The Integumentary System

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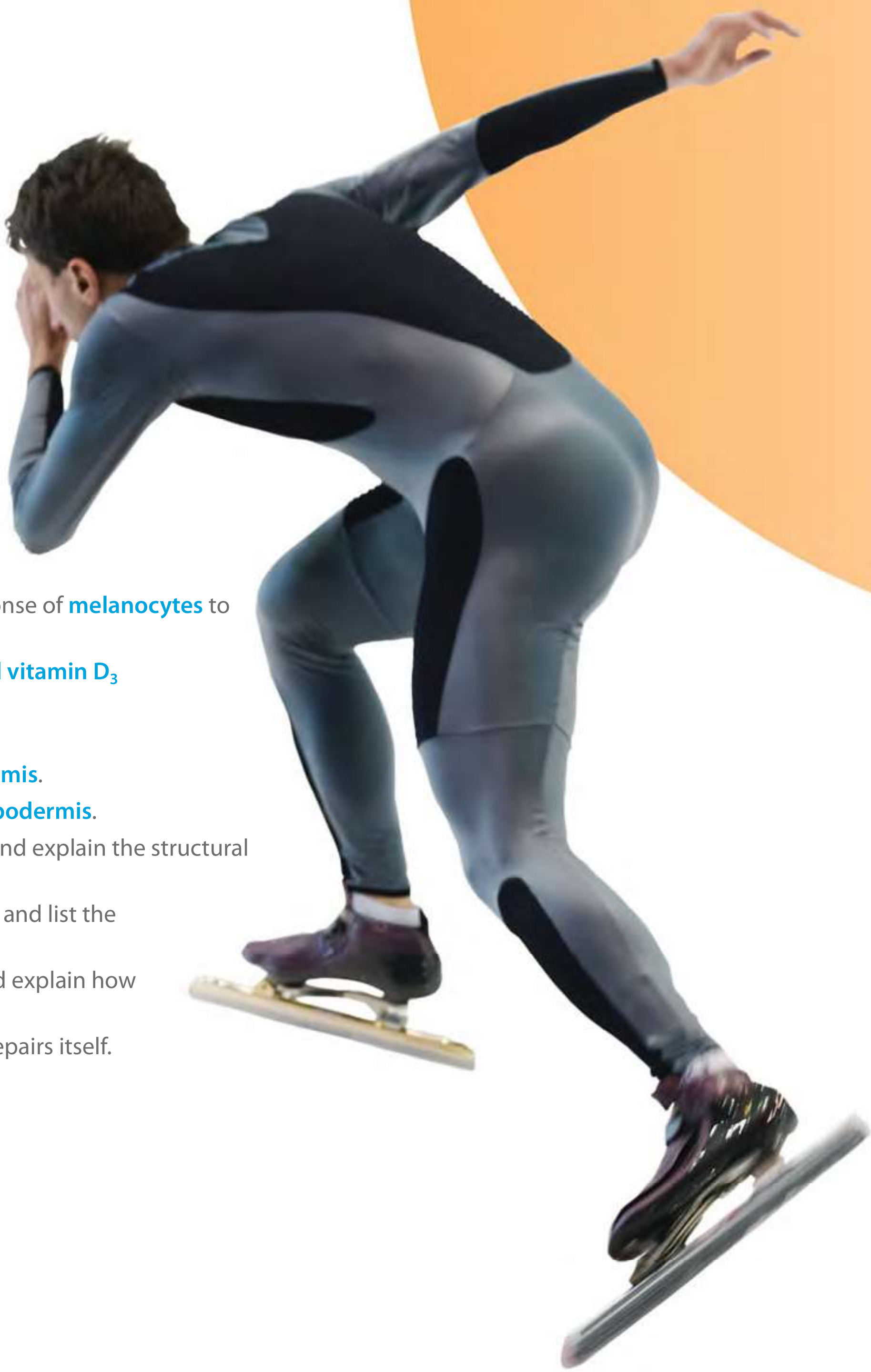

Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

5-1 Describe the main **structural features** of the **epidermis**, and explain the functional significance of each.

5-2 Explain what accounts for individual **differences in skin color**, and discuss the response of **melanocytes** to sunlight exposure.

5-3 Describe the interaction between **sunlight and vitamin D_3 production**.

5-4 Describe the roles of **epidermal growth factor**.

5-5 Describe the structure and functions of the **dermis**.

5-6 Describe the structure and functions of the **hypodermis**.

5-7 Describe the **mechanisms that produce hair**, and explain the structural basis for hair texture and color.

5-8 Discuss the various kinds of **glands in the skin**, and list the secretions of those glands.

5-9 Describe the **anatomical structure of nails**, and explain how they are formed.

5-10 Explain **how the skin responds to injury** and repairs itself.

5-11 Summarize the **effects of aging** on the skin.

Clinical Notes

An Introduction to the Integumentary System

This chapter considers the many and varied functions of the skin, the organ system with which you are probably most familiar. No other organ system is as accessible, large, and underappreciated as the integumentary system. Often referred to simply as the **integument** (in-TEG-ū-ment), this system accounts for about 16 percent of your total body weight. Its surface, 1.5–2 m^2 in area, is continually abraded, attacked by microorganisms, irradiated by sunlight, and exposed to environmental chemicals. The integumentary system is your body's first line of defense against an often hostile environment—the place where you and the outside world meet.

The integumentary system has two major components: the **cutaneous membrane** or skin, and the **accessory structures** (**Figure 5–1**).

1. The cutaneous membrane has two components: the **epidermis** (*epi-*, above) or superficial epithelium, and the **dermis,** an underlying area of connective tissues.
2. The accessory structures include hair, nails, and multicellular exocrine glands. These structures are located primarily in the dermis and protrude through the epidermis to the skin surface.

The integument does not function in isolation. An extensive network of blood vessels branches through the dermis, and sensory receptors that monitor touch, pressure, temperature, and pain provide valuable information to the central nervous system about the state of the body. Deep to the dermis, the loose connective tissue of the **hypodermis,** also known as the superficial fascia or *subcutaneous layer*, separates the integument from the deep fascia around other organs, such as muscles and bones. p. 134 Although the hypodermis is often considered separate from the integument, we will consider it in this chapter because its connective tissue fibers are interwoven with those of the dermis.

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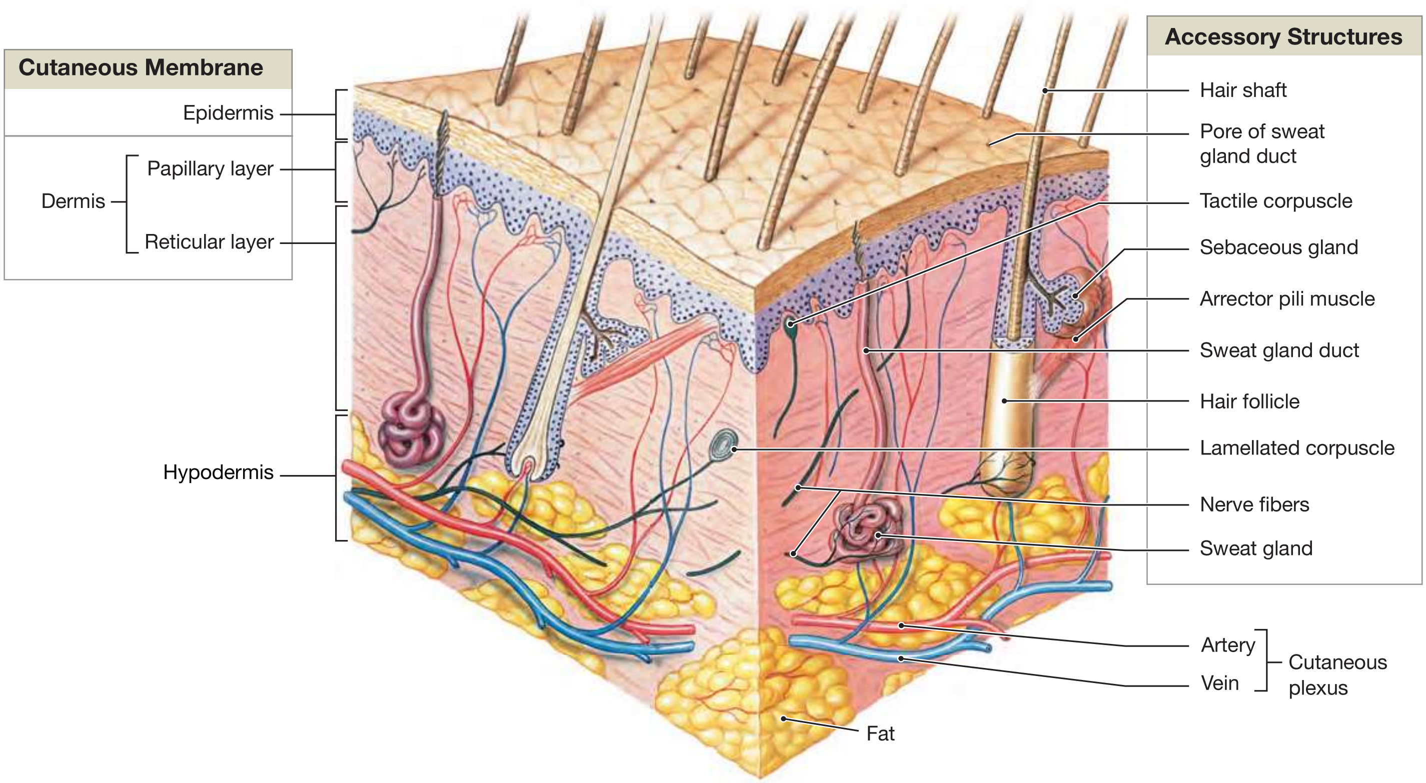
The general functions of the skin and hypodermis include the following:

- *Protection* of underlying tissues and organs against impact, abrasion, fluid loss, and chemical attack.

Figure 5–1 The Components of the Integumentary System. This diagrammatic section of skin illustrates the relationships among the two components of the cutaneous membrane (epidermis and dermis) and the accessory structures of the integumentary system (with the exception of nails, shown in *Figure 5–13*).



- *Excretion* of salts, water, and organic wastes by integumentary glands.
- *Maintenance* of normal body temperature through either insulation or evaporative cooling, as needed.
- *Production* of melanin, which protects underlying tissue from ultraviolet radiation.
- *Production* of keratin, which protects against abrasion and serves as a water repellent.
- *Synthesis of vitamin D_3*, a steroid that is converted to calcitriol, a hormone important to normal calcium metabolism.
- *Storage* of lipids in adipocytes in the dermis and in adipose tissue in the subcutaneous layer.
- *Detection* of touch, pressure, pain, and temperature stimuli, and the relaying of that information to the nervous system. (These *general senses*, which provide information about the external environment, will be considered further in Chapter 15.)

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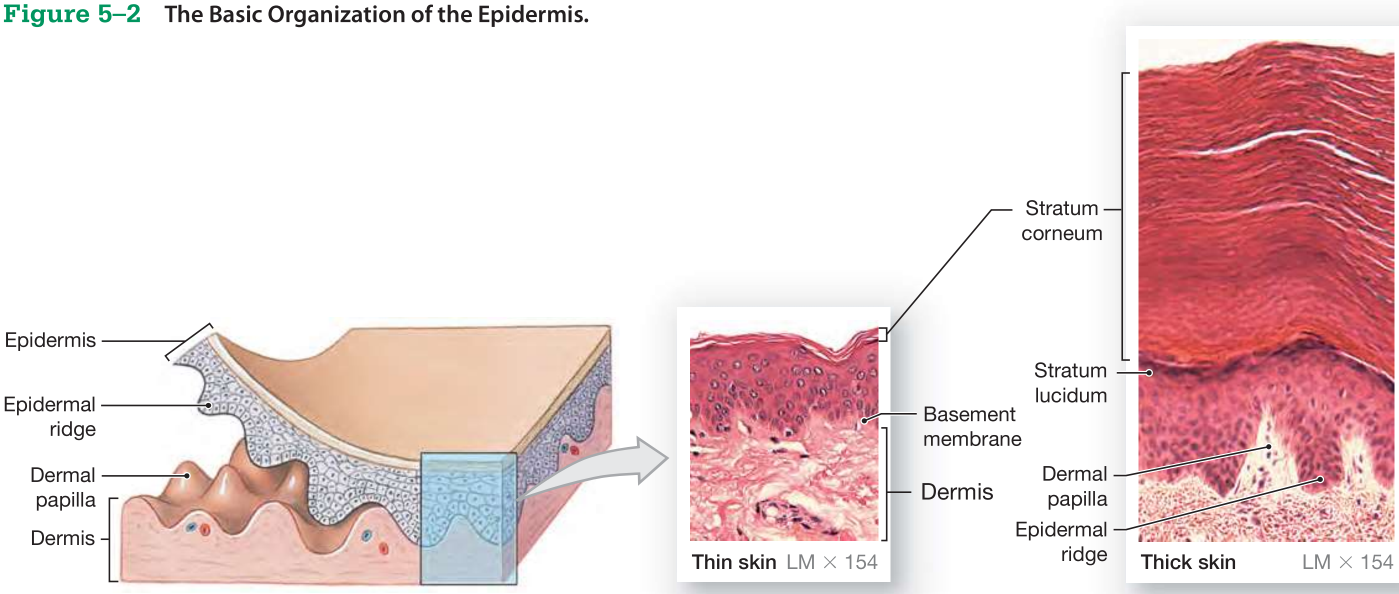
5-1 The epidermis is composed of strata (layers) with various functions

The epidermis consists of a stratified squamous epithelium. Recall from Chapter 4 that such an epithelium provides mechanical protection and also helps keep microorganisms outside the body. p. 114 Like all other epithelia, the epidermis is avascular. Because there are no local blood vessels, epidermal cells rely on the diffusion of nutrients and oxygen from capillaries within the dermis. As a result, the epidermal cells with the highest metabolic demands are found close to the basement membrane, where the diffusion distance is short. The superficial cells, far removed from the source of nutrients, are dead.

