have achieved since then.

Report Content Errors

13.71 Adulthood

FlexBooks 2.0 > Biology For High School Diploma > Adulthood

Last Modified: Jul 04, 2019

[Figure 1]

Does getting older have to be a bad thing?

Being older doesn't necessarily mean being unable to do things and not enjoy life. These seniors look as if they thoroughly enjoy life. And some would say that life begins after all the children have moved out of the house.

Adulthood and Aging

Adulthood does not have a definite starting point. A person may be physically mature by age 16 or 17 but not defined as an adult by law until older ages. In the U.S., you can't join the armed forces or vote until age 18. You can't buy or use alcohol or take on many legal and financial responsibilities until age 21.

The video below, *21 Years,* is a daily video pictorial of the aging process, from birth to 21 years. Over 7,500 images of the same person have been condensed in a little over 6 minutes.

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Early Adulthood

early adulthood coincides with the 20s and early 30s. During early adulthood, people generally form intimate relationships, both in friendship and love. Many people become engaged or marry during this time. Often they are completing their education and becoming established in a career. Health problems in young adults tend to be minor. The most common causes of death are homicides, car crashes, and suicides.

Middle Adulthood

middle adulthood lasts from the mid-30s to the mid-60s. During this stage of life, many people raise a family and strive to attain career goals. They start showing physical signs of aging, such as wrinkles and gray hair. Typically, vision, strength and reaction time start declining. Diseases such as type 2 diabetes, cardiovascular or heart disease, and cancer are often diagnosed during this stage of life. These diseases are also the chief causes of death in middle adulthood.

Heart Disease

Heart disease is the number one killer of Americans, and one of the main killers of people the world over. A common cause of heart disease is arteriosclerosis. This is the stiffening or hardening of the artery that happens, in part, because of growing older. atherosclerosis, which is the buildup of fatty deposits in the arteries, is another cause of cardiovascular disease. When fat accumulates along the walls of arteries, there is less space for blood to flow. This makes it harder for blood to get to all the parts of the body that need it, including the heart itself. The accumulation of fatty deposits, or plaque, can eventually lead to a heart attack or stroke.

Other changes to the heart occur during middle adulthood. For example, to help the heart pump blood through stiffer blood vessel, some parts of the heart wall thicken. The size of the four chambers of the heart also change, as do the valves between the chambers. The resting heart rate does not change as you age, but the heart cannot beat as fast when you are physically active or stressed, as it did when you were younger.

Both genetic and lifestyle choices lead to heart disease. Though you cannot change your genetic background, there are things you can do to slow or prevent the onset of heart disease, especially as you grow older.

- try to be more physically active,
- if you smoke, quit,
- follow a heart healthy diet,
- keep a healthy weight.

Old Age

old age begins in the mid-60s and lasts until the end of life. Many people over 65 have retired from work, freeing up their time for hobbies, grandchildren, and other interests. Stamina, strength, reflex time, and the senses all decline during old age, and the number of brain cell decreases as well. The immune system becomes less efficient, increasing the risk of serious illnesses such as cancer and pneumonia. Diseases such as Alzheimer's disease that cause loss of mental function also become more common.

Causes of Aging

Why do we decline in all these ways as we age? Generally, it's because cells stop dividing and die. There are at least two reasons why cells stop dividing:

1. Cells are programmed to divide only a set number of times.
2. mutation accumulate in DNA, and cells with damaged DNA may not divide.

Summary

- During early adulthood, people form intimate relationships and start careers.
- Serious health problems start showing up in middle adulthood and old age.
- Aging occurs as cells lose their ability to divide.

Review

1. When does adulthood begin?
2. What are the most common causes of death associated with early adulthood?
3. What diseases are often diagnosed during middle adulthood?

4. Aging is associated with the death of cells. Give two reasons why cells die.
5. List three ways to help prevent heart disease as a person ages.

Report Content Errors

13.72 STIs

FlexBooks 2.0 > Biology For High School Diploma > STIs

Last Modified: Aug 01, 2018

[Figure 1]

What does "safe sex" truly mean?

"Safe Sex." The thought of a **sexually transmitted infection** should be enough to make you think about and believe in this saying.

