Unit II

6 Integumentary System

Scanning electron micrograph (SEM) of hair. The light, bristle-like structures are hairs, and the pink at the base of the hairs is skin.

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Module 4: Integumentary System

Learning Outcomes

After you have studied this chapter, you should be able to:

6.1 Introduction
1 Describe what constitutes an organ, and name the large organ of the integumentary system. (p. 180)
2 Discuss the functions of skin. (p. 180)

6.2 Skin and Its Tissues
3 Describe the structure of the layers of the skin. (p. 181)
4 Summarize the factors that determine skin color. (p. 184)

6.3 Accessory Structures of the Skin
5 Describe the accessory structures associated with the skin. (p. 186)
6 Explain the functions of each accessory structure of the skin. (p. 186)

6.4 Regulation of Body Temperature
7 Explain how the skin helps regulate body temperature. (p. 190)

6.5 Healing of Wounds and Burns
8 Describe wound healing. (p. 192)
9 Distinguish among the types of burns, including a description of healing with each type. (p. 192)

6.6 Life-Span Changes
10 Summarize life-span changes in the integumentary system. (p. 194)

LEARN PRACTICE ASSESS

Understanding Words

alb-, white: *alb*inism—condition characterized by a lack of pigment in skin, hair, and eyes.

cut-, skin: sub*cut*aneous—beneath the skin.

derm-, skin: *derm*is—inner layer of the skin.

epi-, upon, after, in addition: *epi*dermis—outer layer of the skin.

follic-, small bag: hair *follic*le—tubelike depression in which a hair develops.

hol-, entire, whole: *hol*ocrine gland—gland that discharges the entire cell containing the secretion.

kerat-, horn: *kerat*in—protein produced as epidermal cells die and harden.

melan-, black: *melan*in—dark pigment produced by certain cells.

por-, passage, channel: *por*e—opening by which a sweat gland communicates to the skin's surface.

seb-, grease: *seb*aceous gland—gland that secretes an oily substance.

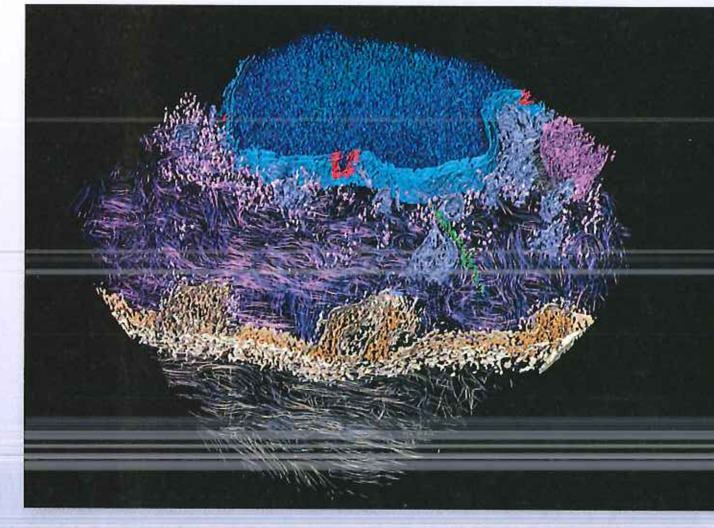
The Secret of Skin's Strength and Flexibility

The skin is an amazing organ. It provides strength and flexibility, is waterproof, and covers our bodies in one smooth sheath. But investigating exactly what lies behind these properties has been hampered by limited technology—until now.

Preparing skin cells for visualization using a light microscope strips away important proteins. Preparing cells for imaging with an electron microscope requires harsh chemical treatment or coating with metal. As a result, these standard forms of microscopy do not provide three-dimensional close-ups of the junctions between cells as they are in the body. A technique called cryo-electron tomography images skin cells in their natural state. Skin samples taken from a healthy man's arm were flash-frozen and then probed from various angles with a special electron microscope. Zeroing in on the desmosomes (see figure 5.1, p. 153), and especially the cadherin proteins that link the cells, revealed the secret of skin's strength and flexibility.

Cadherins extend straight out from the cell membranes of squamous epithelium, yet maintain the ability to move about 20 degrees in any direction. This flexibility is essential for movements associated with growth and development that move and stretch the skin. Cadherin proteins also have a right–left orientation. They link to each other with alternating symmetry, a little like children holding hands, but alternating the direction in which each child faces. The strength of the skin comes from the fact that each cadherin protein binds not only to its neighboring cells in one plane, but to juxtaposed cells too—similar to sheets of stamps glued together. An individual cadherin is not very adhesive, but there is strength in numbers. When cadherins are aligned at the surface of a skin cell facing others on all sides, the combined integrity is great.

Although researchers have observed only static views of the skin using cryo-electron tomography, they hypothesize how this organ might develop. In a developing embryo, skin cells approach as they divide and join initially at sites where a few cadherin proteins bind. As time passes and incoming signals indicate that the skin is where it should be, more cadherins join at the sites of the original ones until the cells are strongly, but flexibly, attached. ■



Cryo-electron tomography provides three-dimensional reconstructions of the junction between two skin cells (40,000×). The cells touch at the tan area. The nucleus of the upper cell is blue, set off by the light blue nuclear envelope. Nuclear pores are red. The purple above the junction is the cytoplasm of the upper cell. The gray-blue below the junction is the cytoplasm of the lower cell. (Note that this view shows only a portion of each cell.)

6.1 INTRODUCTION

Two or more types of tissues grouped together and performing specialized functions constitute an **organ.** The skin, the largest organ in the body by weight, and its various accessory structures make up the **integumentary** (in-teg-u-men'tar-e) **system.** Skin is a strong yet flexible covering of our bodies.

The skin is composed of several types of tissues (fig. 6.1). It is one of the more versatile organs of the body and is vital in maintaining homeostasis. As a protective covering, the skin prevents many harmful substances, as well as microorganisms, from entering the body. Skin also retards water loss by diffusion from deeper tissues and helps regulate body temperature. It houses sensory receptors; contains *epidermal dendritic* (den-drit'ik) *cells* or Langerhans cells that play a role in initiating the immune response by phagocytizing harmful microorganisms; and excretes small quantities of waste. Some skin cells produce vitamin D precursor (dehydrocholesterol), which when exposed to sunlight changes to an inactive form of vitamin D (cholecalciferol). In the liver and kidneys the inactive form is modified and becomes active vitamin D (calcitriol). Vitamin D is necessary for strong bone and tooth development.

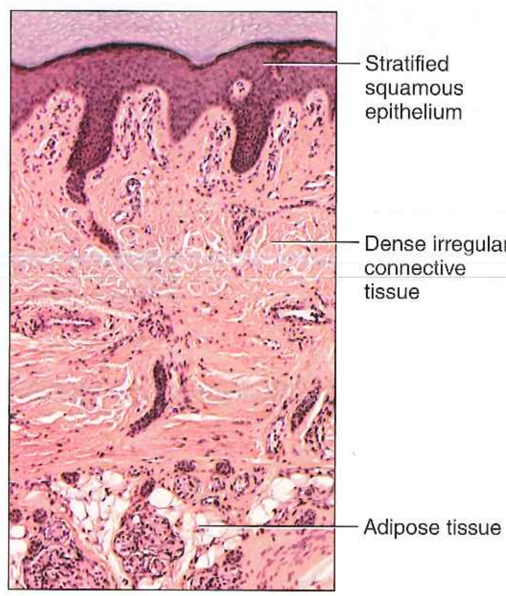


FIGURE 6.1 An organ, such as the skin, is composed of several types of tissues (30×).

Q: *What other tissues, besides those labeled in this figure, are found in the skin?*

Answer can be found in Appendix G on page 938.

PRACTICE

1 What constitutes an organ?
2 List the functions of skin.

6.2 SKIN AND ITS TISSUES

The skin, or cutaneous membrane, includes two distinct layers: epithelial tissue overlying connective tissue. The outer layer, called the **epidermis** (ep″i-der′mis), is composed of stratified squamous epithelium. The inner layer, or **dermis** (der′mis), is thicker than the epidermis and is made up of connective tissue containing collagen and elastic fibers, smooth muscle tissue, nervous tissue, and blood. A *basement membrane* anchored to the dermis by short fibrils separates the two skin layers.

Beneath the dermis, masses of areolar and adipose tissues bind the skin to underlying organs. These tissues are not part of the skin. They form the **subcutaneous layer** (sub″ku-ta′ne-us la′er), or hypodermis (fig. 6.2). The collagenous and elastic fibers of this layer are continuous with those of the dermis. Most of these fibers run parallel to the surface of the skin, extending in all directions. As a result, no sharp boundary separates the dermis and the subcutaneous layer. The adipose tissue of the subcutaneous layer insulates, helping to conserve body heat and impeding the entrance of heat from the outside. The subcutaneous layer also contains the major blood vessels that supply the skin. Branches of these vessels form a network (rete cutaneum) between the dermis and the subcutaneous layer. They, in turn, give off smaller vessels that supply the dermis above and the underlying adipose tissue.

Intradermal injections are injected into the skin. *Subcutaneous injections* are administered through a hollow needle into the subcutaneous layer beneath the skin. Subcutaneous injections and *intramuscular injections,* administered into muscles, are sometimes called hypodermic injections.

Some substances are introduced through the skin by means of an adhesive transdermal patch that includes a small reservoir containing the drug. The drug passes from the reservoir through a permeable membrane at a known rate. It then diffuses into the epidermis and enters the blood vessels of the dermis. Transdermal patches deliver drugs that protect against motion sickness, alleviate chest pain associated with heart disease, and lower blood pressure. A transdermal patch that delivers nicotine is used to help people stop smoking.

PRACTICE

3 Name the tissue in the outer layer of the skin.
4 Name the tissues in the inner layer of the skin.
5 Name the tissues in the subcutaneous layer beneath the skin.
6 What are the functions of the subcutaneous layer?

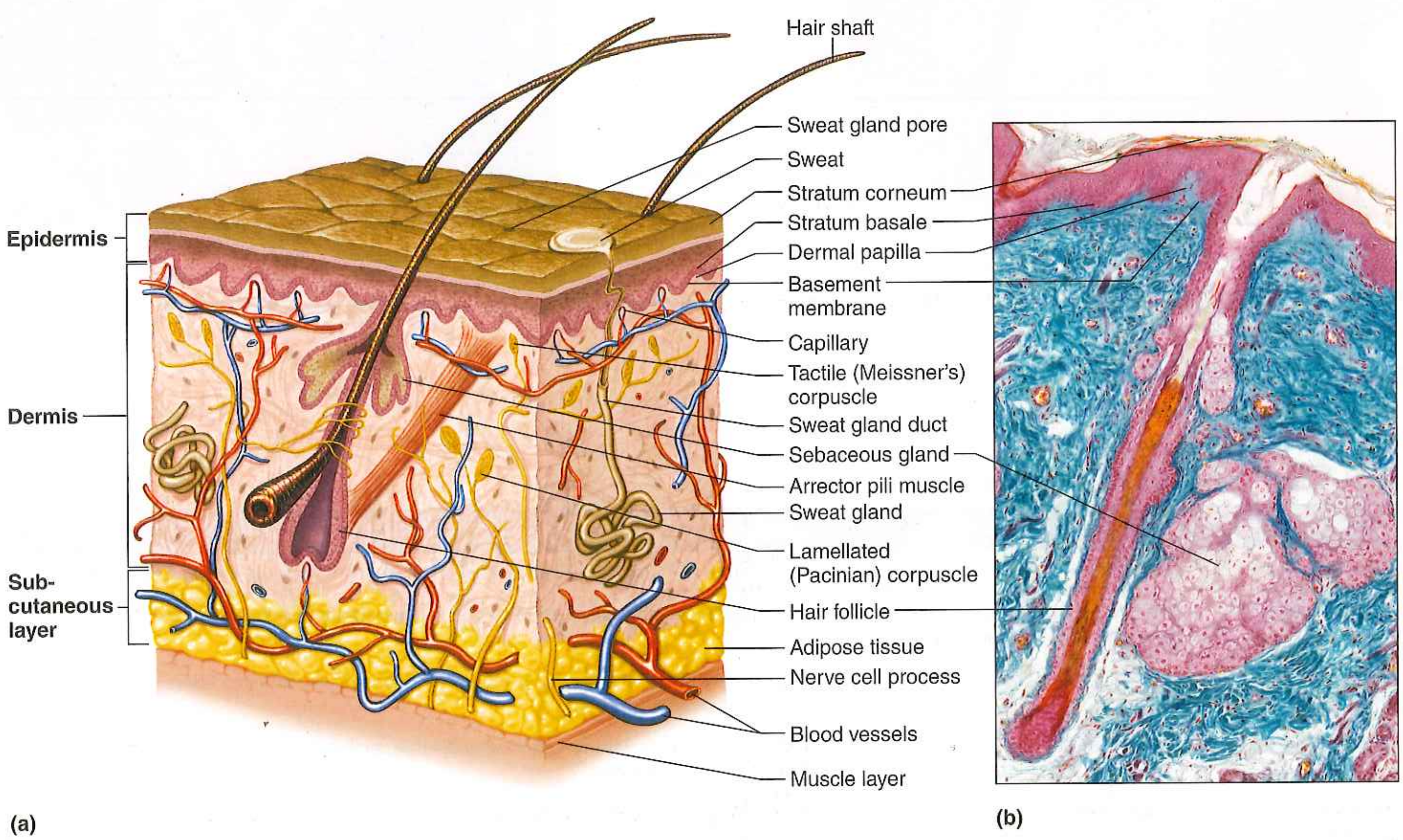


FIGURE 6.2 AP|R Skin. (*a*) A section of skin and the subcutaneous layer. (*b*) A light micrograph depicting the layered structure of the skin (75×).