The epidermis is dominated by **keratinocytes** (ke-RAT-i-nō-sīts), the body's most abundant epithelial cells. These cells, which form several layers, contain large amounts of the protein *keratin* (discussed shortly). **Thin skin** (**Figure 5–2a,b**), which covers most of the body surface, contains four layers of keratinocytes, and is about as thick as the wall of a plastic sandwich bag (about 0.08 mm). **Thick skin** (**Figure 5–2c**), which occurs on the palms of the hands and the soles of the feet, contains a fifth layer, the *stratum lucidum*, and because it has a much thicker superficial layer (the *stratum corneum*), it is about as thick as a standard paper towel (about 0.5 mm). Note that the terms *thick* and *thin* refer to the relative thickness of the epidermis, not to the integument as a whole.

Figure 5–3 shows the layers of keratinocytes in a section of the epidermis in an area of thick skin. The boundaries between the layers are often difficult to see in a standard light micrograph. You will notice that the various layers have Latin names. The word *stratum* (plural, *strata*) means "layer"; the rest of the name refers to the function or appearance of the layer. The strata, in order from the basement membrane toward the free surface, are the *stratum basale*, the *stratum spinosum*, the *stratum granulosum*, the *stratum lucidum*, and the *stratum corneum*.

Figure 5–2 The Basic Organization of the Epidermis.



a The structural relationship and interface between the epidermis and underlying dermis. The proportions of the various layers differ with the location sampled.

b A micrograph of thin skin, which covers most of the exposed body surface.

c A micrograph of thick skin, which covers the surface of the palms and the soles of the feet.

Stratum Basale

The innermost epidermal layer is the **stratum basale** (STRA-tum bah-SA-le) or *stratum germinativum* (STRA-tum jer-mi-na-TĒ-vum) (**Figure 5–3**). Hemidesmosomes attach the cells of this layer to the basement membrane that separates the epidermis from the areolar tissue of the adjacent dermis. ⮌ p. 111 The stratum basale and the underlying dermis interlock, increasing the strength of the bond between the epidermis and dermis. The stratum basale forms **epidermal ridges,** which extend into the dermis and are adjacent to dermal projections called **dermal papillae** (singular, *papilla*; a nipple-shaped mound) that project into the epidermis (**Figure 5–2a**). These ridges and papillae are significant because the strength of the attachment is proportional to the surface area of the basement membrane: The more and deeper the folds, the larger the surface area becomes.

The contours of the skin surface follow the ridge patterns, which vary from small conical pegs (in thin skin) to the complex whorls seen on the thick skin of the palms and soles. Ridges on the palms and soles increase the surface area of the skin and increase friction, ensuring a secure grip. Ridge shapes are genetically determined. The pattern of your epidermal ridges is unique and does not change during your lifetime. The ridge patterns on the tips of the fingers are the basis of fingerprints (**Figure 5–4**), and are used for identification purposes.

Basal cells, or *germinative cells*, dominate the stratum basale. Basal cells are stem cells whose divisions replace the more superficial keratinocytes that are lost or shed at the epithelial surface. Skin surfaces that lack hair also contain specialized epithelial cells known as tactile cells *(Merkel cells)* scattered among the cells of the stratum basale. Tactile cells are sensitive to touch; when compressed, they release chemicals that stimulate sensory nerve endings. (The skin contains many other kinds of sensory receptors, as we will see in later sections.) The brown tones of skin result from the synthetic activities of pigment cells called *melanocytes*, ⮌ p. 122 which are distributed throughout the stratum basale, with cell processes extending into more superficial layers.

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Stratum Spinosum

Each time a stem cell divides, one of the daughter cells is pushed superficial to the stratum basale into the **stratum spinosum** (**Figure 5–3**), which consists of 8 to 10 layers of keratinocytes bound together by desmosomes. ⮌ p. 111 The name *stratum spinosum*, which means "spiny layer," refers to the fact that the cells look like miniature pincushions in standard histological sections. They look that way because the keratinocytes were processed with chemicals that shrank the cytoplasm but left the cytoskeletal elements and desmosomes intact. Some of

Figure 5–3 The Structure of the Epidermis. A portion of the epidermis in thick skin, showing the major layers of stratified epidermal cells. Note that dendritic cells cannot be distinguished in standard histological preparations.

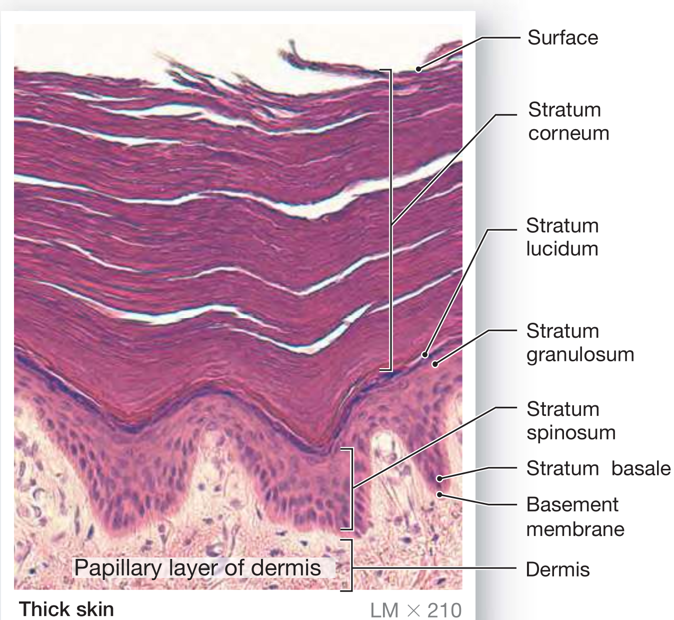
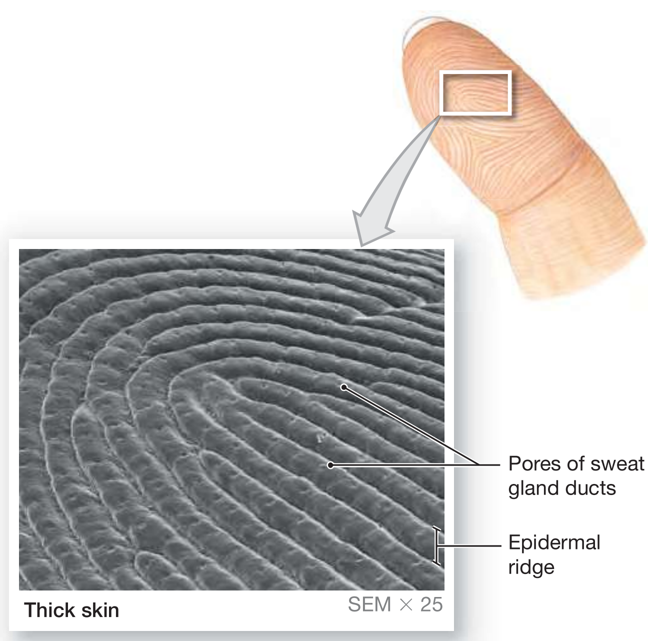


Figure 5–4 The Epidermal Ridges of Thick Skin. Fingerprints reveal the pattern of epidermal ridges. This scanning electron micrograph shows the ridges on a fingertip. The pits are the openings into the ducts of merocrine sweat glands.



the cells entering this layer from the stratum basale continue to divide, further increasing the thickness of the epithelium. The stratum spinosum also contains *dendritic (Langerhans) cells*, which participate in the immune response by stimulating a defense against (1) microorganisms that manage to penetrate the superficial layers of the epidermis and (2) superficial skin cancers. Dendritic cells and other cells of the immune response will be considered in Chapter 22.

Stratum Granulosum

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The region superficial to the stratum spinosum is the **stratum granulosum,** or "grainy layer" (**Figure 5–3**). The stratum granulosum consists of three to five layers of keratinocytes derived from the stratum spinosum. By the time cells reach this layer, most have stopped dividing and have started making large amounts of the proteins **keratin** (KER-a-tin; *keros*, horn) and **keratohyalin** (ker-a-tō-HĪ-a-lin). Keratin, a tough, fibrous protein, is the basic structural component of hair and nails in humans. ⮌ p. 115 As keratin fibers develop, the cells grow thinner and flatter, and their membranes thicken and become less permeable. Keratohyalin forms dense cytoplasmic granules that promote dehydration of the cell as well as aggregation and cross-linking of the keratin fibers. The nuclei and other organelles then disintegrate, and the cells die. Further dehydration creates a tightly interlocked layer of cells that consists of keratin fibers surrounded by keratohyalin.

Stratum Lucidum

In the thick skin of the palms and soles, a glassy **stratum lucidum** ("clear layer") covers the stratum granulosum (**Figure 5–3**). The cells in the stratum lucidum are flattened, densely packed, largely devoid of organelles, and filled with keratin.

Stratum Corneum

At the exposed surface of both thick skin and thin skin is the **stratum corneum** (KOR-nē-um; *cornu*, horn) (**Figure 5–3**). It normally contains 15 to 30 layers of keratinized cells. **Keratinization,** or *cornification*, is the formation of protective, superficial layers of cells filled with keratin. This process occurs on all exposed skin surfaces except the anterior surfaces of the eyes. The dead cells in each layer of the stratum corneum remain tightly interconnected by desmosomes. The connections are so secure that keratinized cells are generally shed in large groups or sheets rather than individually.

It takes 7 to 10 days for a cell to move from the stratum basale to the stratum corneum. The dead cells generally remain in the exposed stratum corneum for an additional two weeks before they are shed or washed away. This arrangement places the deeper portions of the epithelium and underlying tissues beneath a protective barrier of dead, durable, and expendable cells. Normally, the surface of the stratum corneum is relatively dry, so it is unsuitable for the growth of many microorganisms. Maintenance of this barrier involves coating the surface with lipid secretions from sebaceous glands.

The stratum corneum is water resistant, but not waterproof. Water from interstitial fluids slowly penetrates to the surface, to be evaporated into the surrounding air. You lose about 500 mL (about 1 pt) of water in this way each day. The process is called **insensible perspiration,** because you are unable to see or feel the water loss. In contrast, you are usually very aware of the **sensible perspiration** produced by active sweat glands. Damage to the epidermis can increase the rate of insensible perspiration. If the damage breaks connections between superficial and deeper layers of the epidermis, fluid will accumulate in pockets, or *blisters*, within the epidermis. (Blisters also form between the epidermis and dermis if the basement membrane is damaged.) If damage to the stratum corneum reduces its effectiveness as a water barrier, the rate of insensible perspiration skyrockets, and a potentially dangerous fluid loss occurs. This is a serious consequence of severe burns and a complication in the condition known as *xerosis* (excessively dry skin).

When the skin is immersed in water, osmotic forces may move water into or out of the epithelium. ⮌ p. 88 Sitting in a freshwater bath causes water to move into the epidermis, because fresh water is hypotonic (has fewer dissolved materials) compared with body fluids. The epithelial cells of the stratum corneum may swell to four times their normal volumes, a phenomenon particularly noticeable in the thickly keratinized areas of the palms and soles. Swimming in the ocean reverses the direction of osmotic flow; because the ocean is a hypertonic solution, water leaves the body, crossing the epidermis from the underlying tissues. The process is slow, but long-term exposure to seawater endangers survivors of a shipwreck by accelerating dehydration.

Checkpoint

1. **Identify the layers of the epidermis.**
2. **Dandruff is caused by excessive shedding of cells from the outer layer of skin in the scalp. Thus, dandruff is composed of cells from which epidermal layer?**
3. **A splinter that penetrates to the third layer of the epidermis of the palm is lodged in which layer?**
4. **Why does swimming in fresh water for an extended period cause epidermal swelling?**
5. **Some criminals sand the tips of their fingers so as not to leave recognizable fingerprints. Would this practice permanently remove fingerprints? Why or why not?**

See the blue Answers tab at the back of the book.

5-2 ◗ Factors influencing skin color are epidermal pigmentation and dermal circulation

In this section we examine how pigments in the epidermis and blood flow in the dermis influence skin color.

The Role of Epidermal Pigmentation

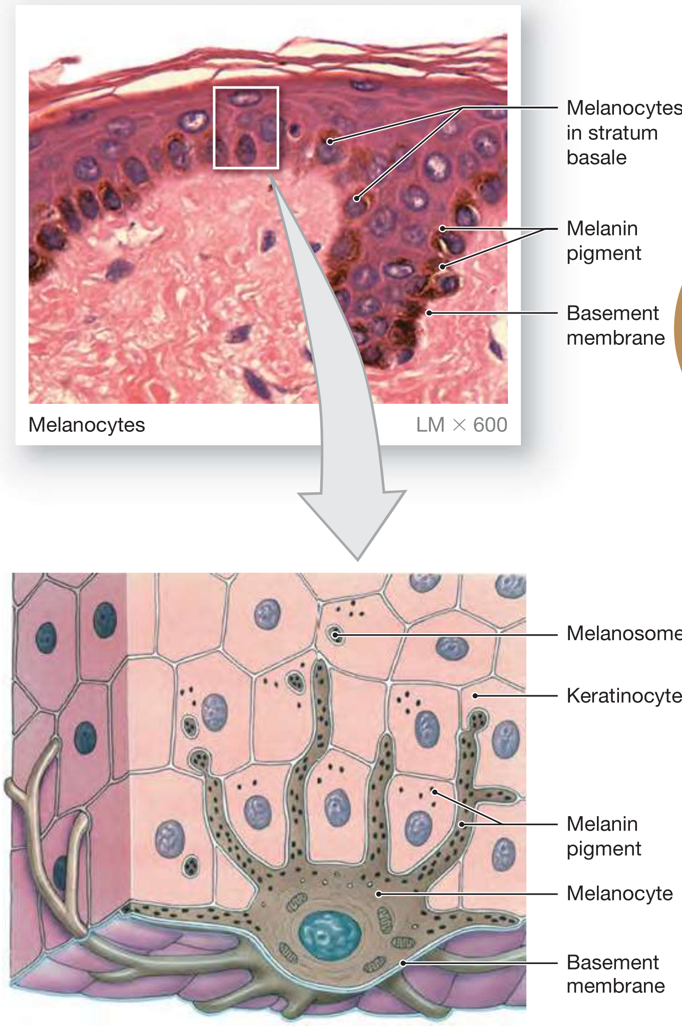
The epidermis contains variable quantities of two pigments: carotene and melanin.