Understanding Sexually Transmitted Infections

A shocking statistic made headlines in 2008. A recent study had found that one in four teen girls in the U.S. had a sexually transmitted infection. A **sexually transmitted infection (STI)** (also known as a **sexually transmitted disease**, or STD) is an infection caused by a pathogen that spreads mainly through sexual contact. Worldwide, a million people a day become infected with STIs. The majority of them are under the age of 25.

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To be considered an STI, an infection must have only a small chance of spreading naturally in ways other than sexual contact. Some infections that can spread through sexual contact, such as the common cold, spread more commonly by other means. These infections are not considered STIs.

Pathogens that Cause STIs

STIs may be caused by several different types of pathogens, including protozoan, insects, bacterium, and virus. For example:

- Protozoa cause an STI called **trichomoniasis**. The pathogen infects the vagina in females and the urethra in males, causing symptoms such as burning and itching. Trichomoniasis is common in young people.
- **pubic lice**, like the one in **Figure** below, are insect parasite that are transmitted sexually. They suck the blood of their host and irritate the skin in the pubic area.

[Figure 2]

Pubic lice like this one are only about as big as the head of a pin.

Most STIs are caused by bacteria or viruses. Bacterial STIs can be cured with antibiotic. Viral STIs cannot be cured. Once you are infected with a viral STI, you are likely to be infected for life.

How STIs Spread

Most of the pathogens that cause STIs enter the body through **mucous membranes** of the reproductive organ. All sexual behaviors that involve contact between mucous membranes put a person at risk for infection. This includes vaginal, anal, and oral sexual behaviors. Many STIs can also be transmitted through body fluids such as blood, semen, and breast milk. Therefore, behaviors such as sharing injection or tattoo needle is another way these STIs can spread.

Why are STIs common in young people? One reason is that young people often take risks. They may think, “It can’t happen to me.” They also may not know how STIs are spread, so they don’t know how to protect themselves. In addition, young people may have multiple sexual partners.

Preventing STIs

The only completely effective way to prevent infection with STIs is to avoid sexual contact and other risky behaviors. Using condoms can lower the risk of becoming infected with STIs during some types of sexual activity. However, condoms are not foolproof. Pathogens may be present on areas of the body not covered by condoms. Condoms can also break or be used incorrectly.

Summary

- STIs are diseases caused by pathogens that spread through sexual contact.
- Abstinence from sexual activity and other risk behaviors is the only completely effective way to prevent the spread of STIs.

Review

1. Describe how STIs spread.
2. What causes most STIs?
3. Can bacterial STIs be cured? If so, how? What about viral STIs?
4. What is the only completely effective way to prevent a sexually transmitted infection?
5. Assume you are preparing a public service announcement (PSA) to explain to teens how and why to avoid STIs. List three facts you think it would be important to include for an informative and persuasive PSA.

Explore More

Use this resource to answer the questions that follow.

https://flexbooks.ck12.org/flx/render/embeddedobject/177265

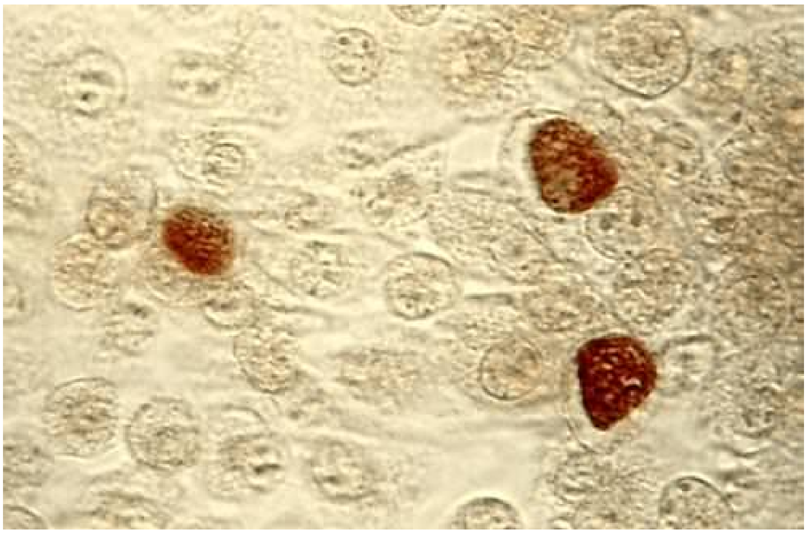
1. List five facts about STDs.
2. List five myths about STDs.

