6 Integumentary System

We have about the same density of hair follicles as our nearest relatives, the chimps and other great apes, but many of our hair follicles remain beneath the surface of our skin after birth. Hence, this human and her gorilla friend differ greatly in hairiness.

THE ORIGIN OF HAIR. Hairs are extensions of specialized cells in the outer skin layer that some of us spend enormous amounts of time washing, drying, curling, straightening, styling, coloring, plucking, and shaving. Yet, compared to other mammals, we humans appear relatively hairless. Appearances are deceiving—we actually have as many hair follicles per square inch of skin as a chimpanzee. The chimp's hairs, however, are longer, thicker, and darker than ours.

All of the 5 million hair follicles of an adult human form during the fifth month of prenatal development, coating the fetus with a downy layer called lanugo. In most newborns, the lanugo has receded beneath the skin surface, perhaps leaving a bit of fuzziness on the ear tips or elsewhere. Persistence of this early hair accounts for much of the difference in hairiness between us and other primates. In a very rare inherited condition in humans called hypertrichosis, some of the lanugo remains and grows long. In less enlightened times, people with severe cases were exhibited in circuses as ape-men or werewolves.

In other mammals, hair provides warmth. It is absent in aquatic mammals such as whales and manatees, and reduced in their semi-aquatic cousins, such as hippos, presumably because a furry coat would impair swimming. What advantages might lighter coats have afforded our ancestors that can explain why this almost uniquely human trait has persisted?

One theory maintains that less hair enabled us to successfully conquer grasslands. Furry, four-footed animals can run fast for a short time, and then slow down due to heating up. With hair dense only atop the head, protecting against sunburn, two-footed humans could run for longer times, enabling them to hunt. The lack of hair enabled our sweat glands to efficiently cool the body. Our hair has also persisted in places where our individual scents cling, which is essential for reproduction and offspring-parent bonding. Yet another explanation for our less hairy appearance is the "parasite-reduction hypothesis": Fur entraps fleas, lice, and ticks, which spread infectious disease. Shed the fur, and we shed the parasites.

Learning Outcomes

After studying this chapter, you should be able to do the following:

6.1 Introduction

1. Define organ, and name the large organ of the integumentary system. (p. 117)

6.2 Skin and Its Tissues

2. List the general functions of the skin. (p. 117)
3. Describe the structure of the layers of the skin. (p. 117)
4. Summarize the factors that determine skin color. (p. 119)

6.3 Accessory Structures of the Skin

5. Describe the anatomy and physiology of each accessory structure of the skin. (p. 122)

6.4 Regulation of Body Temperature

6. Explain how the skin helps regulate body temperature. (p. 124)

6.5 Healing of Wounds

7. Describe the events that are part of wound healing. (p. 125)

Aids to Understanding Words

(Appendix A on page 567 has a complete list of Aids to Understanding Words.)

cut- [skin] sub*cut*aneous: Beneath the skin.

derm- [skin] *derm*is: Inner layer of the skin.

epi- [upon] *epi*dermis: Outer layer of the skin.

follic- [small bag] hair *follic*le: Tubelike depression in which a hair develops.

kerat- [horn] *kerat*in: Protein produced as epidermal cells die and harden.

melan- [black] *melan*in: Dark pigment produced by certain cells.

seb- [grease] *seb*aceous gland: Gland that secretes an oily substance.

6.1 INTRODUCTION

Two or more kinds of tissues grouped together and performing specialized functions constitute an **organ.** The skin, the largest organ in the body by weight, and the various accessory structures associated with it (hair, finger nails, sensory receptors, and glands) make up the **integumentary** (in-teg-u-men′tar-e) **system.** The skin forms a barrier between ourselves and the outside, and as such is vitally important to the functioning of all other organs.

6.2 SKIN AND ITS TISSUES

One of the larger and more versatile organs of the body, the skin is vital in maintaining homeostasis. In addition to providing a protective covering, the skin helps regulate body temperature, retards water loss from deeper tissues, houses sensory receptors, synthesizes various biochemicals, and excretes small quantities of wastes.