Carotene (KAR-uh-tēn) is an orange-yellow pigment that normally accumulates in epidermal cells. It is most apparent in cells of the stratum corneum of light-skinned individuals, but it also accumulates in fatty tissues in the deep dermis and subcutaneous layer. Carotene is found in a variety of orange vegetables, such as carrots and squashes, and thus the skin of individuals who eat lots of carrots can actually turn orange from an overabundance of carotene. The color change is very striking in pale-skinned individuals, but less obvious in people with darker skin pigmentation. Carotene can be converted to vitamin A, which is required for both the normal maintenance of epithelia and the synthesis of photoreceptor pigments in the eye.

Melanin is a brown, yellow-brown, or black pigment produced by melanocytes, pigment cells introduced in Chapter 4. The **melanocytes** involved are located in the stratum basale, squeezed between or deep to the epithelial cells (**Figure 5–5**). Melanocytes manufacture melanin from the amino acid *tyrosine*, and package it in intracellular vesicles called *melanosomes*. These vesicles travel within the processes of melanocytes and are transferred intact to keratinocytes. The transfer of pigmentation colors the keratinocyte temporarily, until the melanosomes are destroyed by fusion with lysosomes. In individuals with pale skin, this transfer occurs in the stratum basale and stratum spinosum, and the cells of more superficial layers lose their pigmentation. In dark-skinned people, the melanosomes are larger and the transfer may occur in the stratum granulosum as well; skin pigmentation is thus darker and more persistent.

The ratio of melanocytes to basal cells ranges between 1:4 and 1:20, depending on the region of the body. The skin covering most areas of the body has about 1000 melanocytes per square millimeter. The cheeks and forehead, the nipples, and the genital region (the scrotum of males and the labia majora of females) have higher concentrations (about 2000 per square millimeter). The differences in skin pigmentation among individuals do not reflect different numbers of melanocytes, but merely different levels of synthetic activity. Even the melanocytes of *albino* individuals are distributed normally, although the cells are incapable of producing melanin. There can also be localized differences in the rates of melanin production

Figure 5–5 Melanocytes. The micrograph and accompanying drawing indicate the location and orientation of melanocytes in the stratum basale of a dark-skinned person.



by your melanocytes. *Freckles* are small, pigmented areas on relatively pale skin. These spots, which typically have an irregular border, represent the areas serviced by melanocytes that are producing larger-than-average amounts of melanin. Freckles tend to be most abundant on surfaces such as the face, probably due to its greater exposure to the sun. *Lentigos* are similar to freckles, but have regular borders and contain abnormal melanocytes. *Senile lentigos*, or *liver spots*, are variably pigmented areas that develop on sun-exposed skin in older individuals with pale skin.

The melanin in keratinocytes protects your epidermis and dermis from the harmful effects of sunlight, which contains significant amounts of **ultraviolet (UV) radiation.** A small amount of UV radiation is beneficial, because it stimulates the epidermal production of a compound required for calcium ion

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homeostasis (a process discussed in a later section). However, UV radiation can also damage DNA, causing mutations and promoting the development of cancer. Within keratinocytes, melanosomes become concentrated in the region around the nucleus, where the melanin pigments act like a sunshade to provide some UV protection for the DNA in those cells.

UV radiation can also produce some immediate effects—burns, which if severe can damage both the epidermis and the dermis. Thus, the presence of pigment layers in the epidermis helps protect both epidermal and dermal tissues. However, although melanocytes respond to UV exposure by increasing their activity, the response is not rapid enough to prevent sunburn the first day you spend at the beach. Melanin synthesis accelerates slowly, peaking about 10 days after the initial exposure. Individuals of any skin color can suffer sun damage to the integument, but dark-skinned individuals have greater initial protection against the effects of UV radiation.

Over time, cumulative damage to the integument by UV exposure can harm fibroblasts, causing impaired maintenance of the dermis. The resulting structural alterations lead to premature wrinkling. In addition, skin cancers can develop from chromosomal damage in basal cells or melanocytes. One of the major consequences of the global depletion of the ozone layer in Earth's upper atmosphere is likely to be a sharp increase in the rates of skin cancers (such as *malignant melanoma*). In recent years such increased cancer rates have been reported in Australia, which has already experienced a significant loss of ozone, as well as in the United States, Canada, and parts of Europe, which have experienced a more moderate ozone loss. For this reason, limiting UV exposure through a combination of protective clothing and sunscreens (or, better yet, sunblocks) is recommended during outdoor activities.

The Role of Dermal Circulation

Blood contains red blood cells filled with the pigment *hemoglobin*, which binds and transports oxygen in the bloodstream. When bound to oxygen, hemoglobin is bright red, giving capillaries in the dermis a reddish tint that is most apparent in lightly pigmented individuals. If those vessels are dilated, the red tones become much more pronounced. For example, your skin becomes flushed and red when your body temperature rises because the superficial blood vessels dilate so that the skin can act like a radiator and lose heat. ⮌ p. 12

When its blood supply is temporarily reduced, the skin becomes relatively pale; a light-skinned individual who is frightened may "turn white" as a result of a sudden drop in blood supply to the skin. During a sustained reduction in circulatory supply, the oxygen levels in the tissues decline, and under these conditions, hemoglobin releases oxygen and turns a much darker red. Seen from the surface, the skin then takes on a bluish coloration called **cyanosis** (sī-uh-NŌ-sis; *kyanos*, blue). In individuals of any skin color, cyanosis is most apparent in areas of very thin skin, such as the lips or beneath the nails. It can occur in response to extreme cold or as a result of cardiovascular or respiratory disorders, such as heart failure or severe asthma.

Because the skin is easily observed, changes in skin appearance can be useful in diagnosing diseases that primarily affect other body systems. Several diseases can produce secondary effects on skin color and pigmentation:

- In *jaundice* (JAWN-dis), the liver is unable to excrete bile, so a yellowish pigment accumulates in body fluids. In advanced stages, the skin and whites of the eyes turn yellow.
- Some tumors affecting the pituitary gland result in the secretion of large amounts of *melanocyte-stimulating hormone (MSH)*. This hormone causes a darkening of the skin, as if the individual has an extremely deep bronze tan.
- In *Addison's disease*, the pituitary gland secretes large quantities of *adrenocorticotropic hormone (ACTH)*, which is structurally similar to MSH. The effect of ACTH on skin color is similar to that of MSH.
- In *vitiligo* (vit-i-LĪ-gō), individuals lose their melanocytes. The condition develops in about 1 percent of the population, and its incidence increases among individuals with thyroid gland disorders, Addison's disease, or several other disorders. It is suspected that vitiligo develops when the immune defenses malfunction and antibodies attack normal melanocytes. The primary problem with vitiligo is cosmetic, especially for individuals with darkly pigmented skin.

Checkpoint

6. **Name the two pigments contained in the epidermis.**
7. **Why does exposure to sunlight or sunlamps darken skin?**
8. **Why does the skin of a fair-skinned person appear red during exercise in hot weather?**

See the blue Answers tab at the back of the book.

5-3 ◗ Sunlight causes epidermal cells to convert a steroid into vitamin D_3

Although too much sunlight can damage epithelial cells and deeper tissues, limited exposure to sunlight is beneficial. When exposed to ultraviolet radiation, epidermal cells in the stratum spinosum and stratum basale convert a cholesterol-related steroid into **cholecalciferol** (kō-le-kal-SIF-er-ol), or **vitamin D_3.** The liver then converts cholecalciferol into an intermediary product used by the kidneys to synthesize the hormone **calcitriol** (kal-si-TRĪ-ol). Calcitriol is essential for the normal absorption of calcium and phosphorus by the small intestine; an inadequate supply leads to impaired bone maintenance and growth.

Clinical Note — Skin Cancer

The ABCs and D of skin cancer

Almost everyone has several benign tumors of the skin; moles and warts are common examples. However, **skin cancers,** which are more dangerous, are the most common form of cancer.

An *actinic keratosis* is a scaly area on sun-damaged skin. It is an indication that sun damage has occurred, but it is not a sign of skin cancer. In contrast, *basal cell carcinoma* (**Figure 5–6a**), a cancer that originates in the stratum basale, is the most common skin cancer. Roughly two-thirds of these cancers appear in body areas subjected to chronic UV exposure. Researchers have identified genetic factors that predispose people to this condition. *Squamous cell carcinomas* are less common, but almost totally restricted to areas of sun-exposed skin. Metastasis seldom occurs in squamous cell carcinomas and virtually never in basal cell carcinomas, and most people survive these cancers. The usual treatment involves the surgical removal of the tumor, and 95 percent of patients survive for five years or longer after treatment. (This statistic, the *5-year survival rate*, is a common method of reporting long-term outcomes.)

Unlike these common and seldom life-threatening cancers, *malignant melanomas* (mel-a-NŌ-muz) (**Figure 5–6b**) are extremely dangerous. In this condition, cancerous melanocytes grow rapidly and metastasize through the lymphatic system. The outlook for long-term survival is in many cases determined by how early the condition is diagnosed. If the cancer is detected early, while it is still localized, the 5-year survival rate is 99 percent; if it is not detected until extensive metastasis has occurred, the survival rate drops to 14 percent.

Figure 5–6 **Skin Cancers.**

a **Basal cell carcinoma**

b **Melanoma**

To detect melanoma at an early stage, you must examine your skin, and you must know what to look for. The mnemonic ABCD makes it easy to remember this cancer's key characteristics:

- **A** is for *asymmetry:* Melanomas tend to be irregular in shape. Typically, they are raised; they may also ooze or bleed.
- **B** is for *border:* The border of a melanoma is generally irregular, and in some cases notched.
- **C** is for *color:* A melanoma is generally mottled, with any combination of tan, brown, black, red, pink, white, and blue tones.
- **D** is for *diameter:* Any skin growth more than about 5 mm (0.2 in.) in diameter, or approximately the area covered by the eraser on a pencil, is dangerous.

Fair-skinned individuals who live in the tropics are most susceptible to all forms of skin cancer, because their melanocytes are unable to shield them from UV radiation. Sun damage can be prevented by avoiding exposure to the sun during the middle of the day and by using a sunblock (not a tanning oil) before any sun exposure. This practice also delays the cosmetic problems of aging and wrinkling. *Everyone* who spends any time out in the sun should choose a broad-spectrum sunblock with a sun protection factor (SPF) of at least 15; blondes, redheads, and people with very pale skin are better off with an SPF of 20 to 30. (The risks are the same for those who spend time in a tanning salon or tanning bed.) The protection offered by these "sunscreens" is afforded by both organic molecules that absorb UV radiation and inorganic pigments that absorb, scatter, and reflect UV rays. The higher the SPF factor, the more of these chemicals the product contains, and the fewer UV rays are able to penetrate to the skin's surface. Wearing a hat with a brim and panels to shield the neck and face, long pants, and long-sleeved shirts provide added protection.

The use of sunblocks will be even more important as the ozone gas in the upper atmosphere is further destroyed by our industrial emissions. Ozone absorbs UV radiation before it reaches Earth's surface; in doing so, ozone assists the melanocytes in preventing skin cancer. Australia, the continent that is most affected by the depletion of ozone above the South Pole (the "ozone hole"), is already reporting an increased incidence of skin cancers.

The term *vitamin* is usually reserved for essential organic nutrients that must be obtained from the diet because the body either cannot make them or makes them in insufficient amounts. If present in the diet, cholecalciferol can be absorbed by the digestive tract, and if the skin cannot make enough cholecalciferol, a dietary supply will maintain normal bone development. Under these circumstances, dietary cholecalciferol acts like a vitamin, and this accounts for the alternative name for cholecalciferol: *vitamin* D_3. If cholecalciferol cannot be produced by the skin and is not included in the diet, bone development is abnormal and bone maintenance is inadequate. For example, children who live in areas with overcast skies and whose diet lacks cholecalciferol

Figure 5–7 **Rickets.** Rickets, a disease caused by vitamin D_3 deficiency, results in the bending of abnormally weak and flexible bones under the weight of the body, plus other structural changes.

can have abnormal bone development. This condition, called *rickets* (**Figure 5–7**), has largely been eliminated in the United States because dairy companies are required to add cholecalciferol, usually identified as "vitamin D," to the milk sold in grocery stores. In Chapter 6, we will consider the hormonal control of bone growth in greater detail.

Checkpoint

9. **Explain the relationship between sunlight exposure and vitamin D_3 synthesis.**
10. **In some cultures, women must be covered completely, except for their eyes, when they go outside. Explain why these women may develop bone problems later in life.**

See the blue Answers tab at the back of the book.

5-4 ◗ Epidermal growth factor has several effects on the epidermis and epithelia

Epidermal growth factor (EGF) is one of the peptide growth factors introduced in Chapter 3. ⮌ p. 100 Although named for its effects on the epidermis, we now know that EGF has widespread effects on epithelia throughout the body; EGF is produced by the salivary glands and glands of the duodenum. Among the roles of EGF are the following:

- Promoting the divisions of basal cells in the stratum basale and stratum spinosum
- Accelerating the production of keratin in differentiating keratinocytes
- Stimulating epidermal development and epidermal repair after injury
- Stimulating synthetic activity and secretion by epithelial glands

In the procedure known as tissue culture, cells are grown under laboratory conditions for experimental or therapeutic use. Epidermal growth factor has such a pronounced effect that it can be used in tissue culture to stimulate the growth and division of epidermal cells (or other epithelial cells). It is now possible to grow sheets of epidermal cells for use in the treatment of severe or extensive burns. The burned areas can be covered by epidermal sheets "grown" from a small sample of intact skin from another part of the burn victim's body. (We will consider this treatment later in the chapter when we discuss burns.)

Checkpoint

11. **Name the sources of epidermal growth factor in the body.**
12. **Identify some roles of epidermal growth factor pertaining to the epidermis.**

See the blue Answers tab at the back of the book.

5-5 ◗ The dermis is the tissue layer that supports the epidermis

The dermis lies between the epidermis and the hypodermis (**Figure 5–1**). In this section we will discuss the organization and properties of the dermis along with dermal circulation and innervation. The dermis has two major components: (1) a superficial *papillary layer* and (2) a deeper *reticular layer* (**Figure 5–1**).