Epidermis

The epidermis is composed entirely of stratified squamous epithelium, and therefore it lacks blood vessels. However, cells of the deepest layer of the epidermis, called the *stratum basale*, can grow and divide because they receive nutrients from blood vessels in the nearby dermis. As new cells enlarge, they push the older epidermal cells away from the dermis toward the surface of the skin. The farther the cells are moved, the poorer their nutrient supply becomes, and in time, they die.

The cell membranes of older skin cells (keratinocytes) thicken and develop many desmosomes that fasten them to each other (see chapter 5, p. 152 and the chapter 6 opening vignette). At the same time, the cells begin to harden, in a process called **keratinization** (ker″ah-tin″i-za′shun). Strands of tough, fibrous, waterproof keratin proteins are synthesized and stored in the cell. As a result, many layers of tough, tightly packed dead cells accumulate in the epidermis, forming an outermost layer called the *stratum corneum*. These dead cells are eventually shed. Rubbing the skin briskly with a towel sheds dead cells.

> Cells of the epidermis can die if they cannot receive nutrients from blood vessels in the dermis. This may happen when a bedridden person lies in one position for a prolonged period—the weight of the body pressing against the bed blocks the skin's blood supply. If cells die, the tissues break down (necrosis), and a pressure ulcer (also called a decubitus ulcer or bedsore) may appear.
>
> Pressure ulcers usually form in the skin overlying bony projections, such as on the hip, heel, elbow, or shoulder. Frequently changing body position or massaging the skin to stimulate blood flow in regions associated with bony prominences can prevent pressure ulcers. For a paralyzed person who cannot feel pressure or respond to it by shifting position, caregivers must turn the body often to prevent pressure ulcers. Beds, wheelchairs, and other specialized equipment can periodically shift the patient, lowering the risk of developing pressure ulcers.

The structural organization of the epidermis varies from region to region. It is thickest on the palms of the hands and the soles of the feet, where it may be 0.8–1.4 mm thick. In

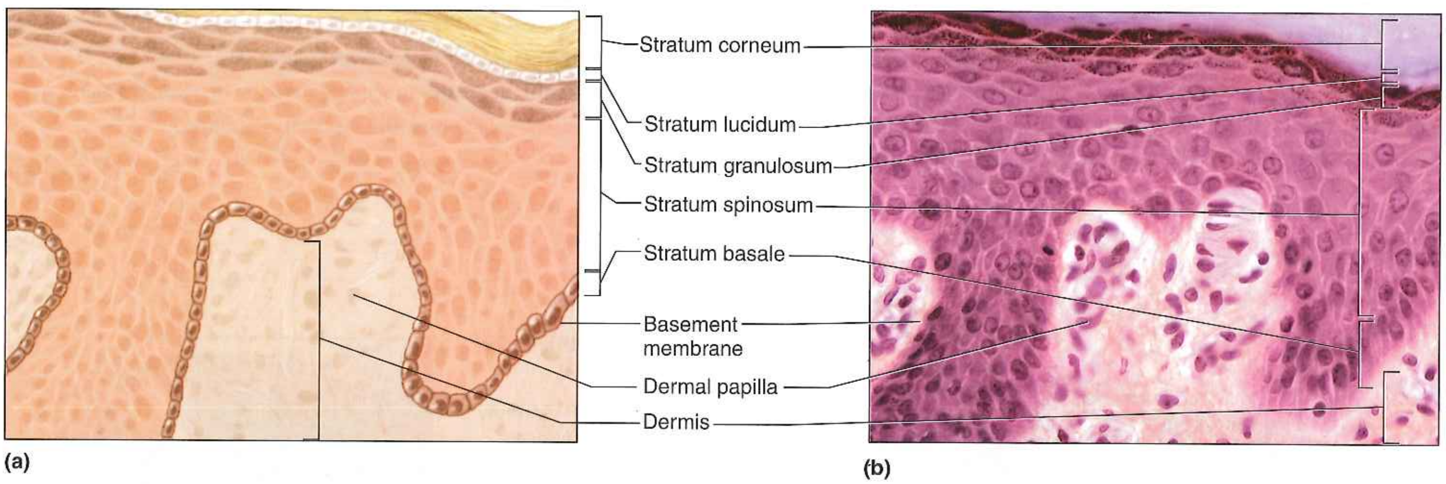


FIGURE 6.3 AP|R Epidermis of thick skin. *(a)* The layers of the epidermis are distinguished by changes in cells as they are pushed toward the surface of the skin. *(b)* Light micrograph of skin (120×).

Q: *Where is thick skin found on the body?*

Answer can be found in Appendix G on page 938.

TABLE 6.1 | Layers of the Epidermis

Layer	Location	Characteristics
Stratum corneum	Outermost layer	Many layers of keratinized, dead epithelial cells that are flattened and non-nucleated
Stratum lucidum	Between stratum corneum and stratum granulosum on soles and palms	Cells appear clear; nuclei, organelles, and cell membranes are no longer visible
Stratum granulosum	Beneath the stratum corneum	Three to five layers of flattened granular cells that contain shrunken fibers of keratin and shriveled nuclei
Stratum spinosum	Beneath the stratum granulosum	Many layers of cells with centrally located, large, oval nuclei and developing fibers of keratin; cells becoming flattened
Stratum basale (basal cell layer)	Deepest layer	A single row of cuboidal or columnar cells that divide and grow; this layer also includes melanocytes

most areas, only four layers are distinguishable. They are the *stratum basale* (*stratum germinativum*, or basal cell layer), the deepest layer; the *stratum spinosum;* the *stratum granulosum;* and the *stratum corneum,* a fully keratinized outermost layer. An additional layer, the *stratum lucidum* (between the stratum granulosum and the stratum corneum) is in the thickened skin of the palms and soles. The cells of these layers change shape as they are pushed toward the surface (fig. 6.3).

In body regions other than the palms and soles, the epidermis is usually thin, averaging 0.07–0.12 mm. The stratum lucidum may be missing where the epidermis is thin. Table 6.1 describes the characteristics of each layer of the epidermis.

In healthy skin, production of epidermal cells in the stratum basale closely balances loss of dead cells from the stratum corneum. As a result, skin does not completely wear away. The rate of cell division increases where the skin is rubbed or pressed regularly, causing the growth of thickened areas called *calluses* on the palms and soles and keratinized conical masses on the toes called *corns.*

> In psoriasis, a chronic skin disease, cells in the epidermis divide seven times more frequently than normal. Excess cells accumulate, forming bright red patches covered with silvery scales, which are keratinized cells. Medications used to treat cancer, such as methotrexate, are used to treat severe cases of psoriasis. Immune suppressing medications, such as topical corticosteroids, are used for treatment of chronic psoriasis. Five million people in the United States and 2% of people worldwide have psoriasis.

The epidermis has important protective functions. It shields the moist underlying tissues against excess water loss, mechanical injury, and the effects of harmful chemicals. When intact, the epidermis also keeps out disease-causing microorganisms (pathogens).

PRACTICE

7 Explain how the epidermis is formed.

8 Distinguish between the stratum basale and the stratum corneum.

9 List the protective functions of the epidermis.

Specialized cells in the epidermis called **melanocytes** produce the dark pigment **melanin** (mel′ah-nin) from the amino acid tyrosine in organelles called melanosomes (fig. 6.4*a*). Melanin provides skin color. Melanin also absorbs ultraviolet radiation in sunlight, which would otherwise cause mutations in the DNA of skin cells and other damaging effects. Clinical Application 6.1 discusses one consequence of excess sun exposure—skin cancer.

Melanocytes lie in the stratum basale of the epidermis. They are the only cells that can produce melanin, but the pigment may also appear in nearby epidermal cells.

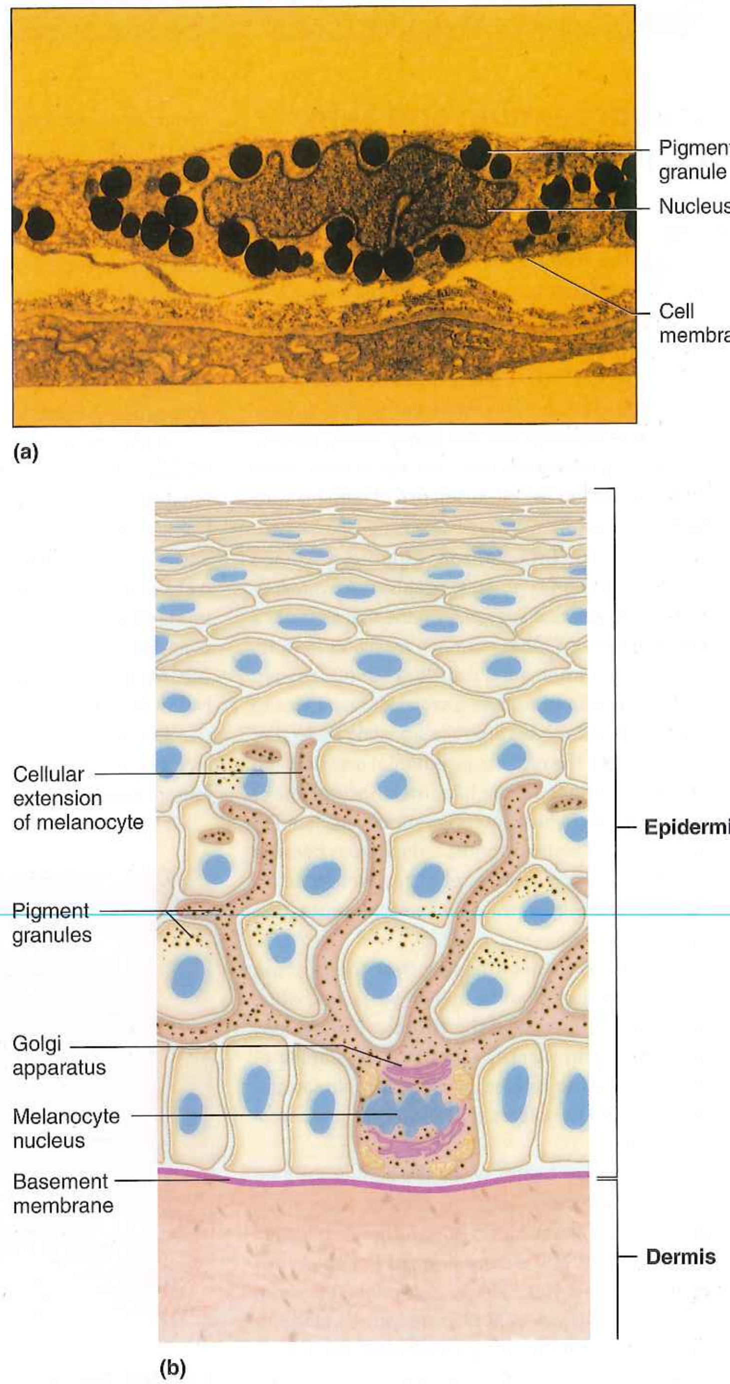


FIGURE 6.4 A melanocyte. (*a*) Transmission electron micrograph of a melanocyte with pigment-containing granules (10,600×). (*b*) A melanocyte may have pigment-containing extensions that pass between epidermal cells and transfer pigment into them. Much of the melanin is deposited above the nucleus, where the pigment can absorb UV radiation from outside before the DNA is damaged.