Skin cells help produce vitamin D, which is necessary for normal bone and tooth development. This vitamin can be obtained in the diet or can form from a substance (dehydrocholesterol) that is synthesized by cells in the digestive system. When dehydrocholesterol reaches the skin by means of the blood and is exposed to ultraviolet light from the sun, it is converted to vitamin D.

Certain skin cells (keratinocytes) assist the immune system by producing hormonelike substances that stimulate development of certain white blood cells (T lymphocytes). These cells defend against infection by disease-causing bacteria and viruses (see chapter 14, pp. 386–388).

The skin includes two distinct layers (fig. 6.1). The outer layer, called the **epidermis** (ep″ĭ-der′mis), is composed of stratified squamous epithelium. The inner layer, or **dermis** (der′mis), is thicker than the epidermis, and it includes connective tissue consisting of collagenous and elastic fibers, epithelial tissue, smooth muscle tissue, nervous tissue, and blood. A *basement membrane* anchors the epidermis to the dermis and separates these two skin layers.

Beneath the dermis is loose connective tissue, predominantly adipose tissue, that binds the skin to the underlying organs forming the **subcutaneous** (sub″ku-ta′ne-us) **layer** (hypodermis). As its name indicates, this layer is beneath the skin and not a true layer of the skin. 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 and underlying adipose tissue.

If the skin of a 150-pound person were spread out flat, it would cover approximately 20 square feet. People who have lost a large amount of weight often develop rashes and skin breakdown due to excess skin. "Body contouring" surgery removes excess skin.

Check Your Recall

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

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 a 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.