The **papillary layer,** which consists of areolar tissue, contains the capillaries, lymphatics, and sensory neurons that supply the surface of the skin. The papillary layer derives its name from the dermal papillae that project between the epidermal ridges (**Figure 5–2a**).

The **reticular layer,** deep to the papillary layer, consists of an interwoven meshwork of dense irregular connective tissue containing both collagen and elastic fibers. ⮌ p. 125 Bundles of collagen fibers extend superficially beyond the reticular layer to blend into those of the papillary layer, so the boundary between the two layers is indistinct. Collagen fibers of the reticular layer also extend into the deeper hypodermis. In addition to extracellular protein fibers, the dermis contains all the cells of connective tissue proper. p. 122 Accessory organs of epidermal origin, such as hair follicles and sweat glands, extend into the dermis. In addition, the reticular and papillary layers of the dermis contain networks of blood vessels and nerve fibers (**Figure 5–1**).

Because of the abundance of sensory receptors in the skin, regional infection or inflammation can be very painful. **Dermatitis** (der-muh-TĪ-tis) is an inflammation of the skin that primarily involves the papillary layer. The inflammation typically begins in a part of the skin exposed to infection or irritated by chemicals, radiation, or mechanical stimuli. Dermatitis may cause no discomfort, or it may produce an annoying itch, as in poison ivy. Other forms of the condition can be quite painful, and the inflammation can spread rapidly across the entire integument.

Dermal Strength and Elasticity

The presence of collagen and elastic fibers give the dermis strength and elasticity. *Collagen fibers* are very strong and resist stretching, but they are easily bent or twisted. *Elastic fibers* permit stretching and then recoil to their original length. The elastic fibers provide flexibility, and the collagen fibers limit that flexibility to prevent damage to the tissue.

The water content of the skin also helps maintain its flexibility and resilience, properties collectively known as *skin turgor*. One of the signs of dehydration is the loss of skin turgor, revealed by pinching the skin on the back of the hand. A dehydrated dermis will remain peaked when pinched, whereas hydrated skin will flatten out. Aging, hormones, and the destructive effects of ultraviolet radiation permanently reduce the amount of elastin in the dermis; the result is wrinkles and sagging skin. The extensive distortion of the dermis that occurs over the abdomen during pregnancy or after substantial weight gain can exceed the elastic limits of the skin. The resulting damage to the dermis prevents it from recoiling to its original size after delivery or weight loss. The skin then wrinkles and creases, creating a network of **stretch marks.**

Tretinoin (Retin-A) is a derivative of vitamin A that can be applied to the skin as a cream or gel. This drug was originally developed to treat acne, but it also increases blood flow to the dermis and stimulates dermal repair. As a result, the rate of wrinkle formation decreases, and existing wrinkles become smaller. The degree of improvement varies among individuals.

Cleavage Lines

Most of the collagen and elastic fibers at any location are arranged in parallel bundles oriented to resist the forces applied to the skin during normal movement. The resulting pattern of fiber bundles in the skin establishes **cleavage (tension) lines.**

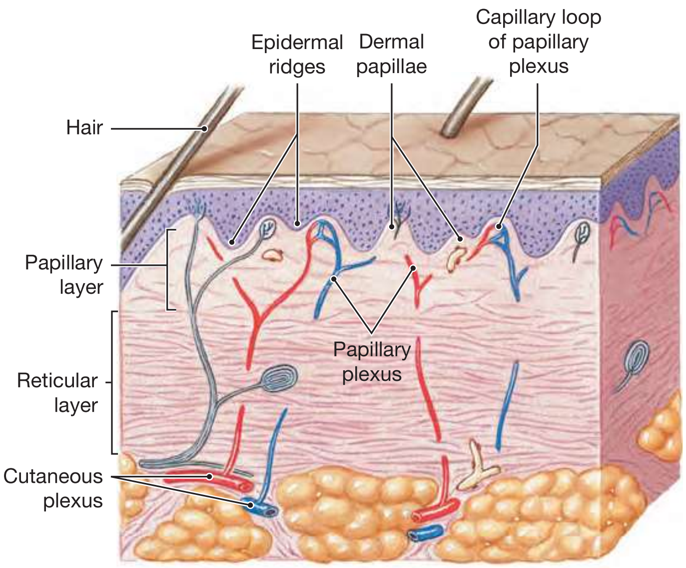
Figure 5–8 Cleavage Lines of the Skin. Cleavage lines follow the pattern of fiber bundles in the skin. They reflect the orientation of collagen fiber bundles in the dermis.

Cleavage lines are clinically significant: A cut parallel to a cleavage line will usually remain closed and heal with little scarring, whereas a cut at right angles to a cleavage line will be pulled open as severed elastic fibers recoil and will result in greater scarring. For these reasons, surgeons choose to make incisions parallel to cleavage lines (**Figure 5–8**).

The Dermal Blood Supply

Arteries supplying the skin form networks in the hypodermis along its border with the reticular layer of the dermis. This network is called the *cutaneous plexus* (**Figure 5–9**). Tributaries of these arteries supply both the adipose tissues of the subcutaneous layer and the tissues of the integument. As small arteries travel toward the epidermis, branches supply the hair follicles, sweat glands, and other structures in the dermis. On reaching the

Figure 5–9 Dermal Circulation. Shown are the cutaneous and papillary plexuses.



papillary layer, the small arteries form another branching network, the *papillary plexus*, which provides arterial blood to capillary loops that follow the contours of the epidermis–dermis boundary (**Figure 5–9**). These capillaries empty into a network of small veins that form a venous plexus deep to the papillary plexus. This network is in turn connected to a larger venous plexus in the hypodermis. Trauma to the skin often results in a *contusion*, or bruise. As a result of the rupture of dermal blood vessels, blood leaks into the dermis, and the area develops the familiar "black and blue" color.

Clinical Note

Decubitis Ulcers Problems with dermal circulation affect both the epidermis and the dermis. An *ulcer* is a localized shedding of an epithelium. *Decubitis ulcers*, or *bedsores*, affect patients whose circulation is restricted, especially when a splint, a cast, or lying in bed continuously compresses superficial blood vessels. Such sores most commonly affect the skin covering joints or bony prominences, where dermal blood vessels are pressed against deeper structures. The chronic lack of circulation kills epidermal cells, removing a barrier to bacterial infection; eventually, dermal tissues deteriorate as well. (Cell death and tissue destruction, or *necrosis*, can occur in any tissue deprived of adequate blood flow.) Bedsores can be prevented or treated by frequently changing the position of the body or by placing patients in specially designed beds containing deflating and inflating air coils; both approaches vary the pressures applied to local blood vessels.

Innervation of the Skin

The integument is filled with sensory receptors, and anything that comes in contact with the skin—from the lightest touch of a mosquito to the weight of a loaded backpack—initiates a nerve impulse that can reach our conscious awareness. Nerve fibers in the skin control blood flow, adjust gland secretion rates, and monitor sensory receptors in the dermis and the deeper layers of the epidermis. We have already noted that the deeper layers of the epidermis contain tactile cells; sensory terminals known as *tactile discs* monitor these cells. The epidermis also contains the extensions of sensory neurons that provide sensations of pain and temperature. The dermis contains similar receptors, as well as other, more specialized receptors. Examples shown in **Figure 5–1** include receptors sensitive to light touch—*tactile corpuscles*, located in dermal papillae—and receptors sensitive to deep pressure and vibration—*lamellated corpuscles*, in the reticular layer.

Even this partial list of the receptors found in the skin is enough to highlight the importance of the integument as a sensory structure. We will return to this topic in Chapter 15, where we consider not only what receptors are present, but how they function.

Checkpoint

13. **Describe the location of the dermis.**
14. **Where are the capillaries and sensory neurons that supply the epidermis located?**
15. **What accounts for the ability of the dermis to undergo repeated stretching?**

See the blue Answers tab at the back of the book.

5-6 The hypodermis is tissue beneath the dermis that connects it to underlying tissues

The connective tissue fibers of the reticular layer are extensively interwoven with those of the **hypodermis.** The boundary between the two is generally indistinct (**Figure 5–1**). Although the hypodermis is not a part of the integument, it is important in stabilizing the position of the skin in relation to underlying tissues, such as skeletal muscles or other organs, while permitting independent movement.

The hypodermis consists of areolar and adipose tissues and is quite elastic. Only its superficial region contains large arteries and veins. The venous circulation of this region contains a substantial amount of blood, and much of this volume will shift to the general circulation if these veins constrict. For that reason, the skin is often described as a *blood reservoir*. The rest of the hypodermis contains a limited number of capillaries and no vital organs. This last characteristic makes **subcutaneous**

Clinical Note

Liposuction The accumulation of excessive amounts of adipose tissue increases the risks of diabetes, stroke, and other serious conditions. Dietary restrictions and increased activity levels are often successful in promoting weight loss and reducing these risks. However, a "quick fix" is often promised by a surgical procedure called **liposuction** or **lipoplasty.** In this procedure, subcutaneous adipose tissue is removed through a tube inserted deep to the skin. Adipose tissue tears relatively easily, and suction applied to the tube rips chunks of adipose tissue from the body. After liposuction, the skin is loose fitting, and until it recoils, a tight-fitting garment is usually worn. Liposuction is relatively common and is increasing in popularity. According to the American Society of Plastic Surgeons, 245,138 liposuction procedures were performed in 2008.

Although it might sound like an easy way to remove unwanted fat, in practice, liposuction can be dangerous. There are risks from anesthesia, bleeding (adipose tissue is quite vascular), sensory loss, infection, and fluid loss. The death rate from liposuction procedures is 1 in 5000—very high for what is basically cosmetic surgery that provides only a temporary solution to a chronic problem. As noted in Chapter 4, unless there are changes in diet and lifestyle, the damaged adipose tissue will repair itself, and areas of areolar tissue will convert to adipose tissue. Over time, the surgery will have to be repeated.

injection—by means of a **hypodermic needle**—a useful method of administering drugs.

Most infants and small children have extensive "baby fat," which provides extra insulation and helps reduce heat loss. Subcutaneous fat also serves as a substantial energy reserve and as a shock absorber for the rough-and-tumble activities of our early years. As we grow, the distribution of subcutaneous fat changes. The greatest changes occur in response to circulating sex hormones. Beginning at puberty, men accumulate subcutaneous fat at the neck, on the arms, along the lower back, and over the buttocks. In contrast, women accumulate subcutaneous fat at the breasts, buttocks, hips, and thighs. In adults of either gender, the subcutaneous layer of the backs of the hands and the upper surfaces of the feet contain few fat cells, whereas distressing amounts of adipose tissue can accumulate in the abdominal region, producing a prominent "potbelly."

Checkpoint

16. **List the two terms for the tissue that connects the dermis to underlying tissues.**
17. **Describe the hypodermis.**
18. **Identify several functions of subcutaneous fat.**

See the blue Answers tab at the back of the book.

5-7 Hair is composed of keratinized dead cells that have been pushed to the surface

Hair and several other structures—hair follicles, sebaceous and sweat glands, and nails—are considered accessory structures of the integument. During embryological development, these structures originate from the epidermis, so they are also known as *epidermal derivatives*. Although located in the dermis, they project through the epidermis to the integumentary surface. ATLAS: Embryology Summary 5: The Development of the Integumentary System

Hairs project above the surface of the skin almost everywhere, except over the sides and soles of the feet, the palms of the hands, the sides of the fingers and toes, the lips, and portions of the external genitalia. The human body has about 2.5 million hairs, and 75 percent of them are on the general body surface, not on the head. Hairs are nonliving structures produced in organs called **hair follicles.**

The hairs and hair follicles on your body have important functions. The 500,000 or so hairs on your head protect your scalp from ultraviolet radiation, help cushion light impacts to the head, and insulate the skull. The hairs guarding the entrances to your nostrils and external ear canals help prevent the entry of foreign particles and insects, and your eyelashes perform a similar function for the surface of the eye. Eyebrows are also important because they help keep sweat out of your eyes. However, hairs are also extremely important as sensory receptors.

Figure 5–10 illustrates important details about the structure of hairs and hair follicles. Each hair follicle opens onto the surface of the epidermis but extends deep into the dermis and usually into the hypodermis. Deep to the epidermis, each follicle is wrapped in a dense connective tissue sheath. A **root hair plexus** of sensory nerves surrounds the base of each hair follicle (**Figure 5–10a**). As a result, you can feel the movement of the shaft of even a single hair. This sensitivity provides an early-warning system that may help prevent injury; for example, you may be able to swat a mosquito before it reaches your skin.

A bundle of smooth muscle cells forms the **arrector pili** (a-REK-tor PI-lē; plural, *arrectores pilorum*) muscle, which extends from the papillary layer of the dermis to the connective tissue sheath surrounding the hair follicle. When stimulated, the arrector pili muscle contracts, pulling on the follicle and forcing the hair to stand erect. Contraction may be the result of emotional states, such as fear or rage, or a response to cold, producing "goose bumps." In a furry mammal, this action increases the thickness of its insulating coat. Although humans do not receive any comparable insulating benefits, the response persists.

Each hair is a long, cylindrical structure that extends outward, past the epidermal surface (**Figure 5–10a,c,d**). The **hair root**—the portion that anchors the hair into the skin—begins

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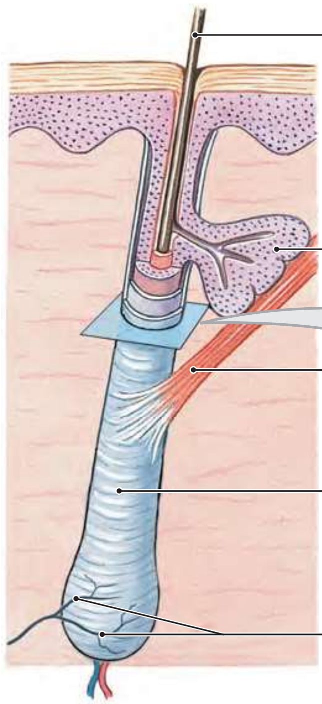
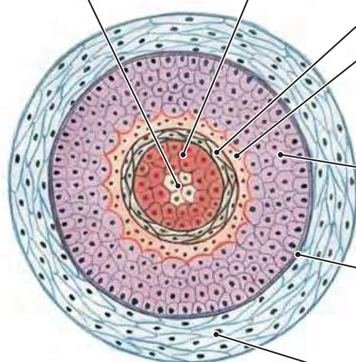
Figure 5–10 Hair Follicles and Hairs.