Report Content Errors

13.73 Bacterial STIs

FlexBooks 2.0 > Biology For High School Diploma > Bacterial STIs

Last Modified: May 21, 2021



[Figure 1]

Single-celled organisms. Can they be dangerous?

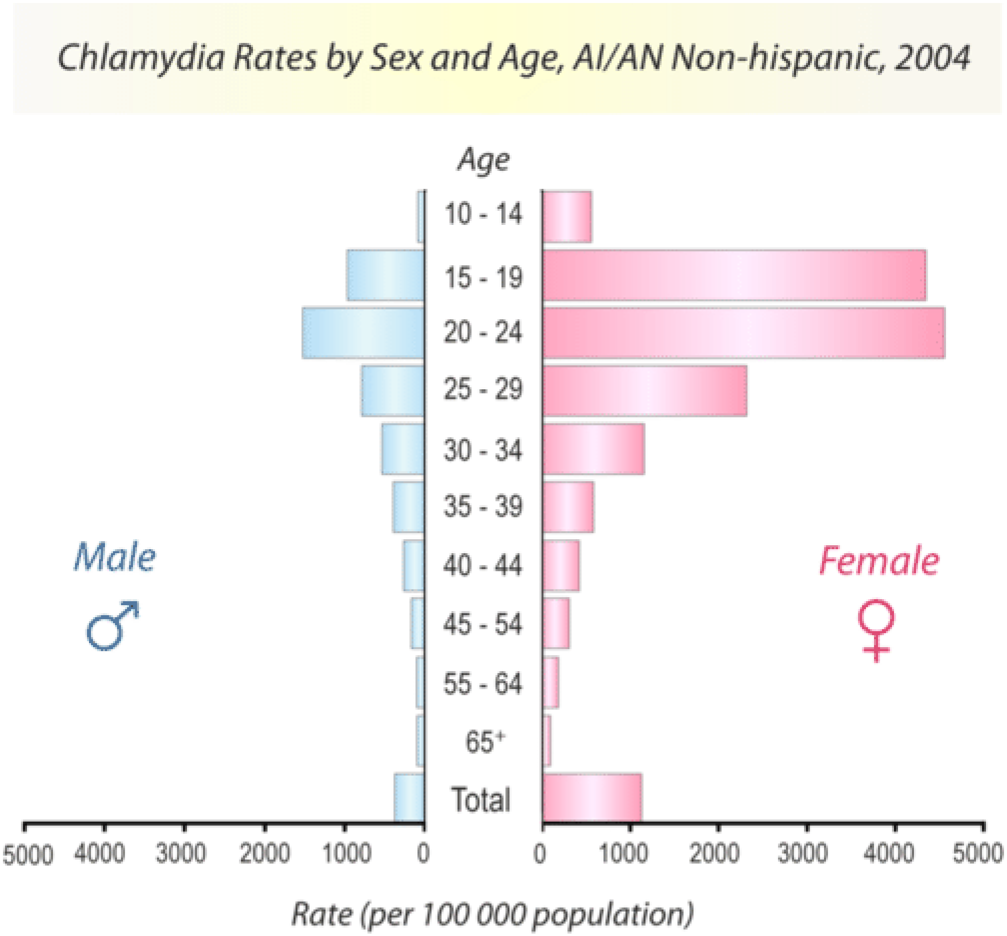
These are **chlamydia**. Innocent-looking single-celled organism. But these bacterium can lead to painful and devastating consequences.

Bacterial STIs

Many STIs are caused by bacteria. Some of the most common bacterial STIs are chlamydia, **gonorrhea**, and **syphilis**. Bacterial STIs can be cured with antibiotic.

Chlamydia

Chlamydia is the most common STI in the United States. As shown in the graph in **Figure** below, females are much more likely than males to develop chlamydia. Like most STIs, rates of chlamydia are highest in teens and young adults.