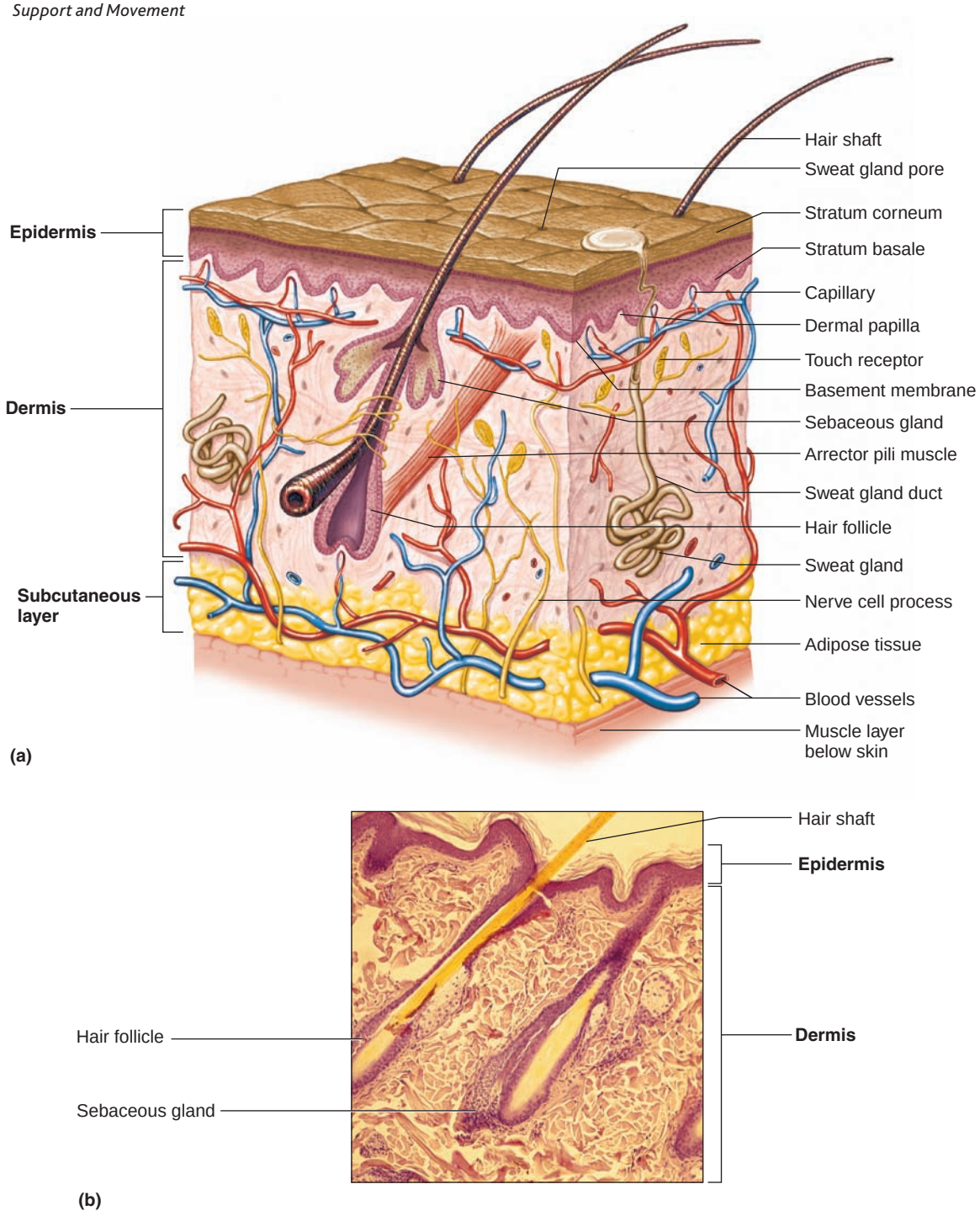


Figure 6.1

Skin. (*a*) The skin is an organ that includes two layers, the epidermis and dermis, that lie atop a subcutaneous ("beneath the skin") layer. A section of skin. (*b*) This light micrograph depicts the layered structure of the skin (75×).

Epidermis

Because the epidermis is composed of stratified squamous epithelium, it lacks blood vessels. However, the deepest layer of epidermal cells, called the *stratum basale* (stra′tum ba′sal), or stratum germinativum, is close to the dermis and is nourished by dermal blood vessels (fig. 6.1*a*). As the cells of this layer divide and grow, the older epidermal cells are pushed away from the dermis toward the skin surface. The farther the cells move, the poorer their nutrient supply becomes, and in time, they die.

The older cells (keratinocytes) harden in a process called **keratinization** (ker″ah-tin″ĭ-za′shun). The cytoplasm fills with strands of a tough, fibrous, waterproof *keratin* protein. As a result, many layers of tough, tightly packed dead cells accumulate in the outermost epidermis, forming a layer called the *stratum corneum*

(kor′ne-um). Dead cells that compose it are eventually shed.

The thickness of the epidermis varies from region to region. In most areas, only four layers can be distinguished: the *stratum basale, stratum spinosum* (spi-no′sum), *stratum granulosum* (gran″u-lo′sum), and *stratum corneum.* An additional layer, the *stratum lucidum* (loo′sid-um), is in the thickened skin of the palms and soles (fig. 6.2). The stratum lucidum may be missing where the epidermis is thin over the rest of the body.

In healthy skin, production of epidermal cells is closely balanced with loss of dead cells from the stratum corneum, so that the skin does not wear away completely. In fact, the rate of cell division increases where the skin is rubbed or pressed regularly, causing growth of thickened areas called *calluses* on the palms and soles, and keratinized conical masses on the toes called *corns.*

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).

Specialized cells in the epidermis called *melanocytes* produce **melanin** (mel′ah-nin), a dark pigment that provides skin color (fig. 6.3*a*). Melanin absorbs ultraviolet radiation in sunlight, preventing mutations in the DNA of skin cells and other damaging effects. Melanocytes lie in the deepest portion of the epidermis. Although they are the only cells that can produce melanin, the pigment also may be present in other epidermal cells nearby. This happens because melanocytes have long, pigment-containing cellular extensions that pass upward between epidermal cells and the extensions transfer melanin granules into these other cells by a process called *cytocrine secretion.* Nearby epidermal cells may contain more melanin than the melanocytes (fig. 6.3*b*). The Topic of Interest on page 121 discusses skin cancer arising from melanocytes and other epidermal cells.