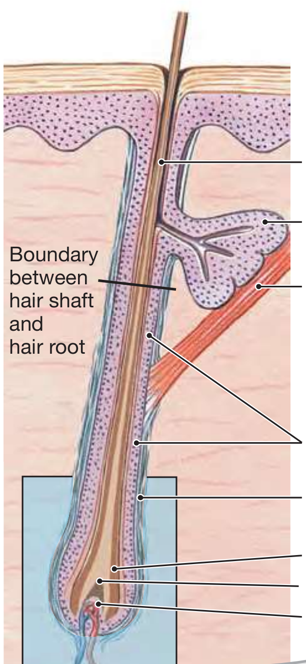
a Single hair follicle, showing the associated accessory structures; a superficial view of the deeper portions of the follicle illustrates the connective tissue sheath and the root hair plexus.

Hair Structure		
The medulla, or core, of the hair contains a flexible **soft keratin**.	The cortex contains thick layers of **hard keratin**, which give the hair its stiffness.	The cuticle, although thin, is very tough, and it contains hard keratin.

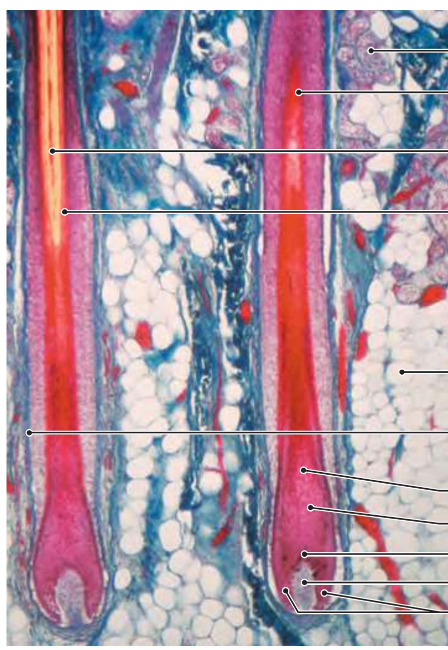


Follicle Structure
The **internal root sheath** surrounds the hair root and the deeper portion of the shaft. The cells of this sheath disintegrate quickly, and this layer does not extend the entire length of the hair follicle.
The **external root sheath** extends from the skin surface to the hair matrix.
The **glassy membrane** is a thickened, clear layer wrapped in the dense connective tissue sheath of the follicle as a whole.
Connective tissue sheath

b Cross section through a hair follicle and a hair, near the junction between the hair root and hair shaft.



c Diagrammatic sectional view along the long axis of a hair follicle.



d Longitudinal section through two hair follicles, showing the base of the follicle and the matrix and papilla at the root of the hair.

at the base of the hair, at the *hair bulb*, and extends distally to the point at which the internal organization of the hair is complete, about halfway to the skin surface. The **hair shaft,** part of which we see on the surface, extends from this halfway point to the exposed tip of the hair.

Hair Production

Hair production begins at the base of a hair follicle (**Figure 5–10**). Here a mass of epithelial cells forms a cap, called the **hair bulb,** which surrounds a small **hair papilla,** a peg of connective tissue containing capillaries and nerves. The superficial cells of the hair bulb are responsible for producing the hair; they form a layer called the **hair matrix.** Basal cells near the center of the hair matrix divide, producing daughter cells that are gradually pushed toward the surface. Daughter cells closest to the center of the matrix form the **medulla,** or core, of the hair. Daughter cells farther from the center of the hair matrix form the **cortex,** an intermediate layer. Those at the edges of the hair matrix form the **cuticle,** which will be the surface of the hair.

As cell divisions continue at the hair matrix, the daughter cells are pushed toward the surface of the skin, and the hair gets longer. Keratinization is completed by the time these cells approach the surface. At the level that corresponds to the start of the hair shaft, the cells of the medulla, cortex, and cuticle are dead, and the keratinization process is at an end. The epithelial cells of the follicle walls are organized into several concentric layers. Moving outward from the hair cuticle, these layers include the internal root sheath, the external root sheath, and the glassy membrane (**Figure 5–10b**).

The Hair Growth Cycle

Hairs grow and are shed according to a **hair growth cycle.** A hair in the scalp grows for two to five years, at a rate of about 0.33 mm per day. Variations in the growth rate and in the duration of the hair growth cycle account for individual differences in the length of uncut hair.

While hair is growing, the cells of the hair root absorb nutrients and incorporate them into the hair structure. As a result, clipping or collecting hair for analysis can be helpful in diagnosing several disorders. For example, hairs of individuals with lead poisoning or other heavy-metal poisoning contain high levels of those metal ions. Hair samples containing nucleated cells can also be used for identification purposes through DNA fingerprinting. ⮌ p. 80

As it grows, the root is firmly attached to the matrix of the follicle. At the end of the growth cycle, the follicle becomes inactive. The hair is now termed a **club hair.** The follicle gets smaller, and over time the connections between the hair matrix and the club hair root break down. When another cycle begins, the follicle produces a new hair; the old club hair is pushed to the surface and is shed.

Healthy adults with a full head of hair typically lose about 100 head hairs each day. Sustained losses of more than 100 hairs per day generally indicate that a net loss of hairs is under way, and noticeable hair loss will eventually result. Temporary increases in hair loss can result from drugs, dietary factors, radiation, an excess of vitamin A, high fever, stress, or hormonal factors related to pregnancy. In males, changes in the level of the sex hormones circulating in the blood can affect the scalp, causing a shift in the type of hair produced (discussed shortly), beginning at the temples and the crown of the head. This alteration is called *male pattern baldness*. Some cases of male pattern baldness respond to drug therapies, such as the topical application of *minoxidil (Rogaine)*.

Types of Hairs

Hairs first appear after about three months of embryonic development. These hairs, collectively known as *lanugo* (la-NOO-gō), are extremely fine and unpigmented. Most lanugo hairs are shed before birth. They are replaced by one of two types of hairs in the adult integument: vellus hairs or terminal hairs. **Vellus hairs** are the fine "peach fuzz" hairs located over much of the body surface. **Terminal hairs** are heavy, more deeply pigmented, and sometimes curly. The hairs on your head, including your eyebrows and eyelashes, are terminal hairs that are present throughout life. Hair follicles may alter the structure of the hairs in response to circulating hormones. For example, vellus hairs are present at the armpits, pubic area, and limbs until puberty; thereafter, the follicles produce terminal hairs, in response to circulating sex hormones.

Tips & Tricks

Associate the word *vellus* ("peach fuzz") with "velvet."

Hair Color

Variations in hair color reflect differences in structure and variations in the pigment produced by melanocytes at the hair papilla. Different forms of melanin give a dark brown, yellow-brown, or red color to the hair. These structural and biochemical characteristics are genetically determined, but hormonal and environmental factors also influence the condition of your hair. As pigment production decreases with age, hair color lightens. White hair results from the combination of a lack of pigment and the presence of air bubbles in the medulla of the hair shaft. As the proportion of white hairs increases, the individual's overall hair color is described as gray. Because hair itself is dead and inert, any changes in its coloration are gradual. We are able to change our hair color by using chemicals that disrupt the cuticle and permit dyes to enter and stain the cortex and medulla. These color treatments damage the hair by disrupting the protective cuticle layer and dehydrating and weakening the hair shaft. As a result, the hair becomes thin and brittle. Conditioners and oil treatments attempt to reduce the effects of this structural damage by rehydrating and recoating the shaft.

Checkpoint

19. **Describe a typical strand of hair.**
20. **What happens when the arrector pili muscle contracts?**
21. **Once a burn on the forearm that destroys the epidermis and extensive areas of the deep dermis heals, will hair grow again in the affected area?**

See the blue Answers tab at the back of the book.

5-8 ◗ Sebaceous glands and sweat glands are exocrine glands found in the skin

In this section we examine the structure and function of various integumentary system accessory structures that produce exocrine secretions, with a focus on sebaceous glands and sweat glands.

Sebaceous Glands

Sebaceous (se-BĀ-shus) **glands,** or *oil glands,* are holocrine glands that discharge an oily lipid secretion into hair follicles (**Figure 5–11**). Sebaceous glands that communicate with a single follicle share a duct and thus are classified as simple branched alveolar glands. ⮌ p. 120 The gland cells produce large quantities of lipids as they mature. The lipid product is released through holocrine secretion, a process that involves the rupture of the secretory cells. ⮌ p. 118

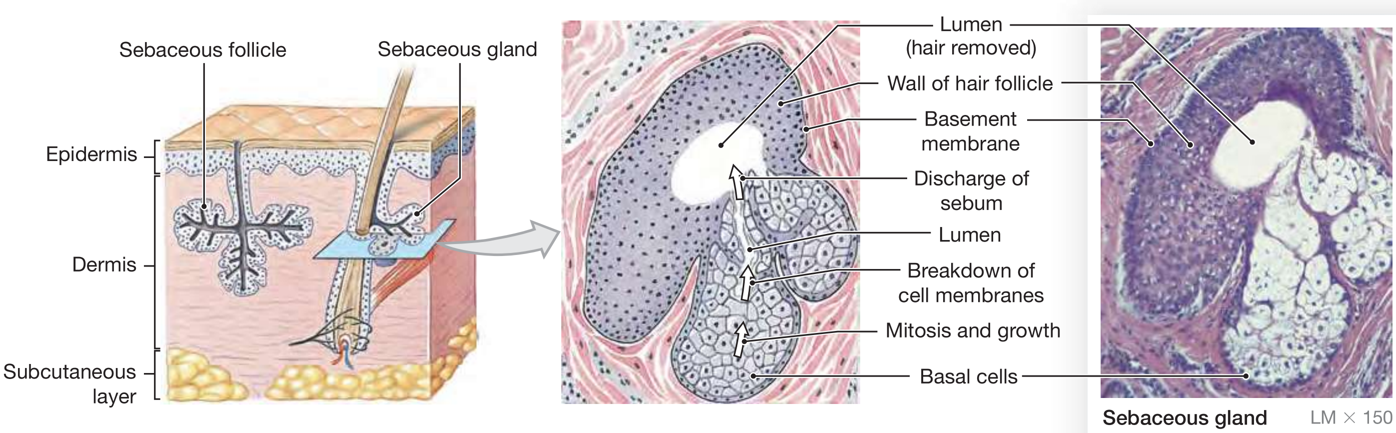
The lipids released from gland cells enter the lumen (open passageway) of the gland. The arrector pili muscles that erect the hair then contract, squeezing the sebaceous gland and forcing the lipids into the hair follicle and onto the surface of the skin. The secreted lipid product, called **sebum** (SĒ-bum), is a mixture of tryglycerides, cholesterol, proteins, and electrolytes. Sebum inhibits the growth of bacteria, lubricates and protects the keratin of the hair shaft, and conditions the surrounding skin. Keratin is a tough protein, but dead, keratinized cells become dry and brittle once exposed to the environment. It is interesting to reflect on our custom of washing and shampooing to remove the oily secretions of sebaceous glands, only to add other lipids to the hair in the form of conditioners, and to the skin in the form of creams and lotions.

Sebaceous follicles are large sebaceous glands that are not associated with hair follicles; their ducts discharge sebum directly onto the epidermis (**Figure 5–11**). Sebaceous follicles are located on the face, back, chest, nipples, and external genitalia.

Surprisingly, sebaceous glands are very active during the last few months of fetal development. Their secretions, mixed with shed epidermal cells, form a protective superficial layer—the *vernix caseosa*—that coats the skin surface. Sebaceous gland activity all but stops after birth, but it increases again at puberty in response to rising levels of sex hormones.

Seborrheic dermatitis is an inflammation around abnormally active sebaceous glands, most often those of the scalp. The affected area becomes red and oily, and increased epidermal scaling occurs. In infants, mild cases are called *cradle cap*. Seborrheic dermatitis is a common cause of dandruff in adults. Anxiety, stress, and fungal or bacterial infections can aggravate the problem.

Figure 5–11 **The Structure of Sebaceous Glands and Sebaceous Follicles.**



Sweat Glands

The skin contains two types of sweat glands, or **sudoriferous glands** (*sudor*, sweat): *apocrine sweat glands* and *merocrine sweat glands* (**Figure 5–12**).

Apocrine Sweat Glands

In the armpits (axillae), around the nipples, and in the pubic region, **apocrine sweat glands** secrete their products into hair follicles (**Figure 5–12a**). These coiled, tubular glands produce a sticky, cloudy, and potentially odorous secretion. The name *apocrine* was originally chosen because it was thought the gland cells use an apocrine method of secretion. ⮌ p. 118 Although we now know that they rely on merocrine secretion, the name has not changed.

Apocrine sweat glands begin secreting at puberty. The sweat produced is a nutrient source for bacteria, which intensify its odor. Surrounding the secretory cells in these glands are special **myoepithelial cells** that contract and squeeze the gland, causing the accumulated sweat to discharge into the hair follicles. The secretory activities of the gland cells and the contractions of myoepithelial cells are controlled by the nervous system and by circulating hormones.

Merocrine Sweat Glands

Merocrine sweat glands are also known as **eccrine** (EK-rin) **sweat glands**. These are coiled, tubular glands that discharge their secretions directly onto the surface of the skin (**Figure 5–12b**). Merocrine sweat glands are far more numerous and widely distributed than apocrine sweat glands. The adult integument contains 2–5 million merocrine sweat glands, which are smaller than apocrine sweat glands and do not extend as deeply into the dermis. The palms and soles have the highest numbers, with the palm possessing an estimated 500 merocrine sweat glands per square centimeter (3000 per square inch).

As noted earlier, the sweat produced by merocrine sweat glands is called sensible perspiration. Sweat is 99 percent water, but it also contains some electrolytes (chiefly sodium chloride), a number of organic nutrients, a peptide with antibiotic properties, and various waste products. It has a pH of 4.0–6.8, and the presence of sodium chloride gives sweat a salty taste. (See the Appendix for a complete analysis of the composition of normal sweat.)