[Figure 2]

This graph shows the number of cases of chlamydia per 100,000 people in the U.S. in 2004. Which age group had the highest rates? How much higher were the rates for females aged 15–19 than for males in the same age group?

Symptoms of chlamydia may include a burning sensation during urination and a discharge from the vagina or penis. Chlamydia can be cured with **antibiotics**, but often there are no symptoms, so people do not seek treatment. Untreated chlamydia can lead to more serious problems, such as **pelvic inflammatory disease (PID)**. This is an infection of the uterus, fallopian tube, and/or ovary. It can scar a woman's reproductive organ and make it difficult for her to become pregnant.

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Gonorrhea

Gonorrhea is another common STI. Symptoms of gonorrhea may include painful urination and discharge from the vagina or penis. Gonorrhea usually can be cured with antibiotics, although the bacteria have developed resistance to many of the drug. Gonorrhea infections may not cause symptoms, especially in females, so they often go untreated. Untreated gonorrhea can lead to PID in females. It can lead to inflammation of the reproductive organs in males as well.

Syphilis

Syphilis is less common than chlamydia or gonorrhea but more serious if untreated. Early symptoms of syphilis infection include a small sore on or near the genitals. The sore is painless and heals on its own, so it may go unnoticed. If treated early, most cases of syphilis can be cured with antibiotics. Untreated syphilis can cause serious damage to the heart, brain, and other organs. It may eventually lead to death.

Summary

- Bacterial STIs include chlamydia, gonorrhea, and syphilis.
- Bacterial STIs usually can be cured with antibiotics.

Review

1. Identify three common STIs that are caused by bacteria.
2. Often, STIs do not cause symptoms. Why is it important to detect and treat STIs even when they do not cause symptoms? Give an example of the consequences of an untreated STI.

3. Which age group had the highest rates of chlamydia? How much higher were the rates for females aged 15–19 than for males in the same age group?
4. Explain how a lack of symptoms might contribute to the spread of STIs.

Report Content Errors

13.74 Viral STIs

FlexBooks 2.0 > Biology For High School Diploma > Viral STIs

Last Modified: Feb 26, 2022

[Figure 1]

How long does a viral STI last?

This is the Human Papilloma virus, which causes a viral STI. Viral STIs can be especially dangerous, as they cannot be cured. Once you get one, it's yours for life. And also, it's the person's you give it to.

Viral STIs

STIs caused by viruses include **genital herpes**, **hepatitis B**, **genital warts**, and **HIV/AIDS**. Whereas bacterial STIs can usually be cured with antibiotic, viral STIs cannot be cured.

Genital Herpes

Genital herpes is an STI caused by a herpes virus. In the United States, as many as one in four people are infected with the virus. Symptoms of genital herpes include painful blisters on the genitals (see **Figure** below). The blisters usually go away on their own, but the virus remains in the body, causing periodic outbreaks of blisters throughout life. Outbreaks may be triggered by stress, illness, or other factors. A person with genital herpes is most likely to transmit the virus during an outbreak.

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Hepatitis B

Hepatitis B is inflammation of the liver caused by infection with the hepatitis B virus. In many people, the immune system quickly eliminates the virus from the body. However, in a small percentage of people, the virus remains in the body and continues to cause illness. It may eventually damage the liver and increase the risk of liver cancer, which is usually fatal.

Genital Warts and Cervical Cancer

Infections with the **human papillomavirus (HPV)** are very common. HPV may cause **genital warts**, which are small, rough growths on the genitals. It may also cause cancer of the cervix in females. A simple test, called a **Pap test** (also known as a Pap smear), can detect **cervical cancer**. If the cancer is detected early, it usually can be cured with surgery. There is also a vaccine , GARDASIL, to prevent infection with HPV. The vaccine is recommended for females aged 11 to 26 years.

Summary

- Viral STIs include genital herpes, hepatitis B, genital warts, and cervical cancer.
- Viral STIs cannot be cured, but some of them can be prevented with vaccines.

Review

1. Name and describe an STI caused by a virus.
2. Discuss treatment for the human papillomavirus.
3. Compare and contrast bacterial and viral STIs with regard to their treatment, cure, and prevention.