Melanocytes have long, pigment-containing cellular extensions that pass upward between neighboring epidermal cells. These extensions transfer melanin granules in melanosomes into neighboring keratinocytes by a process called *cytocrine secretion.* They may accumulate more melanin than melanocytes do (fig. 6.4*b*).

6.1 CLINICAL APPLICATION

Indoor Tanning and Skin Cancer

A deep, dark tan was once considered desirable. In the 1960s a teenager might have spent hours on a beach, skin glistening with oil, maybe even using a reflecting device to concentrate sun exposure on the face. Today more than 30 million people in the United States use indoor tanning beds to temporarily darken their skin, but at a health cost. Rates of new skin cancer cases, particularly among young women, have skyrocketed since 1992, paralleling the increased use of tanning beds by this group.

Usually the DNA damage response, discussed in chapter 4 (p. 144), protects against sun overexposure. Solar radiation activates a gene that encodes a protein called p53 that normally mediates harmful effects of environmental insults in various tissues. In the skin, p53 stimulates a series of responses to sunning: keratinocytes produce signaling molecules that promote the redness (erythema) and swelling of inflammation. Meanwhile, melanocytes make more melanin, which enters keratinocytes. Tanning results. Use of tanning booths is dangerous because it bathes the skin in doses of ultraviolet radiation that can overwhelm the skin's natural protection against cancer.

Researchers hypothesize that the tanning response evolved about a million years ago, when our ancestors lived near the equator. Biology may also explain why we like to sunbathe—it stimulates keratinocytes to release beta-endorphin, a molecule related to opiates that promotes a sense of well-being.

Skin cancer begins when the sun (or tanning bed) exposure overwhelms the protection provided by p53. Most skin cancers arise in nonpigmented epithelial cells in the deep layer of the epidermis or from melanocytes. Skin cancers originating from epithelial cells are called *cutaneous carcinomas* (basal cell carcinoma or squamous cell carcinoma); those arising from melanocytes are *cutaneous melanomas* (melanocarcinomas or malignant melanomas) (fig. 6A).

Cutaneous carcinomas are the most common type of skin cancer, affecting mostly light-skinned people over forty years of age regularly exposed to sunlight. It typically develops from a hard, dry, scaly growth with a reddish base. The lesion may be flat or raised and usually firmly adheres to the skin, appearing most often on the neck, face, or scalp. Surgical removal or radiation treatment usually cures these slow-growing cancers.

A cutaneous melanoma is pigmented with melanin, often with a variety of colored areas—variegated brown, black, gray, or blue. A melanoma usually has irregular rather than smooth outlines and may feel bumpy. The "ABCDE" rule provides a checklist for melanoma: A for asymmetry; B for border (irregular); C for color (more than one); D for diameter (more than 6 millimeters); and E for elevation. Melanoma accounts for only 4% of skin cancers but for 80% of skin cancer deaths.

People of any age may develop a cutaneous melanoma. These cancers are caused by short, intermittent exposure to high-intensity sunlight, such as when a person who usually stays indoors occasionally sustains a blistering sunburn.

Light-skinned people who burn rather than tan are at higher risk of developing a cutaneous melanoma. The cancer usually appears in the skin of the trunk, especially the back, or the limbs, arising from normal-appearing skin or from a mole (nevus). The lesion spreads horizontally through the skin, but eventually may thicken and invade deeper tissues. Surgical removal during the horizontal growth phase arrests the cancer in six of every seven cases. But once the lesion thickens and deepens, it becomes more difficult to treat, and the survival rate is low. Melanomas in people who regularly use tanning beds tend to be thicker and more widely spread at the time of diagnosis than other early melanomas.

To reduce risk of developing skin cancer, avoid exposure to high-intensity sunlight, use sunscreens and sunblocks, and examine the skin regularly. Report any "ABCDE" lesions to a physician. Especially avoid tanning beds. Several European nations have banned them for people under age eighteen, and the U.S. government may follow. ■

(a) (b)

FIGURE 6A Skin cancer. (*a*) Basal cell carcinoma. (*b*) Malignant melanoma.

Humans come in a wide variety of hues. Skin color is determined by heredity, as well as by environmental and physiological factors. Regardless of racial origin, all people have about the same number of melanocytes in their skin. Differences in skin color result from differences in the amount of melanin these cells produce, which is controlled by several genes. The more melanin, the darker the skin. The distribution and size of pigment granules in melanocytes also influence skin color. The granules in very dark skin are single and large; those in lighter skin aggregate in clusters of two to four smaller granules. People who inherit mutations in melanin genes have a condition called *albinism*, which includes non-pigmented skin. Albinism affects people of all races (fig. 6.5).

Environmental factors such as sunlight, ultraviolet light from sunlamps, and X rays affect skin color. These factors rapidly darken existing melanin, and they stimulate melanocytes to produce more pigment and transfer it to nearby epidermal cells within a few days. Unless exposure to sunlight

FIGURE 6.5 The pale irises, skin, and hair of a person with albinism reflect lack of melanin. Albinism is inherited.

continues, the tan fades as pigmented keratinocytes that have been pushed toward the skin surface wear away.

Blood in the dermal vessels adds color to the skin. When blood is well oxygenated, the blood pigment hemoglobin is bright red, making the skin of light-complexioned people appear pinkish. When the blood oxygen concentration is low, hemoglobin is dark red, and the skin appears bluish—a condition called *cyanosis.*

The state of the blood vessels also affects skin color. If the vessels are dilated, more blood enters the dermis, reddening the skin of a light-complexioned person. This may happen when a person is overheated, embarrassed, or under the influence of alcohol. Conversely, conditions that constrict blood vessels cause the skin to lose this reddish color. Thus, if body temperature drops abnormally or if a person is frightened, the skin may appear pale.

A yellow-orange plant pigment called *carotene,* found in yellow vegetables, can give skin a yellowish cast if a person consumes too much of it. The skin color results from accumulation of carotene in the adipose tissue of the subcutaneous layer. Diseases may also affect skin color. A yellowish skin tone can indicate *jaundice,* which is a consequence of liver malfunction.

A newborn who develops the yellowish skin of jaundice shortly after birth may have a blood incompatibility or an immature liver. An observant British hospital nurse discovered a treatment for newborn jaundice in 1958. When taking her tiny charges out in the sun, she noticed that a child whose skin had a yellow pallor developed normal pigmentation when he lay in sunlight. However, the part of the child's body covered by a diaper and therefore not exposed to the sun remained yellow. Further investigation showed that sunlight enables the body to break down bilirubin, the liver substance that accumulates in the skin. Today, newborns who develop persistently yellowish skin may have to lie under artificial "bili lights" for a few days, clad only in protective goggles.

PRACTICE

10 What is the function of melanin?

11 How do genetic factors influence skin color?

12 Which environmental factors influence skin color?

13 How do physiological factors influence skin color?

Dermis

The boundary between the epidermis and the dermis is typically uneven, because ridges from the epidermis project inward and cone-shaped *dermal papillae* extend from the dermis into the spaces between the ridges (see figs. 6.2 and 6.3). Dermal papillae increase the surface area where epidermal cells receive oxygen and nutrients from dermal capillaries.

Dermal papillae are found in the skin all over the body, but they are most abundant in the hands and feet. The friction ridges that the dermal papillae form leave a patterned impression—a fingerprint—when a finger presses against a surface. Fingerprints are used to identify individuals because they are unique. Genes determine general fingerprint patterns. Papillary minutiae of individual fingerprints form as the fetus presses the developing ridges against the uterine wall. No two fetuses move exactly alike, so even the fingerprints of identical twins are not exactly the same.

The dermis binds the epidermis to the underlying tissues. Although no distinct boundary is visible, the dermis has two layers. The upper or *papillary layer* is composed of areolar connective tissue. The lower or *reticular layer* is dense irregular connective tissue that includes tough collagenous fibers and elastic fibers in a gel-like ground substance. Networks of these fibers give the skin toughness and elasticity. On average, the dermis is 1.0–2.0 mm thick; however, it may be as thin as 0.5 mm or less on the eyelids or as thick as 3.0 mm on the soles of the feet.

The dermis also contains muscle fibers. Some regions, such as the skin that encloses the testes (scrotum), contain many smooth muscle cells that can wrinkle the skin when they contract. Other smooth muscles in the dermis are associated with accessory structures such as hair follicles and glands. Many skeletal muscle fibers are anchored to the dermis in the skin of the face. They help produce the voluntary movements associated with facial expressions.

Nerve cell processes are scattered throughout the dermis. Motor processes carry impulses to dermal muscles and glands, and sensory processes carry impulses away from specialized sensory receptors (see fig. 6.2).

One type of sensory receptor in the deeper dermis, lamellated (Pacinian) corpuscles responds to heavy pressure, whereas another type in the upper dermis, tactile (Meissner's) corpuscles, senses light touch and texture. Still other receptors (free nerve endings) respond to temperature changes or to factors that can damage tissues and extend into the epidermis. Sensory receptors are discussed in chapter 12 (p. 446). The dermis also contains accessory structures, including blood vessels, hair follicles, sebaceous glands, and sweat glands.

To create a tattoo, very fine needles inject inks into the dermis. The color is permanent, because dermis cells are not shed, unlike cells of the epidermis. To remove a tattoo, a laser shatters the ink molecules, and the immune system removes the resulting debris. Before laser removal became available in the late 1980s, unwanted tattoos were scraped, frozen, or cut away—all painful procedures.

PRACTICE

14 What types of tissues make up the dermis?

15 What are the functions of these tissues?

6.3 ACCESSORY STRUCTURES OF THE SKIN

Accessory structures of the skin originate from the epidermis and include nails, hair follicles, and skin glands. As long as accessory structures remain intact, severely burned or injured dermis can regenerate.

Nails

Nails are protective coverings on the ends of the fingers and toes. Each nail consists of a *nail plate* that overlies a surface of skin called the *nail bed.* Specialized epithelial cells continuous with the epithelium of the skin produce the nail bed. The whitish, thickened, half-moon-shaped region (lunula) at the base of a nail plate is the most active growing region. The epithelial cells here divide, and the newly formed cells become keratinized. This gives rise to tiny, keratinized scales that become part of the nail plate, pushing it forward over the nail bed. In time, the plate extends beyond the end of the nail bed and with normal use gradually wears away (fig. 6.6).

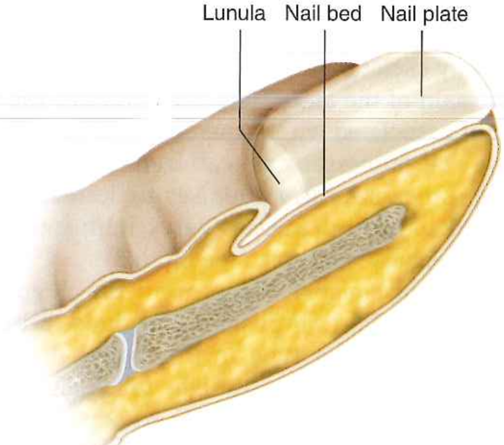


FIGURE 6.6 APIR Nails grow from epithelial cells that divide and become keratinized, forming the rest of the nail.

Q: *What is the most actively growing region of the nail?*

Answer can be found in Appendix G on page 938.

Nail appearance mirrors health. Bluish nail beds may reflect a circulation problem. A white nail bed or oval depressions in a nail can indicate anemia. A pigmented spot under a nail that isn't caused by an injury may be a melanoma. Horizontal furrows may result from a period of serious illness or indicate malnutrition. Certain disorders of the lungs, heart, or liver may cause extreme curvature of the nails. Red streaks in noninjured nails may be traced to rheumatoid arthritis, ulcers, or hypertension.

Hair Follicles

Hair is present on all skin surfaces except the palms, soles, lips, nipples, and parts of the external reproductive organs. However, in some places it is not well developed. For example, hair on the forehead is very fine in many people.