The functions of merocrine sweat gland activity include the following:

- *Cooling the Surface of the Skin to Reduce Body Temperature.* This is the primary function of sensible perspiration. The degree of secretory activity is regulated by neural and hormonal mechanisms; when all the merocrine sweat glands are working at their maximum, the rate of perspiration can exceed a gallon per hour, and dangerous fluid and electrolyte losses can occur. For this reason, athletes participating in endurance sports must drink fluids at regular intervals.
- *Excreting Water and Electrolytes.* Salts (mostly sodium chloride), a number of metabolized drugs, and water are excreted.
- *Providing Protection from Environmental Hazards.* Sweat dilutes harmful chemicals in contact with the skin and discourages

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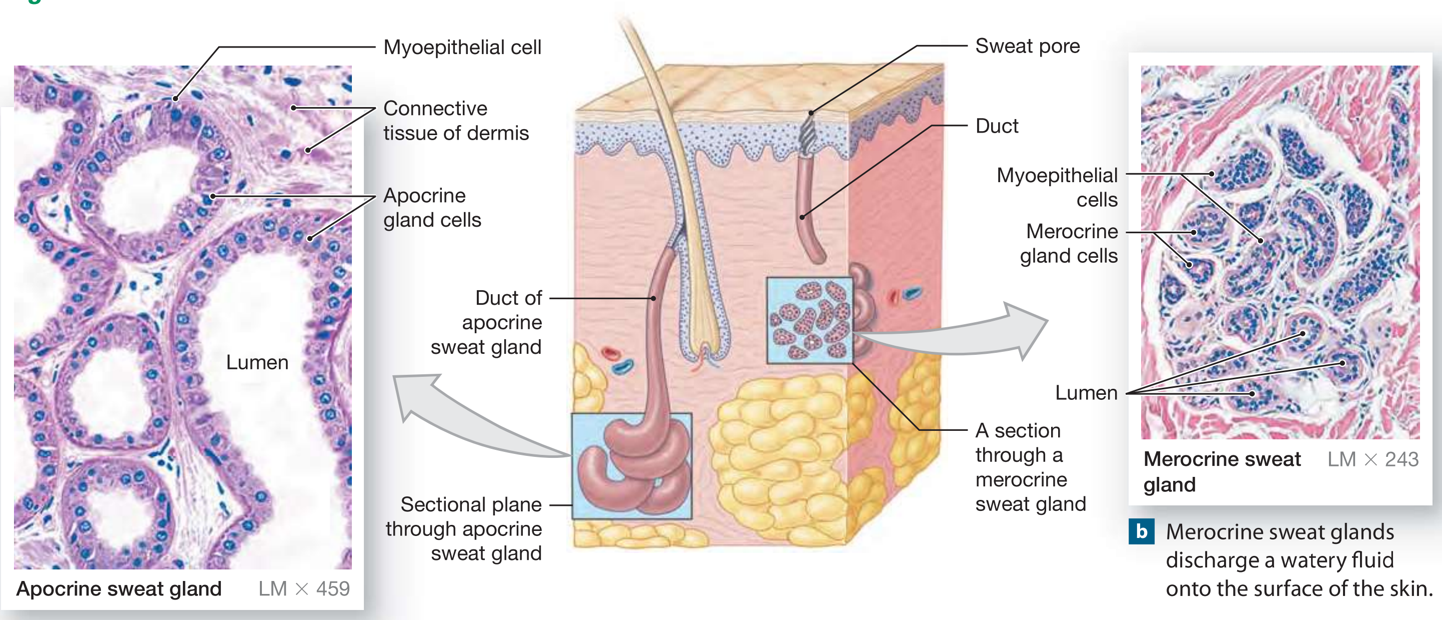
Figure 5–12 Sweat Glands.



a Apocrine sweat glands secrete a thick, odorous fluid into hair follicles.

b Merocrine sweat glands discharge a watery fluid onto the surface of the skin.

the growth of microorganisms in two ways: (1) by either flushing them from the surface or making it difficult for them to adhere to the epidermal surface, and (2) through the action of *dermicidin*, a small peptide that has powerful antibiotic properties.

Other Integumentary Glands

As we have seen, merocrine sweat glands are widely distributed across the body surface, sebaceous glands are located wherever there are hair follicles, and apocrine sweat glands are located in relatively restricted areas. The skin also contains a variety of specialized glands that are restricted to specific locations. Two examples of particular importance are the following:

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1. The **mammary glands** of the breasts are anatomically related to apocrine sweat glands. A complex interaction between sex hormones and pituitary hormones controls their development and secretion. We will discuss mammary gland structure and function in Chapter 28.
2. **Ceruminous** (se-ROO-mi-nus) **glands** are modified sweat glands in the passageway of the external ear. Their secretions combine with those of nearby sebaceous glands, forming a mixture called **cerumen,** or earwax. Together with tiny hairs along the ear canal, earwax helps trap foreign particles, preventing them from reaching the eardrum.

Control of Glandular Secretions and the Homeostatic Role of the Integument

The autonomic nervous system (ANS) controls the activation and deactivation of sebaceous glands and apocrine sweat glands at the subconscious level. Regional control is not possible; the commands issued by the ANS affect all the glands of that type, everywhere on the body surface. Merocrine sweat glands are much more precisely controlled, and the amount of secretion and the area of the body involved can vary independently. For example, when you are nervously awaiting an anatomy and physiology exam, only your palms may begin to sweat.

As we noted earlier, the primary function of sensible perspiration is to cool the surface of the skin and to reduce body temperature. When the environmental temperature is high, this is a key component of *thermoregulation*, the process of maintaining temperature homeostasis. When you sweat in the hot sun, all your merocrine glands are working together. The blood vessels beneath your epidermis are dilated and filled with blood, your skin reddens, and the surface of your skin is warm and wet. As the moisture evaporates, your skin cools. If your body temperature subsequently falls below normal, sensible perspiration ceases, blood flow to the skin is reduced, and the skin surface cools and dries, releasing little heat into the environment. Chapter 1 introduced the negative feedback mechanisms of thermoregulation (p. 12); additional details will be found in Chapter 25.

Checkpoint

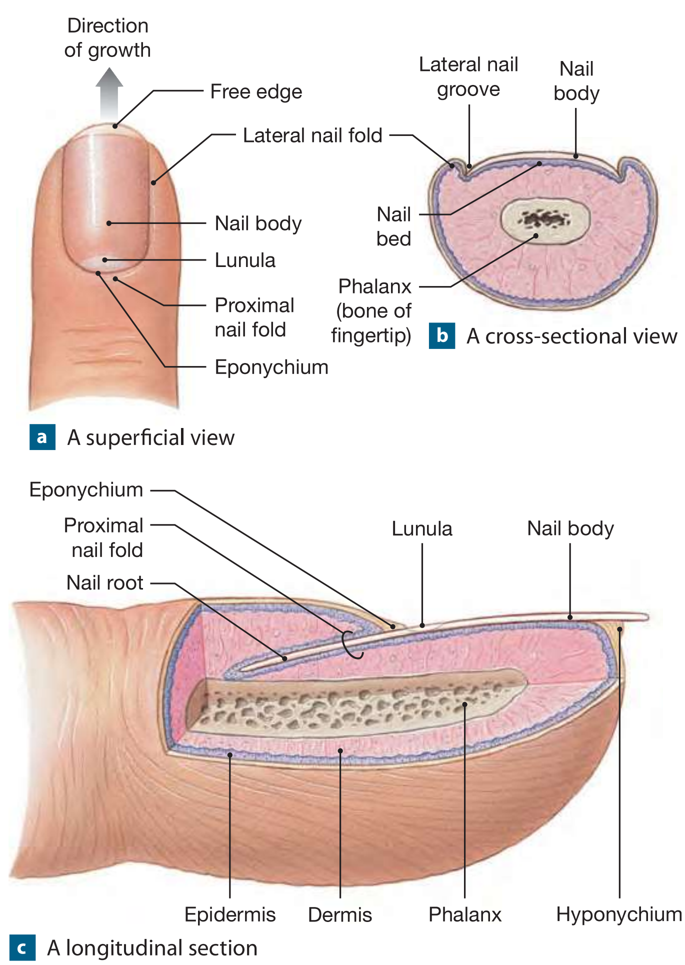
22. **Identify two types of exocrine glands found in the skin.**
23. **What are the functions of sebaceous secretions?**
24. **Deodorants are used to mask the effects of secretions from which type of skin gland?**
25. **Which type of skin gland is most affected by the hormonal changes that occur during puberty?**

See the blue Answers tab at the back of the book.

5-9 Nails are keratinized epidermal cells that protect the tips of fingers and toes

Nails protect the exposed dorsal surfaces of the tips of the fingers and toes (**Figure 5–13a**). They also help limit distortion of the digits when they are subjected to mechanical stress—for example, when you run or grasp objects. The **nail body,** the visible

Figure 5–13 The Structure of a Nail.



portion of the nail, covers an area of epidermis called the **nail bed** (**Figure 5–13b**). The nail body is recessed deep to the level of the surrounding epithelium and is bordered on either side by **lateral nail grooves** (depressions) and **lateral nail folds.** The **free edge** of the nail—the distal portion that continues past the nail bed—extends over the **hyponychium** (hī-pō-NIK-ē-um), an area of thickened stratum corneum (**Figure 5–13c**).

Nail production occurs at the **nail root,** an epidermal fold not visible from the surface. The deepest portion of the nail root lies very close to the bone of the fingertip. A portion of the stratum corneum of the nail root extends over the exposed nail, forming the **eponychium** (ep-ō-NIK-ē-um; *epi-*, over + *onyx*, nail), or **cuticle.** Underlying blood vessels give the nail its characteristic pink color. Near the root, these vessels may be obscured, leaving a pale crescent known as the **lunula** (LOO-nū-la; *luna*, moon) (**Figure 5–13a**).

The body of the nail consists of dead, tightly compressed cells packed with keratin. The cells producing the nails can be affected by conditions that alter body metabolism, so changes in the shape, structure, or appearance of the nails can provide useful diagnostic information. For example, the nails may turn yellow in individuals who have chronic respiratory disorders, thyroid gland disorders, or AIDS. Nails may become pitted and distorted as a result of *psoriasis* (a condition marked by rapid stem cell division in the stratum basale), and concave as a result of some blood disorders.

Checkpoint

26. **What substance makes fingernails hard?**
27. **What term is used to describe the thickened stratum corneum underlying the free edge of a nail?**
28. **Where does nail growth occur?**

See the blue Answers tab at the back of the book.

5-10 Several steps are involved in repairing the integument following an injury

The integumentary system can function independently—it often responds directly and automatically to local influences without the involvement of the nervous or endocrine systems. For example, when the skin is continually subjected to mechanical stresses, stem cells in the stratum basale divide more rapidly, and the depth of the epithelium increases. That is why calluses form on your palms when you perform work with your hands.

A more dramatic display of local regulation can be seen after an injury to the skin. The skin can regenerate effectively, even after considerable damage has occurred, because stem cells persist in both the epithelial and connective tissue components. Basal cell divisions replace lost epidermal cells, and mesenchymal cell divisions replace lost dermal cells. The process can be slow. When large surface areas are involved, problems of infection and fluid loss complicate the situation. The speed and effectiveness of skin repair vary with the type of wound involved. A slender, straight cut, or *incision*, may heal fairly quickly compared with a deep scrape, or *abrasion*, which involves a much greater surface area to be repaired.

Figure 5–14 illustrates the four stages in the regeneration of the skin after an injury. When damage extends through the epidermis and into the dermis, bleeding generally occurs (1). The blood clot, or **scab,** that forms at the surface temporarily restores the integrity of the epidermis and restricts the entry of additional microorganisms into the area (2). The bulk of the clot consists of an insoluble network of *fibrin*, a fibrous protein that forms from blood proteins during the clotting response. The clot's color reflects the presence of trapped red blood cells. Cells of the stratum basale undergo rapid divisions and begin to migrate along the edges of the wound in an attempt to replace the missing epidermal cells. Meanwhile, macrophages patrol the damaged area of the dermis, phagocytizing any debris and pathogens.

If the wound occupies an extensive area or involves a region covered by thin skin, dermal repairs must be under way before epithelial cells can cover the surface. Divisions by fibroblasts and mesenchymal cells produce mobile cells that invade the deeper areas of injury. Endothelial cells of damaged blood vessels also begin to divide, and capillaries follow the fibroblasts, enhancing circulation. The combination of blood clot, fibroblasts, and an extensive capillary network is called **granulation tissue.**

Over time, deeper portions of the clot dissolve, and the number of capillaries declines. Fibroblast activity leads to the appearance of collagen fibers and typical ground substance (3). The repairs do not restore the integument to its original condition, however, because the dermis will contain an abnormally large number of collagen fibers and a few blood vessels. Severely damaged hair follicles, sebaceous or sweat glands, muscle cells, and nerves are seldom repaired, and they too are replaced by fibrous tissue. The formation of this rather inflexible, fibrous, noncellular **scar tissue** completes the repair process but fails to restore the tissue to its original condition (4).

We do not know what regulates the extent of scar tissue formation, and the process is highly variable. For example, surgical procedures performed on a fetus do not leave scars, perhaps because damaged fetal tissues do not produce the same types of growth factors that adult tissues do. In some adults, most often those with dark skin, scar tissue formation may continue beyond the requirements of tissue repair. The result is a thickened mass of scar tissue that begins at the site of injury and grows into the surrounding dermis. This thick, raised area of scar tissue, called a **keloid** (KĒ-loyd), is covered by a shiny, smooth epidermal surface (**Figure 5–15**). Keloids most commonly develop on the upper back, shoulders, anterior chest, or earlobes.

Figure 5–14 Repair of Injury to the Integument. 1 inflammatory phase; 2 migratory phase; 3 proliferation phase; 4 maturation phase.