Report Content Errors

13.75 REFERENCES

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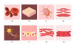
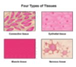
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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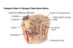	**Credit:** Courtesy of U.S. National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) Program, modified by Marianna Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) for CK-12 Foundation **Source:** http://commons.wikimedia.org/wiki/File:Illu_compact_spongy_bone.jpg **License:** Public Domain
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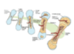	**Credit:** LadyofHats **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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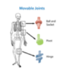	**Credit:** Zachary Wilson, using skeleton by User:GregorDS/Wikimedia Commons **Source:** CK-12 Foundation (skeleton available at http://commons.wikimedia.org/wiki/File:Human_skeleton_diagram_trace.svg) **License:** CC BY-NC 3.0; Skeleton: Public Domain
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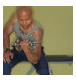
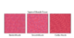
	**Credit:** Flickr: Spirit-Fire **Source:** https://www.flickr.com/photos/spirit-fire/4965080266/ **License:** CC BY 2.0
	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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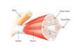
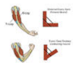
	**Credit:** Courtesy of National Cancer Institute/SEER Training Modules **Source:** http://commons.wikimedia.org/wiki/File:Illu_muscle_structure.jpg **License:** Public Domain
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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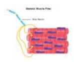
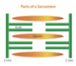
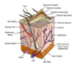
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Sam McCabe and Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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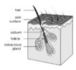
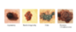
	**Credit:** Jodi So and Marianna Ruiz Villarreal (LadyofHats) **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Courtesy of Skin Cancer Foundation/National Cancer Institute **Source:** Left to right: http://visualsonline.cancer.gov/details.cfm?imageid=2362; http://visualsonline.cancer.gov/details.cfm?imageid=2363; http://visualsonline.cancer.gov/details.cfm?imageid=2364; http://visualsonline.cancer.gov/details.cfm?imageid=2184 **License:** Public Domain
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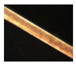
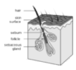
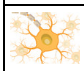
	**Credit:** Jan Homann **Source:** http://commons.wikimedia.org/wiki/File:Menschenhaar_200_fach.jpg **License:** Public Domain
	**Credit:** Courtesy of the National Institutes of Health, User:Tsaitgaist/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Hair_follicle-en.svg **License:** Public Domain
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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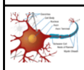
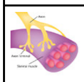
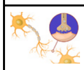
	**Credit:** Zachary Wilson/CK-12 Foundation, based on image by Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) **Source:** Original: http://commons.wikimedia.org/wiki/File:Complete_neuron_cell_diagram_en.svg **License:** CC BY-NC 3.0
	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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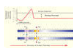	**Credit:** Rupali Raju **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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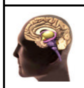	**Credit:** Courtesy of the National Institute for Aging, modified by CK-12 Foundation **Source:** http://commons.wikimedia.org/wiki/File:NIA_human_brain_drawing.jpg **License:** Public Domain
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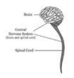	**Credit:** User:Grm wnr/Wikimedia Commons, modified by Sam McCabe **Source:** http://commons.wikimedia.org/wiki/File:Central_nervous_system.svg **License:** Public Domain

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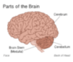	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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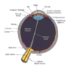	**Credit:** User:Rhcastilhos/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Schematic_diagram_of_the_human_eye_en.svg **License:** Public Domain
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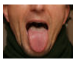	**Credit:** Bruce **Source:** http://www.flickr.com/photos/superfantastic/2247770750 **License:** CC BY 2.0
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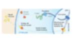	**Credit:** LadyofHats **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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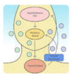	**Credit:** Rupali Raju **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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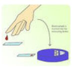
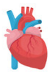
	**Credit:** Rupali Raju **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License