At any time, 90% of hair is in the growth phase. Each hair develops from a group of epidermal cells at the base of a tubelike depression called a **hair follicle** (hār fol′ĭ-kl). This follicle extends from the surface into the dermis and contains the *hair root,* the portion of hair embedded in the skin. The epidermal cells in the *hair bulb* at its base are nourished from dermal blood vessels in a projection of connective tissue (hair papilla) at the deep end of the follicle. As these epidermal cells divide and grow, they push older cells toward the surface. The cells that move upward and away from the nutrient supply become keratinized and die. Their remains constitute the structure of a developing *hair shaft* that extends away from the skin surface. In other words, a hair is composed of dead epidermal cells (figs. 6.7 and 6.8). Both hair and epidermal cells develop from the same types of stem cells.

A healthy person loses from twenty to 100 hairs a day as part of the normal growth cycle of hair. A hair typically grows for two to six years, then rests for two to three months anchored in its follicle. Later, a new hair begins to grow from the base of the follicle, pushing the old hair outward until it drops off. If hairs shed from the scalp are not replaced, baldness results. Clinical Application 6.2 discusses several types of hair loss.

Genes determine hair color by directing the type and amount of pigment that epidermal melanocytes produce. Dark hair has more of the brownish-black **eumelanin,** while blonde hair and red hair have more of the reddish-yellow **pheomelanin.** The white hair of a person with *albinism* lacks melanin altogether. A mixture of pigmented hairs and unpigmented hairs appears gray.

A single gene controls the proportions of eumelanin and pheomelanin in hair. Analysis of this gene in cells from arm bones of Neanderthals from about 45,000 years ago indicates that some of them had reddish hair and pale skin, in contrast to the common view of Neanderthals as having dark pigmentation.

6.2 CLINICAL APPLICATION

Hair Loss

About 1.4 billion people worldwide are bald. The most common type of baldness in adults is pattern baldness, in which the top of the head loses hair. Pattern baldness affects 35 million men and 20 million women in the United States and is also common elsewhere. The women tend to be past menopause, when lowered amounts of the hormone estrogen contribute to hair loss, which occurs more evenly on the scalp than it does in men. Pattern baldness is called *androgenetic alopecia* because it is associated with testosterone, an androgenic (male) hormone. Analysis of scalp samples from the hairless and hairy parts of affected men's heads reveals that hair progenitor cells are lacking in the bald regions. Abnormal hormone levels that mimic menopause may cause hair loss in young women.

Another type of baldness is *alopecia areata*, in which the body manufactures antibodies that attack the hair follicles. This results in oval bald spots in mild cases but complete loss of scalp and body hair in severe cases. About 2.5 million people in the United States have alopecia areata.

Temporary hair loss has several causes. Lowered estrogen levels shortly before and after giving birth may cause a woman's hair to fall out in clumps. Taking birth control pills, cough medications, certain antibiotics, vitamin A derivatives, antidepressants, and many other medications can also cause temporary hair loss. A sustained high fever may prompt hair loss six weeks to three months later.

Many people losing their hair seek treatment (fig. 6B). One treatment is minoxidil (Rogaine), a drug originally used to lower high blood pressure. Rogaine causes new hair to grow in 10% to 14% of cases, and in 90% of people, it slows hair loss. However, when a person stops taking it, any new hair falls out. Hair transplants move hair follicles from a hairy body part to a bald part. They work. Several other approaches, however, can damage the scalp or lead to infection. These include suturing on hair pieces and implants of high-density artificial fibers. Products called "thinning hair supplements" are ordinary conditioners that make hair feel thicker. They are concoctions of herbs and the carbohydrate polysorbate.

A future approach to treating baldness may harness the ability of stem cells to divide and differentiate to give rise to new hair follicles. Stem cells that can produce hair as well as epidermal cells and sebaceous glands lie just above the hair bulb at the base of a hair follicle. The first clue to the existence of these cells was that new skin in burn patients arises from hair follicles. Manipulating stem cells could someday treat extreme hairiness (hirsutism) as well as baldness. ■

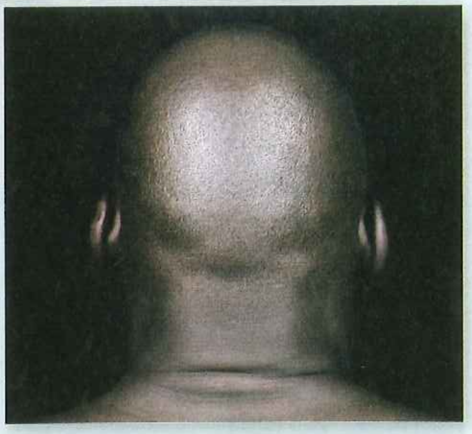
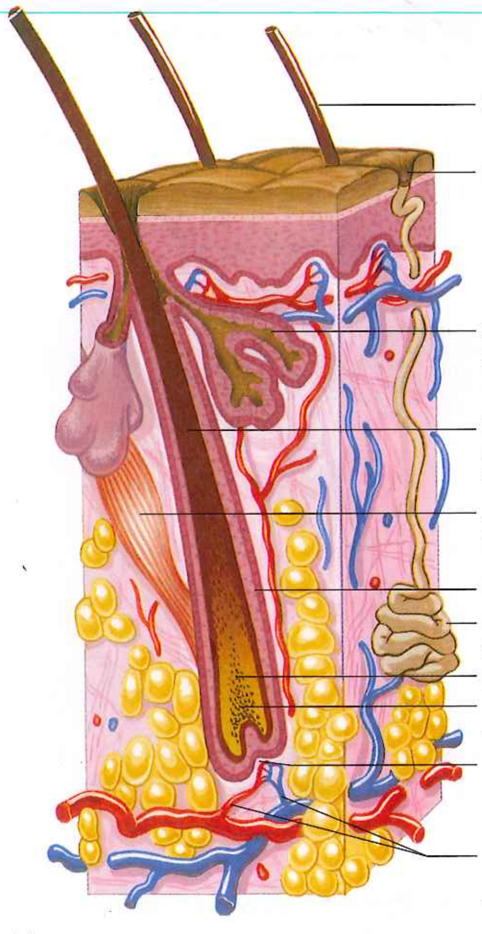
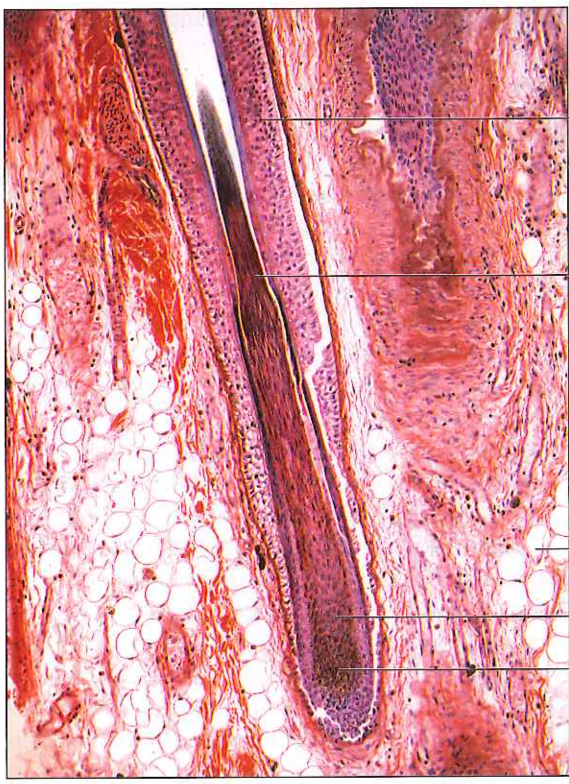


FIGURE 6B Being bald can be beautiful, but many people with hair loss seek ways to grow hair.



(a)



(b)

FIGURE 6.7 APR Hair follicle. (*a*) A hair grows from the base of a hair follicle when epidermal cells divide and older cells move outward and become keratinized. (*b*) Light micrograph of a hair follicle (175×).

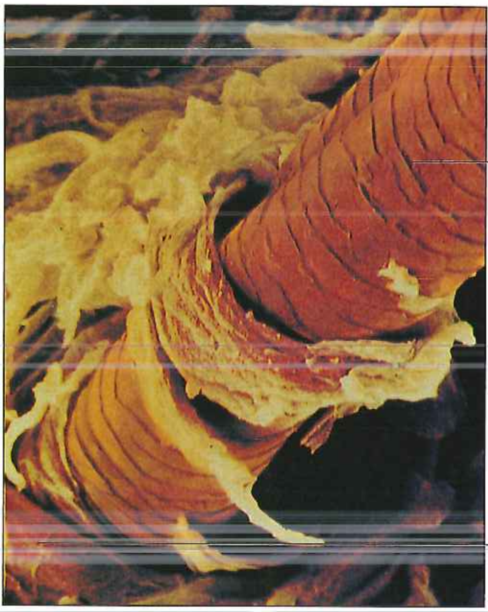


FIGURE 6.8 Scanning electron micrograph of a hair emerging from the epidermis (875×).

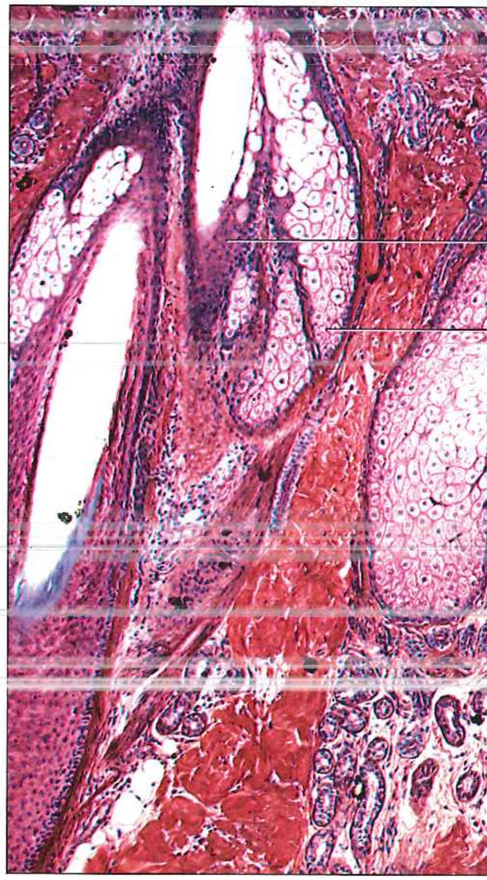


FIGURE 6.9 AP|R A sebaceous gland secretes sebum into a hair follicle, shown here in oblique section (300×).

A bundle of smooth muscle cells, forming the *arrector pili muscle* (see figs. 6.2*a* and 6.7*a*), attaches to each hair follicle. When the muscle contracts, a short hair in the follicle stands on end. If a person is emotionally upset or very cold, nervous stimulation causes the arrector pili muscles to contract, raising gooseflesh, or goose bumps. Each hair follicle is also associated with one or more sebaceous (oil-producing) glands.

Skin Glands

Sebaceous glands (se-ba′shus glandz) (see fig. 6.2) contain groups of specialized epithelial cells and are usually associated with hair follicles. They are holocrine glands (see chapter 5, p. 158), and their cells produce globules of a fatty material that accumulate, swelling and bursting the cells. The resulting mixture of fatty material and cellular debris is called *sebum*.

Sebum is secreted into hair follicles through short ducts and helps keep the hairs and the skin soft, pliable, and waterproof (fig. 6.9). Acne results from excess sebum secretion (Clinical Application 6.3).

Sebaceous glands are scattered throughout the skin but are not on the palms and soles. In some regions, such as the lips, the corners of the mouth, and parts of the external reproductive organs, sebaceous glands open directly to the surface of the skin rather than being connected to hair follicles.

Sweat (swet) **glands,** or sudoriferous glands, are widespread in the skin. Each gland consists of a tiny tube that originates as a ball-shaped coil in the deeper dermis or superficial subcutaneous layer. The coiled portion of the gland is closed at its deep end and is lined with sweat-secreting epithelial cells. The most numerous sweat glands, called **eccrine** (ek′rin) **glands,** respond throughout life to body temperature elevated by environmental heat or physical exercise (fig. 6.10). These glands are abundant on the forehead, neck, and back, where they produce profuse sweat on hot

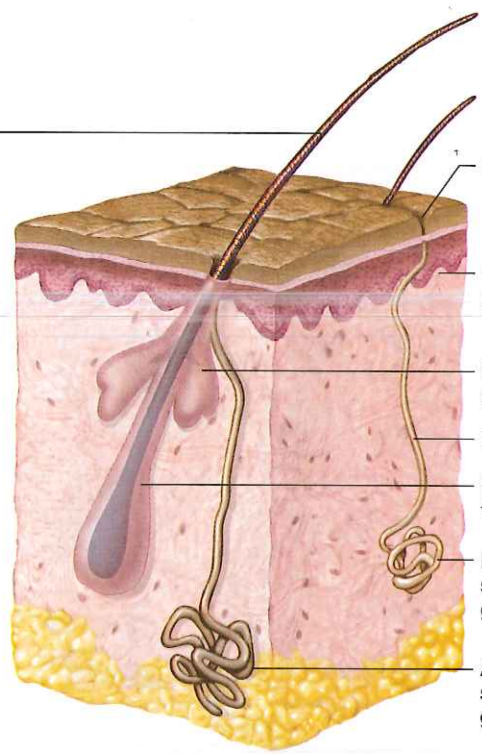


FIGURE 6.10 AP|R Note the difference in location of the ducts of the eccrine and apocrine sweat glands.