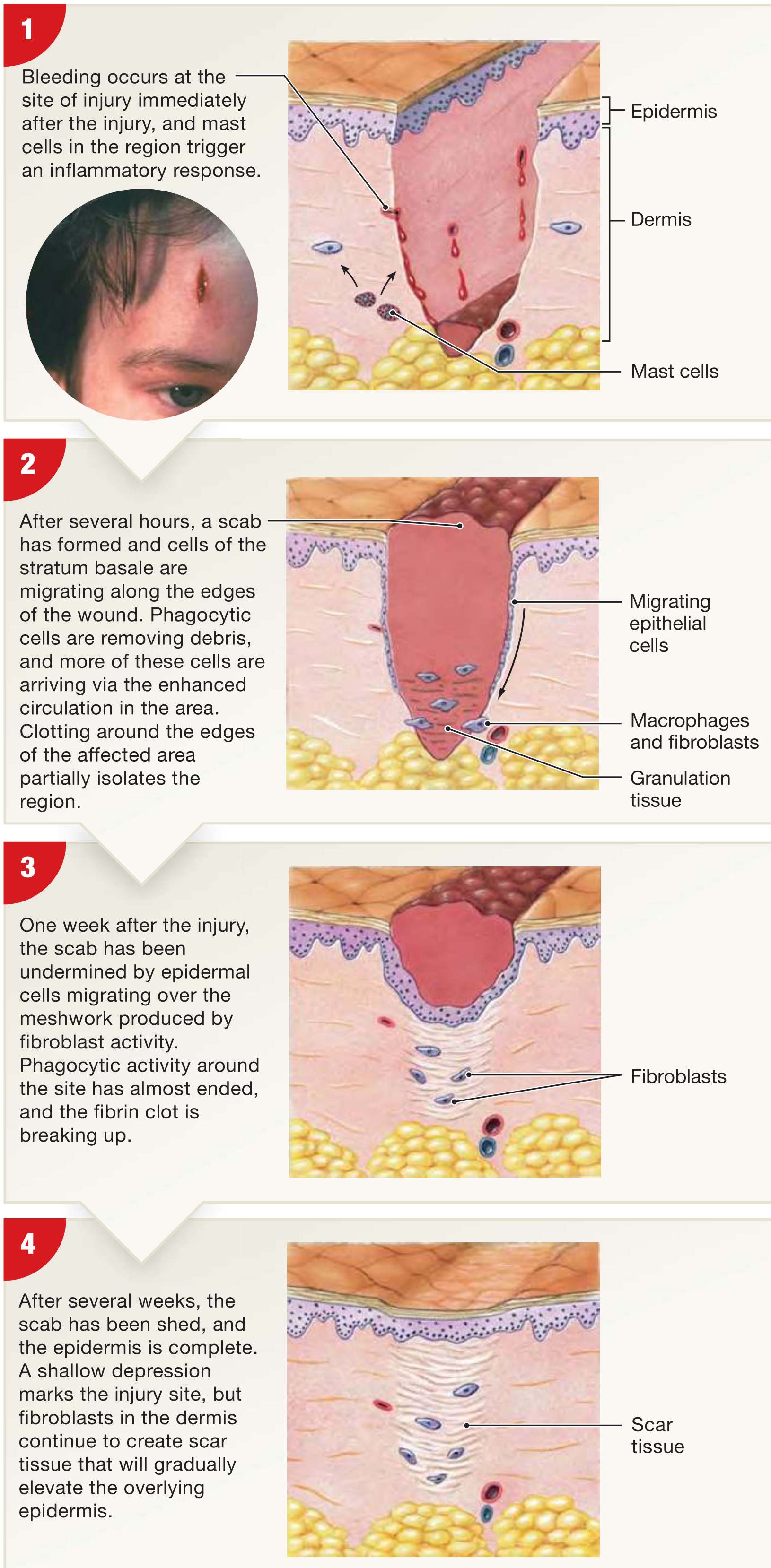


Figure 5–15 A Keloid. Keloids are areas of raised fibrous scar tissue.

They are harmless; indeed some aboriginal cultures intentionally produce keloids as a form of body decoration.

Furthermore, people in societies around the world adorn the skin with culturally significant markings of one kind or another. Tattoos, piercings, keloids and other scar patterns, and even high-fashion makeup are all used to “enhance” the appearance of the integument. Scarification is performed in several African cultures, resulting in a series of complex, raised scars on the skin. Polynesian cultures have long preferred tattoos as a sign of status and beauty. A dark pigment is inserted deep within the dermis of the skin by tapping on a needle, shark tooth, or bit of bone. Because the pigment is inert, the markings remain for the life of the individual, clearly visible through the overlying epidermis. American popular culture has recently rediscovered tattoos as a fashionable form of body adornment.

Tattoos can now be partially or completely removed by laser surgery. The removal process takes time (10 or more sessions may be required to remove a large tattoo), and scars often remain. To remove the tattoo, an intense, narrow beam of light from a laser breaks down the ink molecules in the dermis. Each blast of the laser that destroys the ink also burns the surrounding dermal tissue. Although the burns are minor, they accumulate and result in the formation of localized scar tissue.

Clinical Note

Burns and Grafts

Half a **million** **burned** every year

Burns are significant injuries in that they can damage the integrity of large areas of the skin and compromise many essential functions. Burns result from the exposure of skin to heat, friction, radiation, electrical shock, or strong chemical agents. The severity of the burn depends on the depth of penetration and the total area affected.

First-degree and second-degree burns are also called *partial-thickness burns*, because damage is restricted to the superficial layers of the skin. Only the surface of the epidermis is affected by a *first-degree burn*. In this type of burn, which includes most sunburns, the skin reddens and can be painful. The redness, a sign called **erythema** (er-i-THĒ-muh), results from inflammation of the sun-damaged tissues. In a *second-degree burn*, the entire epidermis and perhaps some of the dermis are damaged. Accessory structures such as hair follicles and glands are generally not affected, but blistering, pain, and swelling occur. If the blisters rupture at the surface, infection can easily develop. Healing typically takes one to two weeks, and some scar tissue may form.

Full-thickness burns, or *third-degree burns*, destroy the epidermis and dermis, extending into the hypodermis. Despite swelling, these burns are less painful than second-degree burns, because sensory nerves are destroyed. Extensive third-degree burns cannot repair themselves, because granulation tissue cannot form and epithelial cells are unable to cover the injury. As a result, the affected area remains open to infection. Extensive third-degree burns often require skin grafts, discussed shortly.

Each year in the United States, roughly 4000 people die from fires and burns. There is a standard reference for calculating the percentage of total surface area damaged. Burns that cover more than 20 percent of the skin surface threaten life, because they affect the following functions:

- ***Fluid and Electrolyte Balance.*** Even areas with partial-thickness burns lose their effectiveness as barriers to fluid and electrolyte losses. In full-thickness burns, the rate of fluid loss through the skin may reach five times the normal level.
- ***Thermoregulation.*** Increased fluid loss means increased evaporative cooling. As a result, more energy must be expended to keep body temperature within acceptable limits.
- ***Protection from Infection.*** The dampness of the epidermal surface, resulting from uncontrolled fluid loss, encourages bacterial growth. If the skin is broken, infection is likely. Widespread bacterial infection, or ***sepsis*** (*septikos*, rotting), is the leading cause of death in burn victims.

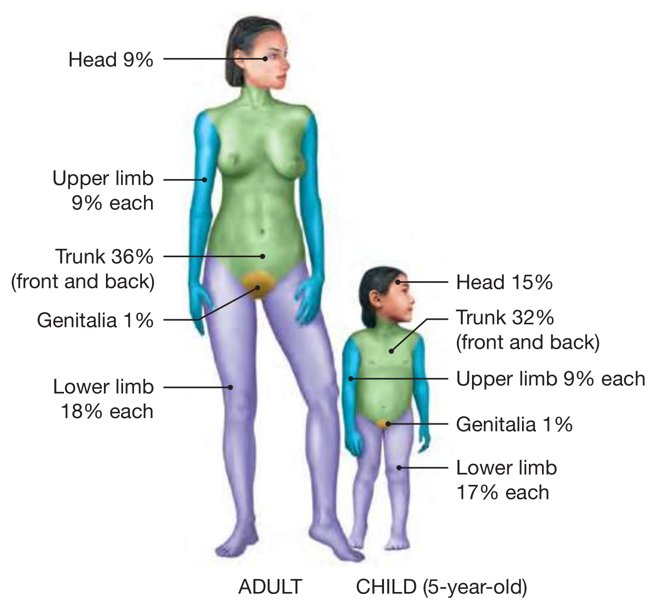
Effective treatment of full-thickness burns focuses on the following four procedures:

1. Replacing lost fluids and electrolytes.
2. Providing sufficient nutrients to meet increased metabolic demands for thermoregulation and healing.
3. Preventing infection by cleaning and covering the burn while administering antibiotic drugs.
4. Assisting tissue repair.

Because large full-thickness burns cannot heal unaided, surgical procedures are necessary to encourage healing. In a **skin graft**, areas of intact skin are transplanted to cover the site of the burn. A *split-thickness graft* involves a transfer of the epidermis and superficial portions of the dermis; a *full-thickness graft* involves the epidermis and both layers of the dermis.

With fluid-replacement therapies, infection control methods, and grafting techniques, young patients with burns over 80 percent of the body have about a 50 percent chance of recovery. Recent advances in cell culturing may improve survival rates. After a postage-stamp-sized section of undamaged epidermis is removed and grown in the laboratory, basal cell divisions produce large sheets of epidermal cells—up to several square meters in area—that can be transplanted to cover the burn area. Although questions remain about the strength and flexibility of the repairs, skin cultivation is a breakthrough in the treatment of serious burns.

Figure 5–16 A Quick Method of Estimating the Percentage of Surface Area Affected by Burns. This method is called the *rule of nines*, because the surface area in adults is divided into multiples of 9. The rule must be modified for children, because their proportions are quite different.



Clinical Note

Skin Abnormalities Because the skin is the most visible organ of the body, abnormalities are easily recognized. Changes in skin color, tone, and overall condition commonly accompany disease and can assist in the diagnosis of conditions involving other systems. A bruise, for example, is a swollen, discolored area where blood has leaked through vessel walls. Extensive bruising without any obvious cause may indicate a blood-clotting disorder; and yellowish skin and mucous membranes may signify *jaundice*, which generally indicates some type of liver disorder. The general condition of the skin can also be significant. In addition to color changes, changes in the flexibility, elasticity, dryness, or sensitivity of the skin commonly follow malfunctions in other organ systems.

Checkpoint

29. **What term describes the combination of fibrin clots, fibroblasts, and the extensive network of capillaries in healing tissue?**
30. **Why can skin regenerate effectively even after considerable damage?**

See the blue Answers tab at the back of the book.

5-11 Effects of aging include dermal thinning, wrinkling, and reduced melanocyte activity

Aging affects all the components of the integumentary system:

- The epidermis thins as basal cell activity declines, and the connections between the epidermis and dermis weaken, making older people more prone to injury, skin tears, and skin infections.
- The number of dendritic cells decreases to about 50 percent of levels seen at maturity (about age 21). This decrease may reduce the sensitivity of the immune system and further encourage skin damage and infection.
- Vitamin D_3 production declines by about 75 percent. The result can be reduced calcium and phosphate absorption, eventually leading to muscle weakness and a reduction in bone strength and density.
- Melanocyte activity declines, and in light-skinned individuals the skin becomes very pale. With less melanin in the skin, people become more sensitive to exposure to the sun and more likely to experience sunburn.
- Glandular activity declines. The skin becomes dry and often scaly, because sebum production is reduced. Merocrine sweat glands are also less active, and with impaired perspiration, older people cannot lose heat as fast as younger people can. Thus, the elderly are at greater risk of overheating in warm environments.
- The blood supply to the dermis is reduced. Reduction in blood flow makes the skin become cool, which in turn can stimulate thermoreceptors, making a person feel cold even in a warm room. However, because reduced circulation and sweat gland function in the elderly lessens their ability to lose body heat, overexertion or exposure to high temperatures (such as those in a sauna or hot tub) can cause body temperatures to soar dangerously high.
- Hair follicles stop functioning or produce thinner, finer hairs. With decreased melanocyte activity, these hairs are gray or white.
- The dermis thins, and the elastic fiber network decreases in size. The integument therefore becomes weaker and less resilient, and sagging and wrinkling occur. These effects are most noticeable in areas of the body that have been exposed to the sun.
- With changes in levels of sex hormones, secondary sexual characteristics in hair and body fat distribution begin to fade.
- Skin repairs proceed more slowly. Thus, whereas repairs to an uninfected blister might take three to four weeks in a young adult, the same repairs could take six to eight weeks at age 65–75. Furthermore, because healing occurs more slowly, recurring infections may result.

The **Systems Integrator** (**Figure 5–17**) reviews the integumentary system. System Integrators will appear after each body system as it is covered to help build your understanding of the interconnections among all other body systems.

Checkpoint

31. **Older individuals do not tolerate the summer heat as well as when they were young, and they are more prone to heat-related illness. What accounts for these changes?**
32. **Why does hair turn white or gray with age?**

See the blue Answers tab at the back of the book.

SYSTEM INTEGRATOR

The INTEGUMENTARY System

The integumentary system provides mechanical protection against environmental hazards. It forms the external surface of the body and provides protection from dehydration, environmental chemicals, and external forces. The integument (skin) is separated and insulated from the rest of the body by the subcutaneous layer, but it is interconnected with the rest of the body by an extensive circulatory network of blood and lymphatic vessels. As a result, although the protective mechanical functions of the skin can be discussed independently, its physiological activities are always closely integrated with those of other systems.

ABOUT THE SYSTEM INTEGRATORS
Since each body system interacts with every other body system, no one system can be completely understood in isolation. The integration of the various systems allows the human body to function seamlessly, and when disease or injury strikes, multiple systems must respond to heal the body.

These charts will introduce the body systems one by one and show how each influences the others to make them function more effectively, and in turn how other body systems influence the system you are studying. As we progress through the organ systems, the complementary nature of these interactions will become clear. Homeostasis depends on the thorough integration of all the body systems working as one.

Figure 5–17 System Integrator.

