Introduction

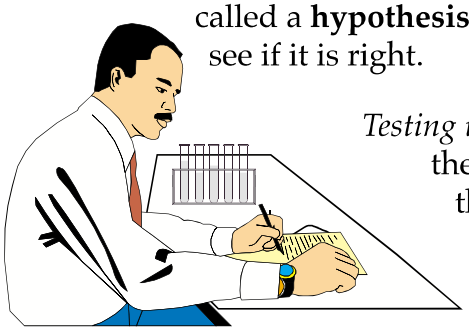
Do you ever wonder about things in nature? Do you wonder why or how? Science provides us with answers about how and why things happen the way they do. Scientists are people who conduct investigations in search of answers. Occasionally, something happens that appears to be totally new. Scientists try to find out how and why it happened. At other times, scientists are unsure if old ideas are really true. They investigate these theories. When a theory appears to be true, scientists may do another investigation. They will see if the theory can predict other answers to the questions of how and why. Sometimes different scientists come to different results. They find different reasons for how or why something has happened. In this case, scientific investigation does two things. First, it compares the possible reasons. Then, it tries to come to a decision about which theory seems the best explanation. The following section describes how scientists find these answers.

Scientific Method

Scientists do certain things in a certain order to find answers. This method is called the **scientific method**. It is a logical way of solving problems or answering questions. The first step is to *identify the problem or ask a question*. The study or research of a problem always begins with a question.

The second step of the scientific method is to *gather data about the question*. Information is collected about the question. **Observations** are made and recorded. This recorded information is called **data**. Another way to gather data is to read books, journals, or other publications that deal with the same or similar problem or question.

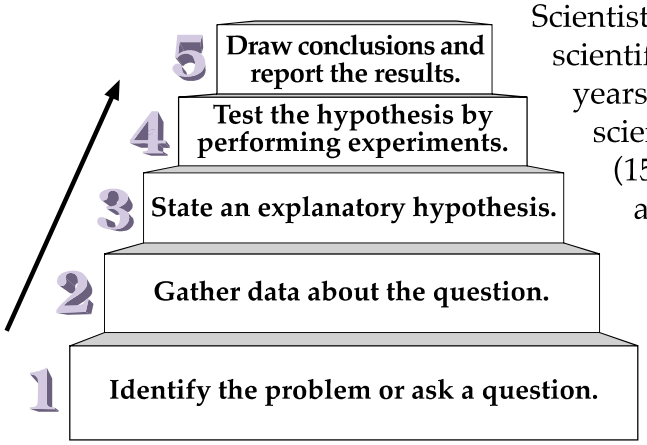
The third step is to *state an explanatory hypothesis*. Looking at the data gathered, scientists make an educated guess and suggest what may be the answer to the problem. This guess, based on observations, is called a **hypothesis**. Then the hypothesis must be tested to see if it is right.



Testing the hypothesis by performing experiments is the fourth step. Activities are planned to test the hypothesis. These activities are called **experiments**. The experiments must be done very carefully. Scientists repeat

the experiments many times before they accept the results. The same conditions have to be repeated over and over. When the data gathered from each experiment agree with the data from other experiments, then the results may be accepted.

Drawing conclusions and reporting the results is the fifth step. After the experiments are completed, a **conclusion** is made. The conclusion is based on analysis of the data that was gathered in the experiment. The conclusion may agree with the hypothesis or it may disagree.



Scientists have been using the scientific method for about 400 years. It began with an Italian scientist named **Galileo Galilei** (1564–1642) who tested ideas about nature to explain the way things happen. Before Galileo, most people believed that heavier objects fell faster than lighter objects. No one bothered to test this idea. Instead, they accepted it as fact. Then Galileo decided to use the scientific method to investigate this hypothesis. Galileo found that objects fall at the same rate of acceleration regardless of their weight because gravity makes all objects accelerate at the same rate. However, gravity is not the only force at work. Objects are also affected by air resistance, the force air exerts on an object. This was a gigantic change in the way the world was seen and understood. Since that time, many other scientists have conducted investigations about gravity. They too have found that Galileo was right about the way things fall.

Even now, such major changes occasionally take place. It is more common, however, for the changes to be small. Whether big or small, changes take place because scientists all over the world share information. Often many scientists are working on the same problem. If the results among the different scientists are not the same, the hypothesis, approach, or methods may have to be changed. If a hypothesis has been tested many times and seems correct, it is called a **scientific theory**. After a theory has been tested and supported many times, it becomes a **scientific law**. In science, no theory or law is ever considered proven. Galileo showed us the reason for this, and, in fact, what Galileo said about gravity is still considered theory.