6.3 CLINICAL APPLICATION

Acne

Many young people are all too familiar with *acne vulgaris*, a disorder of the sebaceous glands. Excess sebum and squamous epithelial cells clog the glands, producing blackheads and whiteheads (collectively comedones). The blackness is not dirt but results from the accumulated cells blocking light. In addition, the clogged sebaceous gland provides an attractive environment for anaerobic bacteria. Their presence signals the immune system to trigger inflammation. The inflamed, raised area is a pimple (pustule).

A Hormonal Problem

Acne is the most common skin disease, affecting 80% of people at some time between the ages of eleven and thirty. It is usually hormonally induced. Just before puberty, the adrenal glands increase production of androgens, which stimulate increased secretion of sebum. At puberty, sebum production surges again. Acne usually develops because the sebaceous glands are extra responsive to androgens, but in some cases, androgens may be produced in excess (fig. 6C).

Acne can cause skin blemishes far more serious than the perfect models in acne medication ads depict. Scarring from acne can lead to emotional problems. Fortunately, several highly effective treatments are available.

What to Do—And Not Do

Acne is not caused by uncleanliness or eating too much chocolate or greasy food. Although cleansing products containing soaps, detergents, or astringents can remove surface sebum, they do not stop the flow of oil that contributes to acne. Abrasive products are harmful because they irritate the skin and increase inflammation.

Most acne treatments take weeks to months to work. Women with acne are sometimes prescribed certain types of birth control pills because the estrogens counter androgen excess. Isotretinoin is a very effective derivative of vitamin A but has side effects and causes birth defects. Systemic antibiotics can treat acne by clearing bacteria from sebaceous glands. Topical treatments include tretinoin (another vitamin A derivative), salicylic acid (an aspirin solution), and benzoyl peroxide.

Treatment for severe acne requires a doctor's care. Drug combinations are tailored to the severity of the condition (table 6A). ■

FIGURE 6C Acne is a common skin condition usually associated with a surge of androgen activity.

TABLE 6A | Acne Treatments (by Increasing Severity)

Condition	Treatment
Noninflammatory comedonal acne (blackheads and whiteheads)	Topical tretinoin or salicylic acid
Papular inflammatory acne	Topical antibiotic
Widespread blackheads and pustules	Topical tretinoin and systemic antibiotic
Severe cysts	Systemic isotretinoin
Explosive acne (ulcerated lesions, fever, joint pain)	Systemic corticosteroids

days or during intense physical activity. They also release the moisture that appears on the palms and soles when a person is emotionally stressed.

A tube (duct) that opens at the surface as a *pore* carries the fluid that the eccrine sweat glands secrete (fig. 6.11). Sweat is mostly water, but it also contains small amounts of salts and wastes such as urea and uric acid. Thus, sweating is also an excretory function.

> A human body has 2 to 5 million sweat glands that secrete up to 12 quarts of sweat a day. We are the only mammals to have eccrine glands widespread in the skin. In other mammals, the glands are associated with hairs.

The secretions of certain sweat glands, called **apocrine** (ap′o-krin) **glands,** develop a scent as skin bacteria metabolize them (see fig. 6.10). (Although these glands are currently called apocrine, they secrete by the same mechanism as eccrine glands—see merocrine glands described in chapter 5, p. 158.) Apocrine sweat glands become active at puberty and can wet certain areas of the skin when a person is emotionally upset, frightened, or in pain. Apocrine

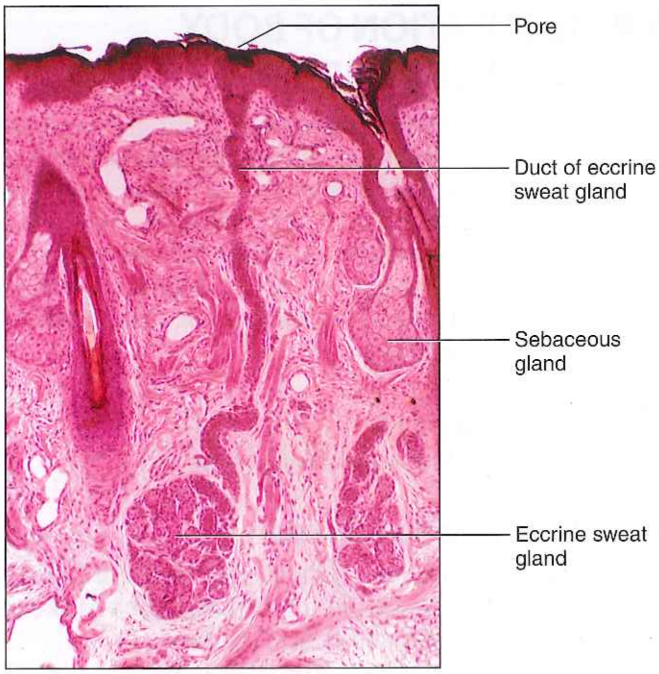


FIGURE 6.11 APR Light micrograph of the skin showing an eccrine sweat gland with its duct extending to a pore (30×).

TABLE 6.2 | Skin Glands

Type	Description	Function	Location
Sebaceous glands	Groups of specialized epithelial cells	Keep hair soft, pliable, waterproof	Near or connected to hair follicles, everywhere but on palms and soles
Eccrine sweat glands	Abundant sweat glands with odorless secretion	Lower body temperature	Originate in deep dermis or subcutaneous layer and open to surface on forehead, neck, and back
Apocrine sweat glands	Less numerous sweat glands with secretions that develop odors	Wet skin during pain, fear, emotional upset, and sexual arousal	Near hair follicles in armpit and groin
Ceruminous glands	Modified sweat glands	Secrete earwax	External acoustic meatus
Mammary glands	Modified sweat glands	Secrete milk	Breasts

sweat glands are also active during sexual arousal. In adults, the apocrine glands are most numerous in axillary regions and the groin. Ducts of these glands open into hair follicles.

Other sweat glands are structurally and functionally modified to secrete specific fluids, such as the ceruminous glands of the external acoustic meatus that secrete ear wax (see chapter 12, p. 456) and the female mammary glands that secrete milk (see chapter 23, pp. 891–892). Table 6.2 summarizes skin glands.

PRACTICE

16 Describe the structure of the nail bed.

17 Explain how a hair forms.

18 What causes goose bumps?

19 What is the function of the sebaceous glands?

20 Distinguish between eccrine sweat glands and apocrine sweat glands.

6.4 REGULATION OF BODY TEMPERATURE

The regulation of body temperature is vitally important because even slight shifts can disrupt the rates of metabolic reactions. Normally, the temperature of deeper body parts remains close to a set point of 37°C (98.6°F). The maintenance of a stable temperature requires that the amount of heat the body loses be balanced by the amount it produces. The skin plays a key role in the homeostatic mechanism that regulates body temperature.

RECONNECT
To Chapter 1, Homeostasis, pages 18–19.

Heat Production and Loss

Heat is a product of cellular metabolism. The major heat producers are the more active cells of the body, such as skeletal and cardiac muscle cells and cells of the liver.

When body temperature rises above the set point, the nervous system stimulates structures in the skin and other organs to release heat. For example, during physical exercise, active muscles release heat, which the blood carries away. The warmed blood reaches the part of the brain (the hypothalamus) that controls the body's temperature set point, which signals muscles in the walls of dermal blood vessels to relax. As these vessels dilate (vasodilation), more blood enters them, and some of the heat the blood carries escapes to the outside. At the same time, deeper blood vessels contract (vasoconstriction), diverting blood to the surface, and the skin reddens. The heart is stimulated to beat faster, moving more blood out of the deeper regions.

The primary means of body heat loss is **radiation** (ra-de-a'shun), by which infrared heat rays escape from warmer surfaces to cooler surroundings. These rays radiate in all directions, much like those from the bulb of a heat lamp.

Conduction and convection release less heat than does radiation. In **conduction** (kon-duk'shun), heat moves from the body directly into the molecules of cooler objects in contact with its surface. For example, heat is lost by conduction into the seat of a chair when a person sits down. The heat loss continues as long as the chair is cooler than the body surface touching it. Heat is also lost by conduction to the air molecules that contact the body. As air becomes heated, it moves away from the body, carrying heat with it, and is replaced by cooler air moving toward the body. This type of continuous circulation of air over a warm surface is **convection** (kon-vek'shun).

Still another means of body heat loss is **evaporation** (e-vap"o-ra'shun). When the body temperature rises above normal, the nervous system stimulates eccrine sweat glands to release sweat onto the surface of the skin. As this fluid evaporates (changes from a liquid to a gas), it carries heat away from the surface, cooling the skin.

When body temperature drops below the set point, as may occur in a very cold environment, the brain triggers different responses in the skin structures. Muscles in the walls of dermal blood vessels are stimulated to contract. This action decreases the flow of heat-carrying blood through the skin, which loses color, and helps reduce heat loss by radiation, conduction, and convection. At the same time, sweat glands remain inactive, decreasing heat loss by evaporation. If body temperature continues to drop, the nervous system may stimulate muscle cells in the skeletal muscles throughout the body to contract slightly. This action requires an increase in the rate of cellular respiration, which releases heat as a by-product. If this response does not raise the body temperature to normal, small groups of muscles may rhythmically contract with greater force, causing the person to shiver, generating more heat. Figure 6.12 summarizes the body's temperature-regulating mechanism, and Clinical Application 6.4 examines two causes of elevated body temperature.

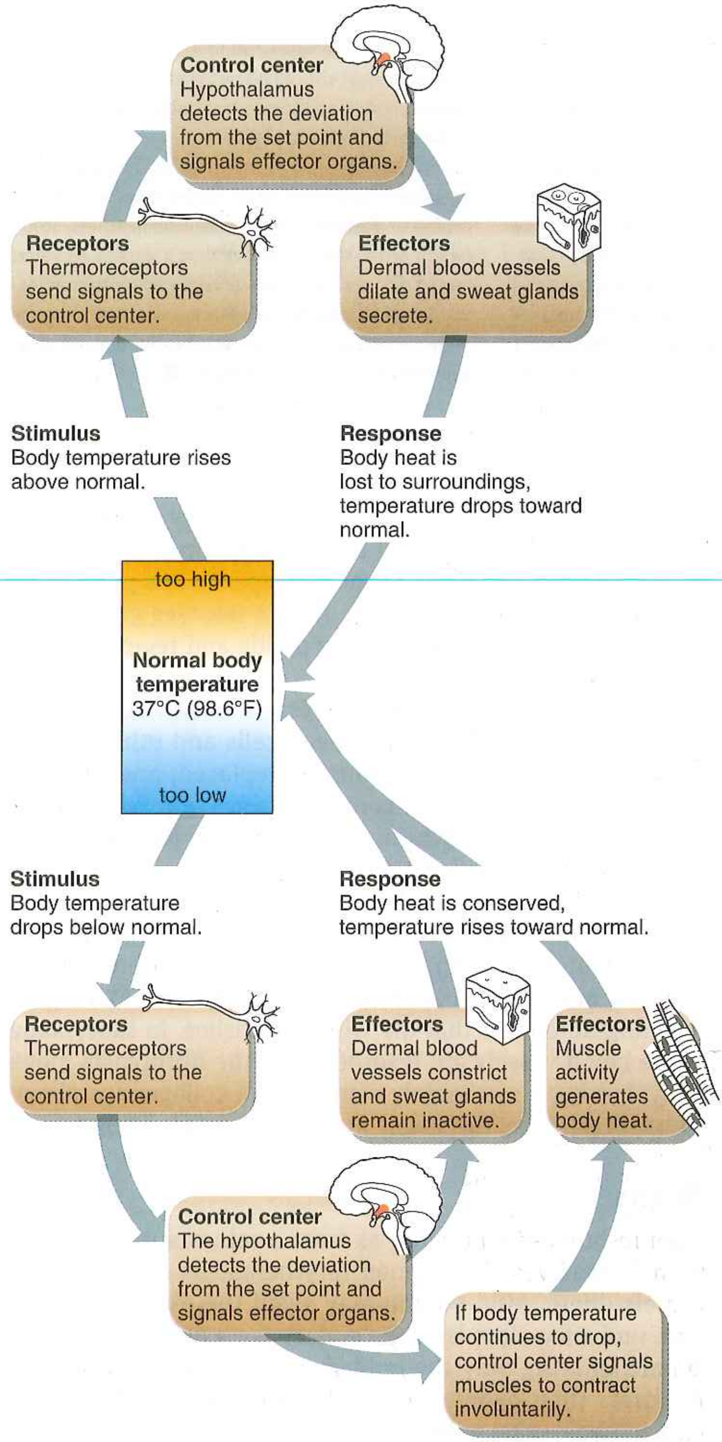


FIGURE 6.12 Body temperature regulation is an example of homeostasis.