Skeletal Page 275
Muscular Page 369
Nervous Page 543
Endocrine Page 632
Cardiovascular Page 759
Lymphatic Page 807
Respiratory Page 857
Digestive Page 910
Urinary Page 992
Reproductive Page 1072

Related Clinical Terms

carbuncle: A skin infection that often involves a group of hair follicles. The infected material forms a lump, which occurs deep in the skin; the medical term for multiple boils.
cold sore: A lesion that typically occurs in or around the mouth and is caused by a dormant herpes simplex virus that may be reactivated by factors such as stress, fever, or sunburn. Also called *fever blister*.
comedo: The primary sign of acne consisting of an enlarged pore filled with skin debris, bacteria, and sebum (oil); the medical term for a blackhead.
dermatology: The branch of medicine concerned with the diagnosis, treatment, and prevention of diseases of the skin, hair, and nails.
5
eczema: Rash characterized by inflamed, itchy, dry, scaly, or irritated skin.
frostbite: Injury to body tissues caused by exposure to below-freezing temperatures, typically affecting the nose, fingers, or toes and sometimes resulting in gangrene.
furuncle: A skin infection involving an entire hair follicle and nearby skin tissue; the medical term for a boil.
gangrene: A term that describes dead or dying body tissue that occurs because the local blood supply to the tissue is either lost or is inadequate to keep the tissue alive.
impetigo: An infection of the surface of the skin, caused by staphylococcus ("staph") and streptococcus ("strep") bacteria.
nevus: A benign pigmented spot on the skin such as a mole.
onycholysis: A nail disorder characterized by a spontaneous separation of the nail plate starting at the distal free margin and progressing proximally.
pallor: An unhealthy pale appearance.
porphyria: A rare hereditary disease in which the blood pigment hemoglobin is abnormally metabolized. Porphyrins are excreted in the urine, which becomes dark; other symptoms include mental disturbances and extreme sensitivity of the skin to light.
rosacea: A condition in which certain facial blood vessels enlarge, giving the cheeks and nose a flushed appearance.
scleroderma: An idiopathic chronic autoimmune disease characterized by hardening and contraction of the skin and connective tissue, either locally or throughout the body.
tinea: A skin infection caused by a fungus; also called ringworm.
urticaria: Skin condition characterized by red, itchy, raised areas that appear in varying shapes and sizes; commonly called hives.

Chapter Review

Study Outline

An Introduction to the Integumentary System p. 145

1. The **integument,** or **integumentary system,** consists of the **cutaneous membrane** or *skin* (which includes the **epidermis** and the **dermis**) and the **accessory structures.** Beneath the dermis lies the **hypodermis** or subcutaneous layer. *(Figure 5–1)*
2. Functions of the integument include *protection, excretion, temperature maintenance, vitamin D_3 synthesis, nutrient storage,* and *sensory detection*.

5-1 The epidermis is composed of strata (layers) with various functions p. 146

3. **Thin skin,** consisting of four layers of **keratinocytes,** covers most of the body. Heavily abraded body surfaces may be covered by **thick skin** containing five layers of keratinocytes. *(Figure 5–2)*
4. The epidermis provides mechanical protection, prevents fluid loss, and helps keep microorganisms out of the body.
5. Cell divisions in the **stratum basale,** the deepest epidermal layer, replace more superficial cells. *(Figure 5–3)*
6. As epidermal cells age, they pass through the stratum basale, **stratum spinosum,** the **stratum granulosum,** the **stratum lucidum** (in thick skin), and the **stratum corneum.** In the process, they accumulate large amounts of **keratin.** Ultimately, the cells are shed. *(Figure 5–3)*
7. **Epidermal ridges,** interlocked with **dermal papillae** of the underlying dermis, improve the gripping ability of the palms and soles and increase the skin's sensitivity. *(Figure 5–4)*
8. *Dendritic cells* in the stratum spinosum are part of the immune system. *Tactile cells* in the stratum basale provide sensory information about objects that touch the skin.

5-2 Factors influencing skin color are epidermal pigmentation and dermal circulation p. 149

9. The color of the epidermis depends on two factors: dermal blood supply and epidermal pigmentation.
10. The epidermis contains the pigments **carotene** and **melanin. Melanocytes,** which produce melanin, protect us from **ultraviolet (UV) radiation.** *(Figure 5–5)*
11. Interruptions of the dermal blood supply or poor oxygenation in the lungs can lead to **cyanosis.**

5-3 Sunlight causes epidermal cells to convert a steroid into vitamin D_3 p. 150

12. Epidermal cells synthesize **vitamin D_3** or **cholecalciferol,** when exposed to the UV radiation in sunlight.

5-4 Epidermal growth factor has several effects on the epidermis and epithelia p. 152

13. **Epidermal growth factor (EGF)** promotes growth, division, and repair of the epidermis, and epithelial gland synthetic activity and secretion.

5-5 The dermis is the tissue layer that supports the epidermis p. 152

14. The dermis consists of the superficial **papillary layer** and the deeper **reticular layer.** *(Figures 5–1, 5–2)*

15. The papillary layer of the dermis contains blood vessels, lymphatics, and sensory nerves that supply the epidermis. The reticular layer consists of a meshwork of collagen and elastic fibers oriented to resist tension in the skin.
16. Extensive distension of the dermis can cause **stretch marks.**
17. The pattern of collagen and elastic fiber bundles forms **cleavage lines.** *(Figure 5–8)*
18. Arteries to the skin form the **cutaneous plexus** and the **papillary plexus** in the hypodermis and the papillary dermis, respectively. *(Figure 5–9)*
19. Integumentary sensory receptors detect both light touch and pressure.

5-6 ◗ The hypodermis is tissue beneath the dermis that connects it to underlying tissues p. 154

20. The **hypodermis,** or subcutaneous layer, stabilizes the skin's position against underlying organs and tissues. *(Figure 5–1)*

5-7 ◗ Hair is composed of keratinized dead cells that have been pushed to the surface p. 155

21. **Hairs** originate in complex organs called **hair follicles.** Each hair has a **root** and a **shaft.** At the base of the root are a **hair papilla,** surrounded by a **hair bulb,** and a **root hair plexus** of sensory nerves. Hairs have a **medulla,** or core of soft keratin, surrounded by a **cortex** of hard keratin. The **cuticle** is a superficial layer of dead cells that protects the hair. *(Figure 5–10)*
22. Our bodies have both **vellus hairs** ("peach fuzz") and heavy **terminal hairs.** A hair that has stopped growing is called a **club hair.**
23. Each **arrector pili** muscle can erect a single hair. *(Figure 5–10)*
24. Our hairs grow and are shed according to the **hair growth cycle.** A typical hair on the head grows for two to five years and is then shed.

5-8 ◗ Sebaceous glands and sweat glands are exocrine glands found in the skin p. 158

25. A typical **sebaceous gland** discharges waxy **sebum** into a lumen and, ultimately, into a hair follicle. **Sebaceous follicles** are large sebaceous glands that discharge sebum directly onto the epidermis. *(Figure 5–11)*
26. The two types of sweat glands, or **sudoriferous glands,** are apocrine and merocrine sweat glands. **Apocrine sweat glands** produce an odorous secretion. The more numerous **merocrine sweat glands** produce a watery secretion known as sensible perspiration. *(Figure 5–12)*
27. **Mammary glands** of the breasts are structurally similar to apocrine sweat glands. **Ceruminous glands** in the ear produce a waxy substance called **cerumen.**

5-9 ◗ Nails are keratinized epidermal cells that protect the tips of fingers and toes p. 160

28. The **nail body** of a **nail** covers the **nail bed.** Nail production occurs at the **nail root,** which is covered by the **cuticle,** or **eponychium.** The **free edge** of the nail extends over the **hyponychium.** *(Figure 5–13)*

5-10 ◗ Several steps are involved in repairing the integument following an injury p. 161

29. Based on the division of stem cells, the skin can regenerate effectively even after considerable damage. The process begins with bleeding and includes the formation of a **scab, granulation tissue,** and **scar tissue.** *(Figure 5–14)*

5-11 ◗ Effects of aging include dermal thinning, wrinkling, and reduced melanocyte activity p. 164

30. With aging, the integument thins, blood flow decreases, cellular activity decreases, and repairs occur more slowly.

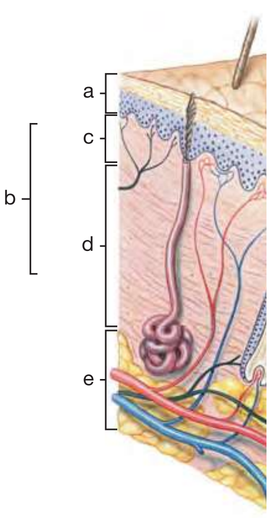
5

Review Questions

See the blue Answers tab at the back of the book.

LEVEL 1 Reviewing Facts and Terms

1. Identify the different portions (a–d) of the cutaneous membrane and the underlying layer of loose connective tissue (e) in the diagram to the right.
   (a) ___________
   (b) ___________
   (c) ___________
   (d) ___________
   (e) ___________



2. The two major components of the integumentary system are
   (a) the cutaneous membrane and the accessory structures.
   (b) the epidermis and the hypodermis.
   (c) the hair and the nails.
   (d) the dermis and the hypodermis.
3. Beginning at the basement membrane and traveling toward the free surface, the epidermis includes the following layers:
   (a) corneum, lucidum, granulosum, spinosum, basale.
   (b) granulosum, lucidum, spinosum, basale, corneum.
   (c) basale, spinosum, granulosum, lucidum, corneum.
   (d) lucidum, granulosum, spinosum, basale, corneum.
4. Each of the following is a function of the integumentary system, *except*
   (a) protection of underlying tissue.
   (b) excretion of salts and wastes.
   (c) maintenance of body temperature.
   (d) synthesis of vitamin C.
   (e) storage of nutrients.
5. Exposure of the skin to ultraviolet radiation
   (a) can result in increased numbers of melanocytes forming in the skin.
   (b) can result in decreased melanin production in melanocytes.
   (c) can cause destruction of vitamin D_3.
   (d) can result in damage to the DNA of cells in the stratum basale.
   (e) has no effect on the skin cells.

5

6. The two major components of the dermis are the
   (a) superficial fascia and cutaneous membrane.
   (b) epidermis and hypodermis.
   (c) papillary layer and reticular layer.
   (d) stratum basale and stratum corneum.
7. The cutaneous plexus and papillary plexus consist of
   (a) blood vessels providing the dermal blood supply.
   (b) a network of nerves providing dermal sensations.
   (c) specialized cells for cutaneous sensations.
   (d) gland cells that release cutaneous secretions.
8. The accessory structures of the integument include the
   (a) blood vessels, glands, muscles, and nerves.
   (b) tactile cells, lamellated corpuscles, and tactile corpuscles.
   (c) hair, skin, and nails.
   (d) hair follicles, nails, sebaceous glands, and sweat glands.
9. The portion of the hair follicle where cell divisions occur is the
   (a) shaft. (b) matrix.
   (c) root hair plexus. (d) cuticle.
10. The two types of exocrine glands in the skin are
   (a) merocrine and sweat glands.
   (b) sebaceous and sweat glands.
   (c) apocrine and sweat glands.
   (d) eccrine and sweat glands.
11. Apocrine sweat glands can be controlled by
   (a) the autonomic nervous system.
   (b) regional control mechanisms.
   (c) the endocrine system.
   (d) both a and c.
12. The primary function of sensible perspiration is to
   (a) get rid of wastes.
   (b) protect the skin from dryness.
   (c) maintain electrolyte balance.
   (d) reduce body temperature.
13. The stratum corneum of the nail root, which extends over the exposed nail, is called the
   (a) hyponychium. (b) eponychium.
   (c) lunula. (d) cerumen.
14. Muscle weakness and a reduction in bone strength in the elderly result from decreased
   (a) vitamin D_3 production. (b) melanin production.
   (c) sebum production. (d) dermal blood supply.
15. In which layer(s) of the epidermis does cell division occur?
16. What is the function of the arrector pili muscles?
17. What widespread effects does epidermal growth factor (EGF) have on the integument?
18. What two major layers constitute the dermis, and what components are in each layer?
19. List the four stages in the regeneration of the skin after an injury.

LEVEL 2 Reviewing Concepts

20. How do insensible perspiration and sensible perspiration differ?
21. In clinical practice, drugs can be delivered by diffusion across the skin; this delivery method is called transdermal administration. Why are fat-soluble drugs more suitable for transdermal administration than drugs that are water soluble?
22. In our society, a tan body is associated with good health. However, medical research constantly warns about the dangers of excessive exposure to the sun. What are the benefits of a tan?
23. Why is it important for a surgeon to choose an incision pattern according to the cleavage lines of the skin?
24. The fibrous protein that is responsible for the strength and water resistance of the skin surface is
   (a) collagen. (b) eleidin.
   (c) keratin. (d) elastin.
   (e) keratohyalin.
25. The darker an individual's skin color,
   (a) the more melanocytes she has in her skin.
   (b) the more layers she has in her epidermis.
   (c) the more melanin her melanocytes produce.
   (d) the more superficial her blood vessels are.
26. In order for bacteria on the skin to cause an infection in the skin, they must accomplish all of the following, *except*
   (a) survive the bactericidal components of sebum.
   (b) avoid being flushed from the surface of the skin by sweat.
   (c) penetrate the stratum corneum.
   (d) penetrate to the level of the capillaries.
   (e) escape the dendritic cells.

LEVEL 3 Critical Thinking and Clinical Applications

27. In the elderly, blood supply to the dermis is reduced and sweat glands are less active. This combination of factors would most affect
   (a) the ability to thermoregulate.
   (b) the ability to heal injured skin.
   (c) the ease with which the skin is injured.
   (d) the physical characteristics of the skin.
   (e) the ability to grow hair.
28. Two patients are brought to the emergency room. One has cut his finger with a knife; the other has stepped on a nail. Which wound has a greater chance of becoming infected? Why?
29. Exposure to optimum amounts of sunlight is necessary for proper bone maintenance and growth in children.
   (a) What does sunlight do to promote bone maintenance and growth?
   (b) If a child lives in an area where exposure to sunlight is rare because of pollution or overcast skies, what can be done to minimize impaired maintenance and growth of bone?
30. One of the factors to which lie detectors respond is an increase in skin conductivity due to the presence of moisture. Explain the physiological basis for the use of this indicator.
31. Many people change the natural appearance of their hair, either by coloring it or by altering the degree of curl in it. Which layers of the hair do you suppose are affected by the chemicals added during these procedures? Why are the effects of the procedures not permanent?