Scientific Testing

Suppose you wanted to find out if storing popcorn in the refrigerator would make a difference in the number of kernels that did not pop. You would need to also test popcorn stored at room temperature as a *control*, or the standard for comparison. All other conditions for both batches of popcorn would need to be the same: the same brand, same freshness, same storage time, and same method of preparation. Only one condition, the place of storage, should differ. All other factors are *constants* and cannot change.

Scientists often test their hypotheses by conducting experiments under controlled conditions in the scientific **laboratory**. In some cases, conditions cannot be controlled. It would be hard to control conditions when investigating the way people behave or the way the trees in a large forest interact. In these cases, it may not be possible or ethical to conduct an experiment in a laboratory. Instead, scientists observe the widest range of natural behavior possible. Scientists may survey large numbers of people. They may record conditions in the forest for years and years. By doing this, scientists gather information that can be compared to laboratory results.

Another way to test theories about parts of the world is to use a **scale model**. Imagine you wanted to know how a building would behave during an earthquake. You couldn't create an actual earthquake in a laboratory. Instead, you might construct a small scale model of the building. Then you could shake it, simulating an earthquake. More and more, models using **computer simulations** are being made. One advantage of computer simulations is they permit scientists to test theories many times.

Sometimes theories are tested using **analogs**. Analogs are things that are similar but not exactly alike. Scientists use the similarities between analogs to learn. For example, you might want to know how a now extinct dinosaur flew. You might study how bats actually do fly. Bats are analogs to dinosaurs because both bats and dinosaurs flew without having feathers. There are some differences between the two, but the scientists study their similarities. With the right preparation, the results of this investigation would be a fairly accurate prediction and would show what it would take to make a long-dead dinosaur fly. Try to think of an analog to a human. Could you study the analog to learn things about humans? Whether using analogs, computer simulations, or scale models, scientists work to be sure that their results are generally accurate.

Laboratory Testing and Safety

In the laboratory, scientists must be careful to follow all **safety** rules. Careful procedures and safe handling of the **apparatus** (**equipment**) are important for both the scientist and the experiment. Using caution and following safety rules protect scientists from accidents. Avoiding accidents and following laboratory rules also protect the results of the experiments.

Equipment must be kept clean and dry. This care will prevent other substances from interfering with the results of the experiment. Substances used in experiments must be measured accurately. The amount of the substances used will affect the *reaction* or *outcome*. Even the temperature of the room may affect an experiment. All conditions in the scientific laboratory must be controlled and monitored carefully.

Whatever methods of testing are used in the laboratory, safety is the greatest concern. The safety rules which follow have been developed to help you have a safe laboratory experience.

Safety Rules

1. Read and follow directions while working in the science laboratory. When possible, read instructions before entering the laboratory.
2. Always wear protective devices, such as aprons. Wear goggles when working with dangerous or hot chemicals, with objects that may hit you in the eye, or whenever the teacher instructs you to do so.
3. NEVER taste or directly inhale chemicals. The smell of chemicals is sensed by *wafting*. Your teacher can demonstrate this technique.
4. DO NOT bring food or drink into the lab.
5. Wash hands thoroughly after each lab.
6. DO NOT rub eyes or put hands in mouth.
7. Wear clothing suitable for the lab. Cotton clothing is better than polyester or nylon. Always keep your shoes on while in the lab. Roll up long or loose sleeves.
8. DO NOT look directly into the mouth of a filled test tube. DO NOT point the mouth of a filled test tube at another student. The liquid can splash into eyes.
9. DO NOT perform any experiments unless the instructor is in the room.
10. Report ALL minor and major accidents to your instructor.
11. Know the location of the safety shower, fire blanket, and eye wash. Know how to use these important pieces of safety equipment.
12. Turn off burners and the gas outlet when not in use. Never leave a lit burner unattended.
13. Keep lab tables clean and neat to prevent accidents. Wipe all areas at the end of the lab.
14. MAKE SAFETY A HABIT!

Summary

To explain things that occur in nature, scientists ask questions and solve problems. The reasons for doing this include investigating new situations, testing old hypotheses, determining the ability of a theory to predict, and comparing apparently conflicting theories. Scientists use five steps in problem solving. They 1) identify the problem, 2) collect information, 3) state a hypothesis, 4) test the hypothesis, and 5) draw a conclusion. They use experiments to test their ideas or hypotheses. Scientists use controls to maintain the reliability of their results, but sometimes it is not possible to use a control. In these cases, large amounts of data are gathered. At other times, scale models, computer simulations, or analogous systems may be used to test theories and produce reliable results. Ideas that have been tested and appear valid are called theories. Theories that have not been disproven over a long period of time are called laws. To maintain safety in the laboratory and assure the effectiveness of their experiments, scientists must follow all laboratory and safety rules.