Problems in Temperature Regulation

The body's temperature-regulating mechanism does not always operate satisfactorily, and the consequences may be dangerous. For example, air can hold only a limited volume of water vapor, so on a hot, humid day, the air may become nearly saturated with water. At such times, the sweat glands may be activated, but the sweat cannot quickly evaporate. The skin becomes wet, but the person remains hot and uncomfortable. In addition, if the air temperature is high, heat loss by radiation is less effective. If the air temperature exceeds body temperature, the person may gain heat from the surroundings, elevating body temperature even higher. Body temperature may rise, in a condition called hyperthermia. Hyperthermia is a core body temperature exceeding 106°F. The skin becomes dry, hot, and flushed. The person becomes weak, dizzy, and nauseous, with headache and a rapid, irregular pulse.

Hypothermia, or lowered body temperature, can result from prolonged exposure to cold or as part of an illness. It can be extremely dangerous. Hypothermia begins with shivering and a feeling of coldness. If not treated, it progresses to mental confusion, lethargy, loss of reflexes and consciousness, and, eventually, the shutdown of major organs. If the temperature in the body's core drops just a few degrees, fatal respiratory failure or heart arrhythmia may result. However, the extremities can withstand drops of 20°F to 30°F below normal.

Certain people are at higher risk for developing hypothermia due to less adipose tissue in the subcutaneous layer beneath the skin (less insulation). These include the very old, very thin individuals, and the homeless. The very young with undeveloped nervous systems have difficulty regulating their body temperature. Dressing appropriately and staying active in the cold can prevent hypothermia. A person suffering from hypothermia must be warmed gradually so that respiratory and cardiovascular functioning remain stable.

Hypothermia is intentionally induced during certain surgical procedures involving the heart, brain, or spinal cord. In heart surgery, body temperature may be lowered to between 78°F (26°C) and 89°F (32°C), which lowers the body's metabolic rate so that less oxygen is required. Hypothermia for surgery is accomplished by packing the patient in ice or by removing blood, cooling it, and returning it.

PRACTICE

21 Why is regulation of body temperature so important?

22 How is body heat produced?

23 How does the body lose excess heat?

24 How does the skin help regulate body temperature?

25 What are the dangers of hyperthermia and hypothermia?

6.4 CLINICAL APPLICATION

Elevated Body Temperature

It was a warm June morning when the harried and hurried father strapped his five-month-old son Bryan into the backseat of his car and headed for work. Tragically, the father forgot to drop his son off at the babysitter's. When his wife called him at work late that afternoon to inquire why the child was not at the sitter's, the shocked father realized his mistake and hurried down to his parked car. But it was too late—Bryan had died. Left for ten hours in the car in the sun, all windows shut, the baby's temperature had quickly soared. Two hours after he was discovered, the child's temperature still exceeded 41°C (106°F).

Sarah L.'s case of elevated body temperature was more typical. She awoke with a fever of 40°C (104°F) and a sore throat. At the doctor's office, a test revealed that Sarah had a *Streptococcus* infection. The fever was her body's attempt to fight the infection.

The true cases of Bryan and Sarah illustrate two reasons why body temperature may rise—inability of the temperature homeostatic mechanism to handle an extreme environment and an immune system response to infection. In Bryan's case, sustained exposure to very high heat overwhelmed his temperature-regulating mechanism, resulting in hyperthermia. Body heat built up faster than it could dissipate, and body temperature rose, even though the set point of the thermostat was normal. His blood vessels dilated so greatly in an attempt to dissipate the excess heat that after a few hours, his cardiovascular system collapsed.

Fever is a special case of hyperthermia in which temperature rises in response to an elevated set point. In fever, molecules on the surfaces of the infectious agents (usually bacteria or viruses) stimulate phagocytes to release a substance called interleukin-1 (also called endogenous pyrogen, meaning "fire maker from within"). The bloodstream carries interleukin-1 to the hypothalamus, where it raises the set point controlling temperature. In response, the brain signals skeletal muscles to contract (shivering) and increase heat production, blood flow to the skin to decrease, and sweat glands to decrease secretion. As a result, body temperature rises to the new set point, and fever develops. The increased body temperature helps the immune system kill the pathogens.

Rising body temperature requires different treatments, depending on the degree of elevation. Hyperthermia in response to exposure to intense, sustained heat should be rapidly treated by administering liquids to replace lost body fluids and electrolytes, sponging the skin with water to increase cooling by evaporation, and covering the person with a refrigerated blanket. Fever can be lowered with ibuprofen or acetaminophen, or aspirin in adults. Some health professionals believe that a slightly elevated temperature should not be reduced (with medication or cold baths) because it may be part of a normal immune response. A high or prolonged fever, however, requires medical attention.

6.5 HEALING OF WOUNDS AND BURNS

Inflammation is a normal response to injury or stress. Blood vessels in affected tissues dilate and become more permeable, allowing fluids to leak into the damaged tissues. Inflamed skin may become reddened, swollen, warm, and painful to touch. However, the dilated blood vessels provide the tissues with more nutrients and oxygen, which aids healing. The specific events in the healing process depend on the nature and extent of the injury.

A GLIMPSE AHEAD | **To Chapters 14, 15, and 16**

Vasodilation increases blood flow to an inflamed area. Cells in the blood help to eliminate dangerous microorganisms.

Cuts

If a break in the skin is shallow, epithelial cells along its margin are stimulated to divide more rapidly than usual. The newly formed cells fill the gap.

If an injury extends into the dermis or subcutaneous layer, blood vessels break and the released blood forms a clot in the wound. A clot consists mainly of a fibrous protein (fibrin) that forms from another protein in the plasma, blood cells and platelets trapped in the protein fibers. Tissue fluids seep into the area and dry. The blood clot and the dried tissue fluids form a *scab* that covers and protects underlying tissues. Epithelial cells proliferate beneath the scab, bridging the wound. Before long, fibroblasts migrate into the injured region and begin secreting collagenous fibers that bind the edges of the wound. Suturing or otherwise closing a large break in the skin speeds this process. In addition, the connective tissue matrix releases *growth factors* that stimulate certain cells to divide and regenerate the damaged tissue.

As healing continues, blood vessels extend beneath the scab. Phagocytic cells remove dead cells and other debris. Eventually, the damaged tissues are replaced, and the scab sloughs off. If the wound is deep, extensive production of collagenous fibers may form an elevation above the normal epidermal surface, called a *scar*.

In large, open wounds, healing may be accompanied by formation of small, rounded masses called *granulations* that develop in the exposed tissues. A granulation consists of a new branch of a blood vessel and a cluster of collagen-secreting fibroblasts that the vessel nourishes. In time, some of the blood vessels are resorbed, and the fibroblasts move away, leaving a scar largely composed of collagenous fibers. Figure 6.13 shows the stages in the healing of a wound.

Burns

Slightly burned skin, such as from a minor sunburn, may become warm and reddened (erythema) as dermal blood vessels dilate. Mild edema may swell the exposed tender skin, and a few days later the surface layer of skin may peel. A burn injuring only the epidermis is a *superficial partial-thickness* (first-degree) *burn*. Healing usually takes a few days to two weeks, with no scarring.

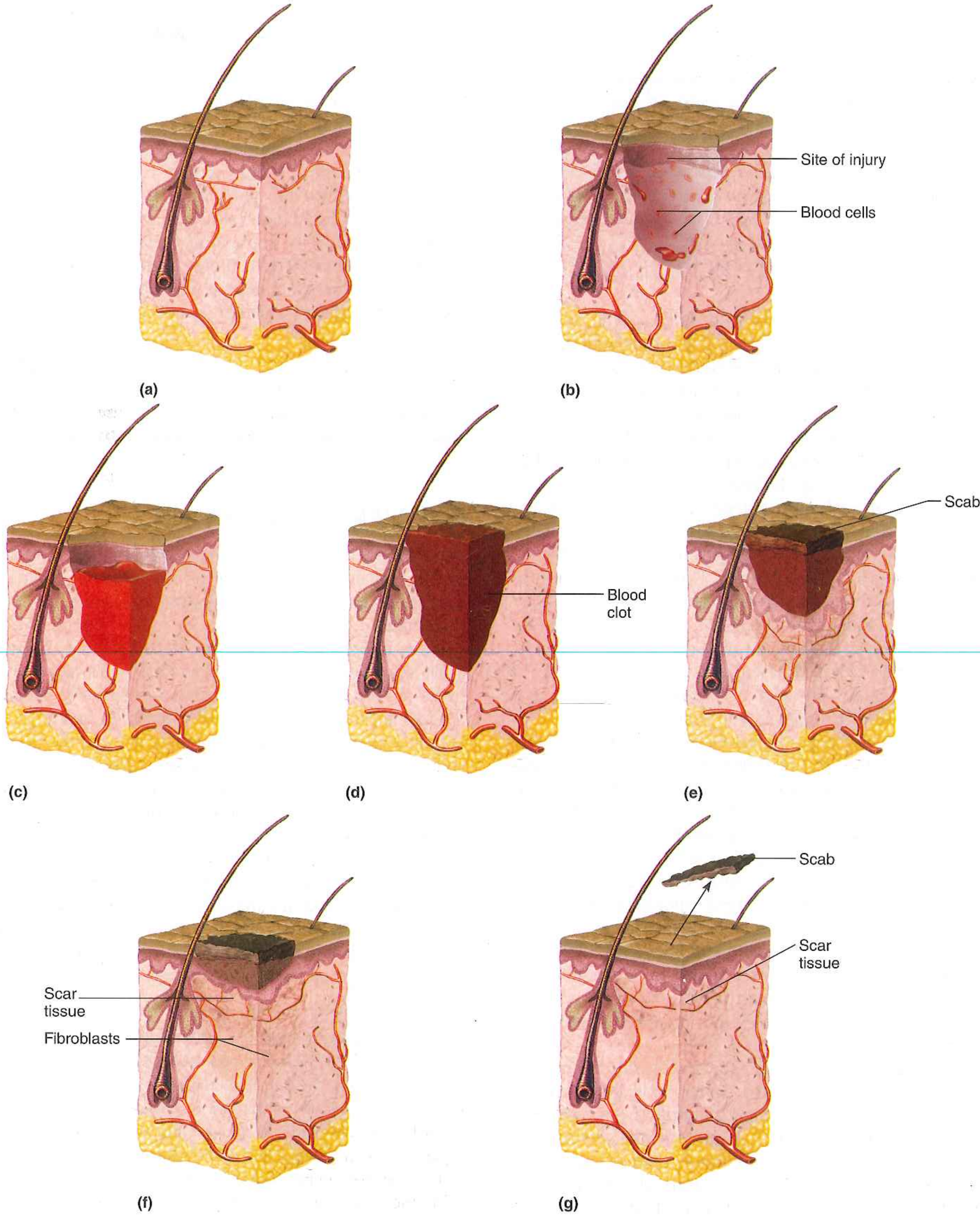


FIGURE 6.13 Healing of a wound. (*a*) If normal skin is (*b*) injured, (*c*) blood escapes from dermal blood vessels, and (*d*) a blood clot soon forms. (*e*) The blood clot and dried tissue fluid form a scab that protects the damaged region. (*f*) Later, blood vessels send out branches, and fibroblasts migrate into the area. The fibroblasts produce new connective tissue fibers, and (*g*) when the skin is mostly repaired, the scab sloughs off. Scar tissue continues to form, elevating the epidermal surface.