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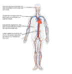
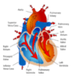
	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Mariana Ruiz Villarreal (Wikimedia: LadyofHats), modified by CK-12 Foundation **Source:** http://commons.wikimedia.org/wiki/File:Human_healthy_pumping_heart_en.svg **License:** Public Domain
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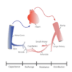	**Credit:** Rupali Raju **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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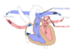	**Credit:** Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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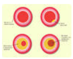	**Credit:** Rupali Raju **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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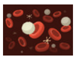	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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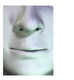	**Credit:** Ciprian Silviu Ionescu **Source:** https://www.flickr.com/photos/billybillyboy/2271809793/ **License:** CC BY 2.0
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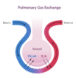	**Credit:** Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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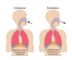	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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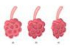	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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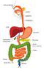
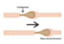
	**Credit:** Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons) **Source:** http://commons.wikimedia.org/wiki/File:Digestive_system_simplified.svg **License:** Public Domain
	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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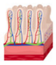
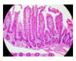
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Ed Uthman - "Normal Small Intestine Mucosa" **Source:** https://www.flickr.com/photos/78147607@N00/5916217283 **License:** CC BY 2.0
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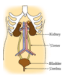
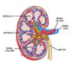
	**Credit:** Courtesy of National Cancer Institute/SEER Training Modules **Source:** http://commons.wikimedia.org/wiki/File:Illu_urinary_system.svg **License:** Public Domain
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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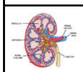	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0

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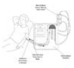	**Credit:** Jodi So **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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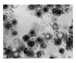	**Credit:** CDC/Dr. Erskine Palmer **Source:** https://en.wikipedia.org/wiki/File:Herpes_simplex_virus_TEM_B82-0474_lores.jpg **License:** Public Domain
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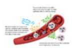
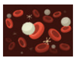
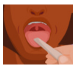
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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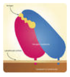	**Credit:** Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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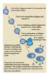	**Credit:** Courtesy of the National Institutes of Health and User:DO11.10/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:B_cell_activation.png **License:** Public Domain
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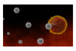
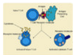
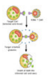
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Courtesy of the National Institutes of Health and User:DO11.10/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Antigen_presentation.jpg **License:** Public Domain
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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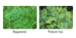	**Credit:** Ragweed: Homer Edward Price; Poison ivy: John J. Mosesso/National Biological Information Infrastructure **Source:** Ragweed: http://www.flickr.com/photos/28340342@N08/2976017730/; Poison ivy: http://life.nbii.gov/dml/mediadetail.do?id=703&pt=l2Search&navbar=page1_view1_title_asc_15 **License:** (Ragweed) CC BY 2.0; (Poison ivy) Public Domain

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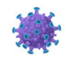	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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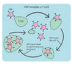
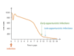
	**Credit:** Rupali Raju **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Hana Zavadska **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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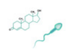
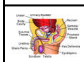
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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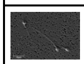
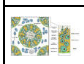
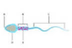
	**Credit:** Wikimedia Commons User: Forskerunv **Source:** https://commons.wikimedia.org/wiki/File:Spermatozoa-human-3140x.jpg **License:** Public Domain
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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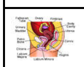	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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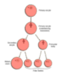	**Credit:** User:Mysid/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Gray5.svg **License:** Public Domain
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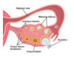	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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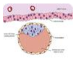	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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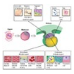
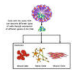
	**Credit:** Zachary Wilson **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
	**Credit:** Laura Guerin **Source:** CK-12 Foundation **License:** CC BY-NC 3.0
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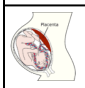
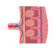
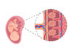
	**Credit:** Gray's Anatomy, modified by User:Amada44/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Placenta.svg **License:** Public Domain
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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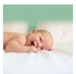	**Credit:** cutebabyblog **Source:** https://www.flickr.com/photos/168592423@N02/45782746015 **License:** Public Domain
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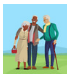	**Credit:** CK-12 Foundation **Source:** CK-12 Foundation **License:** CK-12 Curriculum Materials License
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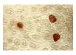	**Credit:** Centers for Disease Control and Prevention **Source:** https://commons.wikimedia.org/wiki/File:ChlamydiaTrachomatisEinschlussk%C3%B6rperchen.jpg **License:** Public Domain
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