Acute sunburn (solar erythema) is an inflammatory reaction of the skin to excessive exposure to ultraviolet radiation in sunlight. The skin becomes very red, swollen, and painful, with discomfort peaking between 6 and 48 hours after exposure. Within a few days the skin may peel, as surface cells die and are shed. Peeling, an example of apoptosis (programmed cell death), prevents cancer from developing by ridding the body of susceptible cells. Microscopic skin changes begin within a half hour of intense sun exposure, including damage to cells in the upper, epidermal layer of the skin, and swelling of blood vessels in the deeper, dermal layer.

A burn that destroys some epidermis as well as some underlying dermis is a *deep partial-thickness* (second-degree) *burn*. Fluid escapes from damaged dermal capillaries, accumulating beneath the outer layer of epidermal cells, forming blisters. The injured region becomes moist and firm and may vary in color from dark red to waxy white. Such a burn most commonly occurs as a result of exposure to hot objects, hot liquids, flames, or burning clothing.

The extent of healing of a deep partial-thickness burn depends upon stem cells that are associated with accessory structures of the skin. These structures include hair follicles, sweat glands, and sebaceous glands. They survive the injury because although they are derived from the epidermis, they extend into the dermis. During healing, the stem cells divide, and their daughter cells grow out onto the surface of the dermis, spread over it, and differentiate as new epidermis. In time, the skin usually completely recovers, and scar tissue does not develop unless an infection occurs.

A burn that destroys the epidermis, dermis, and the accessory structures of the skin is called a *full-thickness* (third-degree) *burn*. The injured skin becomes dry and leathery, and it may vary in color from red to black to white.

A full-thickness burn usually results from immersion in hot liquids or prolonged exposure to hot objects, flames, or corrosive chemicals. Because most of the epithelial cells in the affected region are destroyed, spontaneous healing occurs by growth of epithelial cells inward from the margin of the burn. If a burn is severe and extensive, treatment may require removing a thin layer of skin from an unburned region of the body and transplanting it to the injured area. This procedure is an example of an *autograft*, a transplant within the same individual.

If a burn is too extensive to replace with skin from other parts of the body, cadaveric skin from a skin bank may be used to cover the injury. Such an *allograft* (from person to person) is a temporary covering that shrinks the wound, helps prevent infection, and preserves deeper tissues. In time, after healing begins, an autograft may replace the temporary covering, as skin becomes available from healed areas. Skin grafts can leave extensive scars.

Various skin substitutes are also used to temporarily cover extensive burns. These include amniotic membrane that surrounded a human fetus and artificial membranes composed of silicone, polyurethane, or nylon together with a network of collagenous fibers. Another type of skin substitute comes from cultured human epithelial cells. In a laboratory, a bit of human skin the size of a postage stamp can grow to the size of a bath mat in about three weeks. Skin substitutes are a major focus of tissue engineering, discussed in From Science to Technology 5.2 (p. 174).

The treatment of a burn patient requires estimating the extent of the body's affected surface. Physicians use the "rule of nines," subdividing the skin's surface into regions, each accounting for 9% (or some multiple of 9%) of the total surface area (fig. 6.14). This estimate is important in planning to replace body fluids and electrolytes lost from injured tissues and for covering the burned area with skin or skin substitutes.

PRACTICE

26 What is the tissue response to inflammation?

27 How does a scab slough off?

28 Which type of burn is most likely to leave a scar? Why?

6.6 LIFE-SPAN CHANGES

We are more aware of aging-related changes in skin than in other organ systems, because we can easily see them. Aging skin affects appearance, temperature regulation, and vitamin D formation.

The epidermis thins as the decades pass. As the cell cycle slows, epidermal cells grow larger and more irregular in shape, but are fewer. Skin may appear scaly because, at the microscopic level, more sulfur–sulfur bonds form within keratin molecules. Patches of pigment commonly called "age spots" or "liver spots" appear and grow (fig. 6.15). These are sites of oxidation of fats in the secretory cells of apocrine and eccrine glands and reflect formation of oxygen free radicals.

The dermis becomes reduced as synthesis of the connective tissue proteins collagen and elastin slows. The combination of a shrinking dermis and loss of some fat from the subcutaneous layer results in wrinkling and sagging of the skin. Fewer fibroblasts delay wound healing. Some of the changes in the skin's appearance result from specific deficits. The decrease in oil from sebaceous glands dries the skin.

Various treatments temporarily smooth facial wrinkles. "Botox" is an injection of a very dilute solution of botulinum toxin. Produced by the bacterium *Clostridium botulinum*, the toxin causes food poisoning. It also blocks nerve activation of certain muscle cells, including the facial muscles that control smiling, frowning, and squinting. After three months, though, the facial nerves contact the muscles at different points, and the wrinkles return. (Botox used at higher doses to treat neuromuscular conditions can cause adverse effects.) Other anti-wrinkle treatments include chemical peels and dermabrasion to reveal new skin surface; collagen injections; and transplants of subcutaneous fat from the buttocks to the face.

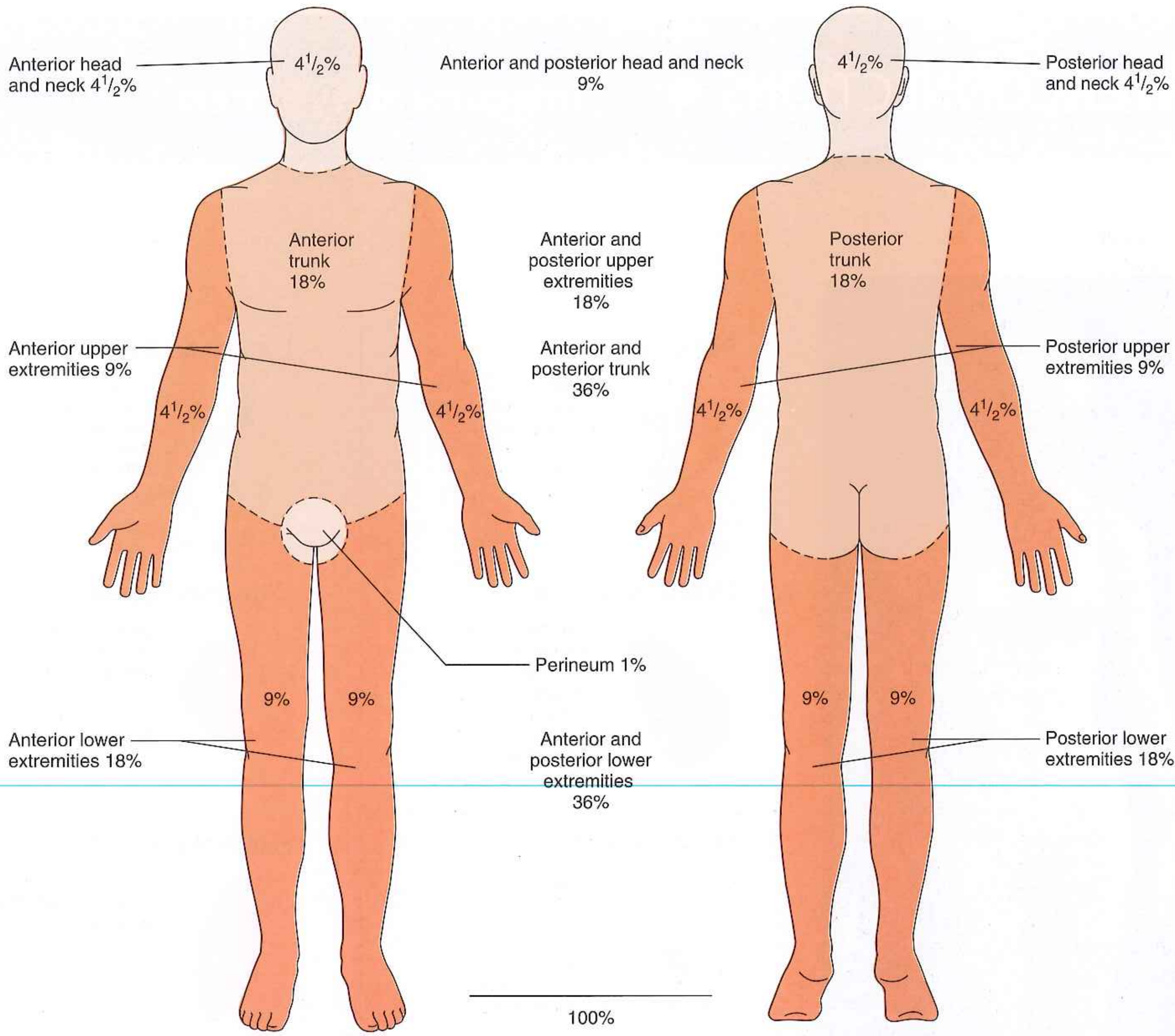
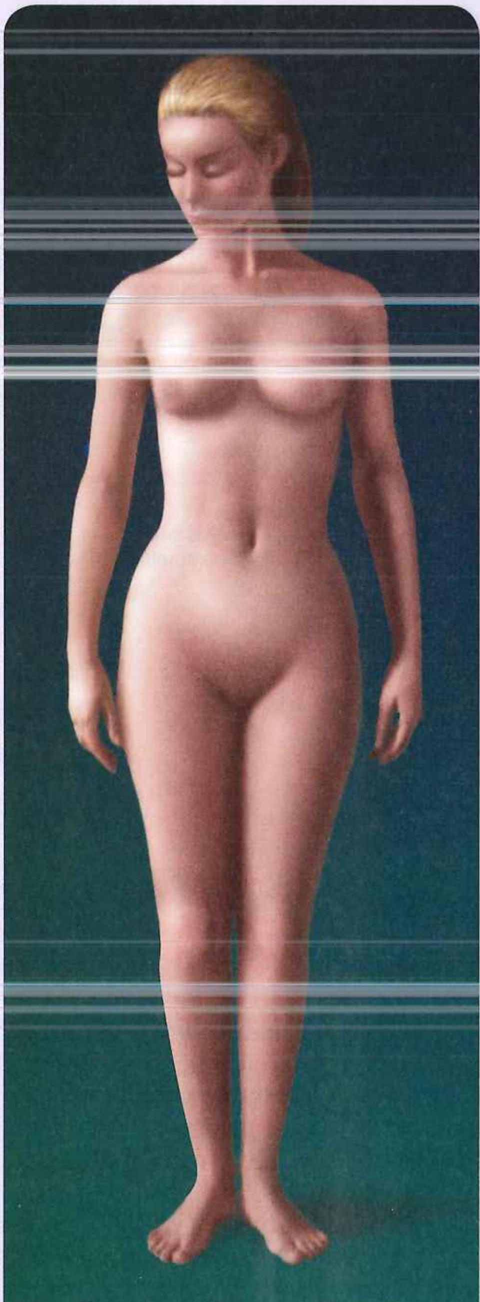


FIGURE 6.14 As an aid for estimating the extent of damage burns cause, the body is subdivided into regions, each representing 9% (or some multiple of 9%) of the total skin surface area.

FIGURE 6.15 Aging-associated changes are obvious in the skin.

The skin's accessory structures also show signs of aging. Slowed melanin production whitens hair as the follicle becomes increasingly transparent. Hair growth slows, the hairs thin, and the number of follicles decreases. Males may develop pattern baldness. A diminished blood supply to the nail beds impairs their growth, dulling and hardening them. Sensitivity to pain and pressure diminishes with age as the number of sensory receptors falls. A ninety-year-old's skin has only one-third the number of such sensory receptors as the skin of a young adult.

The ability to control temperature falters as the number of sweat glands in the skin falls, as the capillary beds that surround sweat glands and hair follicles shrink, and as the ability to shiver declines. In addition, the number of blood vessels in the deeper layers decreases, as does the ability to



Integumentary System

The skin provides protection, contains sensory organs, and helps control body temperature.

Skeletal System

Vitamin D, production of which begins in the skin, helps provide calcium for bone matrix.

Muscular System

Involuntary muscle contractions (shivering) work with the skin to control body temperature. Muscles act on facial skin to create expressions.

Nervous System

Sensory receptors provide information about the outside world to the nervous system. Nerves control the activity of sweat glands.

Endocrine System

Hormones help to increase skin blood flow during exercise. Other hormones stimulate either the synthesis or the decomposition of subcutaneous fat.

Cardiovascular System

Skin blood vessels play a role in regulating body temperature.

Lymphatic System

The skin, acting as a barrier, provides an important first line of defense for the immune system.

Digestive System

Excess calories may be stored as subcutaneous fat. Vitamin D activated by the skin stimulates dietary calcium absorption.

Respiratory System

Stimulation of skin receptors may alter respiratory rate.

Urinary System

The kidneys help compensate for water and electrolytes lost in sweat.

Reproductive System

Sensory receptors play an important role in sexual activity and in the suckling reflex.

shunt blood toward the body's interior to conserve heat. As a result, an older person is less able to tolerate the cold and cannot regulate heat. In the winter, an older person might set the thermostat ten to fifteen degrees higher than a younger person would. Fewer blood vessels in and underlying the skin account for the pale complexions of some older individuals. Changes in the distribution of blood vessels also contribute to development of pressure sores in a bedridden person whose skin does not receive adequate circulation.

Aging of the skin is also related to skeletal health. The skin is the site of formation of vitamin D from its precursor, which requires exposure to the sun. Vitamin D is necessary for absorption of calcium, needed for bone structure. Many older people do not get outdoors much, and the wavelengths of light that are important for vitamin D formation do not readily penetrate glass windows. In addition, older skin has a diminished ability to activate the vitamin. Therefore, homebound seniors can benefit from vitamin D supplements to help maintain bone structure.

PRACTICE

29 What changes occur with age in the epidermis and dermis?

30 How do the skin's accessory structures change over time?

31 Why do older people have more difficulty controlling body temperature than do younger people?

CHAPTER SUMMARY

6.1 INTRODUCTION (PAGE 179)

The skin, the largest organ in the body by weight, and its accessory structures constitute the integumentary system. Skin is a protective covering, retards water loss, helps regulate body temperature, houses sensory receptors, contains cells that play a role in immunity, aids in the formation of vitamin D from its precursor, and excretes wastes.

6.2 SKIN AND ITS TISSUES (PAGE 181)

Skin is composed of an epidermis and a dermis separated by a basement membrane. A subcutaneous layer, not part of the skin, lies beneath the dermis. The subcutaneous layer is composed of areolar tissue and adipose tissue that helps conserve body heat. This layer contains blood vessels that supply the skin.

1. Epidermis
   a. The epidermis is stratified squamous epithelium that lacks blood vessels.
   b. The deepest layer, called the stratum basale, contains cells that divide and grow.
   c. Epidermal cells undergo keratinization as they are pushed toward the surface.
   d. The outermost layer, called the stratum corneum, is composed of dead epidermal cells.
   e. Production of epidermal cells in the stratum basale balances the rate at which they are lost at the surface.
   f. The epidermis protects underlying tissues against water loss, mechanical injury, and the effects of harmful chemicals.
   g. Melanin, a pigment produced from the amino acid tyrosine, provides skin color and protects underlying cells from the effects of ultraviolet light.
   h. Melanocytes transfer melanin to nearby epidermal cells.
   i. All humans have about the same number of melanocytes. Skin color is largely due to the amount of melanin in the epidermis.
      (1) Each person inherits genes for melanin production.
         (a) Dark skin is due to genes that cause large amounts of melanin to be produced; lighter skin is due to genes that cause lesser amounts of melanin to form.
         (b) Mutant genes may cause a lack of melanin in the skin.
      (2) Environmental factors that influence skin color include sunlight, ultraviolet light, and X rays. These factors darken existing melanin and stimulate additional melanin production.
      (3) Physiological factors influence skin color.
         (a) The oxygen content of the blood in dermal vessels may cause the skin of light-complexioned persons to appear pinkish or bluish.
         (b) Carotene in the subcutaneous layer may cause the skin to appear yellowish.
         (c) Disease may affect skin color.
2. Dermis
   a. Cone-shaped dermal papillae contain blood capillaries that provide epidermal cells with oxygen and nutrients.
   b. Dermal papillae create friction ridges that leave a fingerprint when a finger presses against a surface.
   c. The dermis has two layers.
      (1) The upper papillary layer is areolar connective tissue.
      (2) The lower reticular layer is dense irregular connective tissue that binds the epidermis to underlying tissues.
   d. The dermis contains smooth and skeletal muscle tissues.
   e. Nervous tissue is scattered throughout the dermis.
      (1) Some dermal nerve cell processes carry impulses to muscles and glands of the skin.
      (2) Other dermal nerve cell processes are associated with sensory receptors in the skin.

6.3 ACCESSORY STRUCTURES OF THE SKIN (PAGE 186)

1. Nails
   a. Nails are protective covers on the ends of fingers and toes.
   b. They consist of keratinized epidermal cells.
2. Hair follicles
   a. Hair covers nearly all regions of the skin.
   b. Each hair develops from epidermal cells at the base of a tubelike hair follicle.
   c. As newly formed cells develop and grow, older cells are pushed toward the surface and undergo keratinization.
   d. A hair usually grows for a while, rests, and then is replaced by a new hair.
   e. Hair color is determined by genes that direct the type and amount of pigment in hair cells.
   f. A bundle of smooth muscle cells and one or more sebaceous glands are attached to each hair follicle.
3. Skin glands
   a. Sebaceous glands secrete sebum, which softens and waterproofs both the skin and hair.
   b. Sebaceous glands are usually associated with hair follicles.
   c. Sweat glands are located in nearly all regions of the skin.
   d. Each sweat gland consists of a coiled tube.
   e. Eccrine sweat glands, located on the forehead, neck, back, palms, and soles, respond to elevated body temperature or emotional stress.
   f. Sweat is primarily water but also contains salts and waste products.
   g. Apocrine sweat glands, located in the axillary regions and groin, moisten the skin when a person is emotionally upset, scared, in pain, or sexually aroused.

6.4 REGULATION OF BODY TEMPERATURE (PAGE 190)

Regulation of body temperature is vital because heat affects the rates of metabolic reactions. Normal temperature of deeper body parts is close to a set point of 37°C (98.6°F).

1. Heat production and loss
   a. Heat is a by-product of cellular respiration.
   b. When body temperature rises above normal, more blood enters dermal blood vessels and the skin reddens.
   c. Heat is lost to the outside by radiation, conduction, convection, and evaporation.
   d. Sweat gland activity increases heat loss by evaporation.
   e. When body temperature drops below normal, dermal blood vessels constrict, causing the skin to lose color, and sweat glands become inactive.
   f. If body temperature continues to drop, skeletal muscles involuntarily contract; this increases cellular respiration, which produces additional heat.
2. Problems in temperature regulation
   a. Air can hold a limited volume of water vapor.
   b. When the air is saturated with water, sweat may fail to evaporate and body temperature may remain elevated.
   c. Hyperthermia is a body temperature above 106°F. It causes weakness, dizziness, nausea, headache, and a rapid, irregular pulse.
   d. Hypothermia is lowered body temperature. It causes shivering, mental confusion, lethargy, loss of reflexes and consciousness, and eventually major organ failure.

6.5 HEALING OF WOUNDS AND BURNS (PAGE 192)

Skin injuries trigger inflammation. The affected area becomes red, warm, swollen, and tender.

1. A cut in the epidermis is filled in by dividing epithelial cells. Clots close deeper cuts, sometimes leaving a scar where connective tissue produces collagenous fibers, forming an elevation above the normal epidermal surface. Granulations form as part of the healing process in large, open wounds.
2. A superficial partial-thickness burn heals quickly with no scarring. The area is warm and red. A burn penetrating to the dermis is a deep partial-thickness burn. It blisters. Deeper skin structures help heal this more serious type of burn. A full-thickness burn is the most severe and may require a skin graft.

6.6 LIFE-SPAN CHANGES (PAGE 194)

1. Aging skin affects appearance as "age spots" or "liver spots" appear and grow, along with wrinkling and sagging.
2. Due to changes in the number of sweat glands and shrinking capillary beds in the skin, elderly people are less able to tolerate the cold and cannot regulate heat.
3. Older skin has a diminished ability to produce vitamin D necessary for skeletal health.

CHAPTER ASSESSMENTS

6.1 Introduction

1 Two or more tissues grouped together and performing specialized functions define a(n) ______________. (p. 180)
a. organelle
b. cell
c. organ
d. organ system
e. organism

2 The largest organ(s) in the body by weight is (are) the ______________. (p. 180)
a. liver
b. intestines
c. lungs
d. skin
e. brain

3 Functions of the skin include ______________. (p. 180)
a. retarding water loss
b. body temperature regulation
c. sensory reception
d. excretion
e. all of the above

4 List the functions of skin not mentioned in question 3. (p. 180)

6.2 Skin and Its Tissues

5 The epidermis is composed of layers of ______________ tissue. (p. 181)

6 Distinguish between the epidermis and the dermis. (p. 181)

7 Explain the functions of the subcutaneous layer. (p. 181)

8 Explain what happens to epidermal cells as they undergo keratinization. (p. 182)

9 Place the layers of the epidermis in order (1–5) from the outermost layer to the layer attached to the dermis by the basement membrane. (p. 182)
________ stratum spinosum
________ stratum corneum
________ stratum basale
________ stratum lucidum
________ stratum granulosum

10 Describe the function of melanocytes. (p. 183)

11 Discuss the function of melanin, other than providing color to the skin. (p. 183)

12 Explain how environmental factors affect skin color. (p. 184)

13 Describe three physiological factors that affect skin color. (p. 185)

14 Name the tissue(s) of the dermis. (p. 185)

15 Review the functions of dermal nervous tissue. (p. 185)

6.3 Accessory Structures of the Skin

16 Describe how nails are formed. (p. 186)

17 Distinguish between a hair and a hair follicle. (p. 186)

18 Review how hair color is determined. (p. 186)

19 Explain the function of sebaceous glands. (p. 188)

20 The sweat glands that respond to elevated body temperature and are commonly found on the forehead, neck, and back are ______________ glands. (p. 188)
a. sebaceous
b. holocrine
c. eccrine
d. apocrine
e. ceruminous

6.4 Regulation of Body Temperature

21 Explain the importance of body temperature regulation. (p. 190)

22 Describe the role of the skin in promoting the loss of excess body heat. (p. 190)

23 Match each means of losing body heat with its description. (p. 190)

(1) radiation	A. fluid changes from liquid to a gas
(2) conduction	B. heat moves from body directly into molecules of cooler objects in contact with its surface
(3) convection	C. heat rays escape from warmer surfaces to cooler surroundings
(4) evaporation	D. continuous circulation of air over a warm surface

24 Describe the body's responses to decreasing body temperature. (p. 190)

25 Review how air saturated with water vapor may interfere with body temperature regulation. (p. 191)

6.5 Healing of Wounds and Burns

26 Distinguish between the healing of shallow and deeper breaks in the skin. (p. 192)

27 Distinguish among first-, second-, and third-degree burns. (p. 192)

28 Describe possible treatments for a third-degree burn. (p. 194)

6.6 Life-Span Changes

29 Discuss three effects of aging on skin. (p. 194)

INTEGRATIVE ASSESSMENTS/CRITICAL THINKING

OUTCOMES 1.5, 6.3, 6.4

1. What methods might be used to cool the skin of a child experiencing a high fever? For each method you list, identify the means by which it promotes heat loss—radiation, conduction, convection, or evaporation.

OUTCOMES 5.3, 6.2

2. Why would collagen and elastin added to skin creams be unlikely to penetrate the skin—as some advertisements imply they do?

OUTCOMES 5.3, 6.2, 6.4

3. A premature infant typically lacks subcutaneous adipose tissue. Also, the surface area of an infant's body is relatively large compared to its volume. How do these factors affect the ability of an infant to regulate its body temperature?

OUTCOMES 6.1, 6.2, 6.3, 6.4, 6.5

4. Using the rule of nines, estimate the extent of damage for an individual whose body, clad only in a short nightgown, was burned as she was leaving the burning room. What special problems might result from the loss of the individual's functional skin surface? How might this individual's environment be modified to compensate partially for such a loss?

OUTCOME 6.2

5. Which of the following would result in the more rapid absorption of a drug: a subcutaneous injection or an intradermal injection? Why?
6. Everyone's skin contains about the same number of melanocytes even though people come in many different colors. How is this possible?

OUTCOMES 6.2, 6.5

7. As a rule, a superficial partial-thickness burn is more painful than one involving deeper tissues. How would you explain this observation?

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