Skin Color

Skin color is due largely to melanin. All people have about the same number of melanocytes in their skin. Differences in skin color result from differences in the amount of melanin that melanocytes produce and in the distribution and size of the pigment granules. Skin color is mostly genetically determined. If genes instruct melanocytes to produce abundant melanin, the skin is dark.

Environmental and physiological factors also influence skin color. Sunlight, ultraviolet light from sunlamps, or X rays stimulate production of additional pigment. Blood in the dermal vessels may affect skin color as physiological changes occur. When blood is well oxygenated, the blood pigment (hemoglobin) is bright red, making the skin of light-complexioned people appear pinkish. On the other hand, when blood oxygen concentration is low, hemoglobin is dark red, and the skin

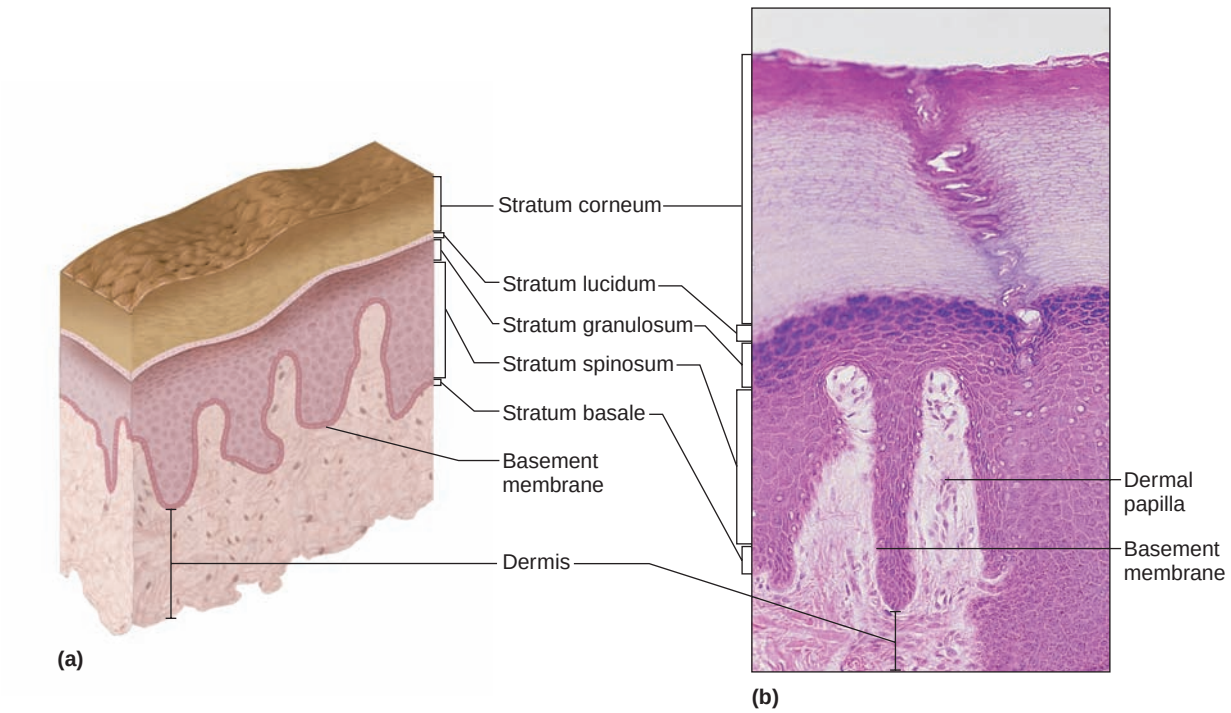


Figure 6.2

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 (30×).

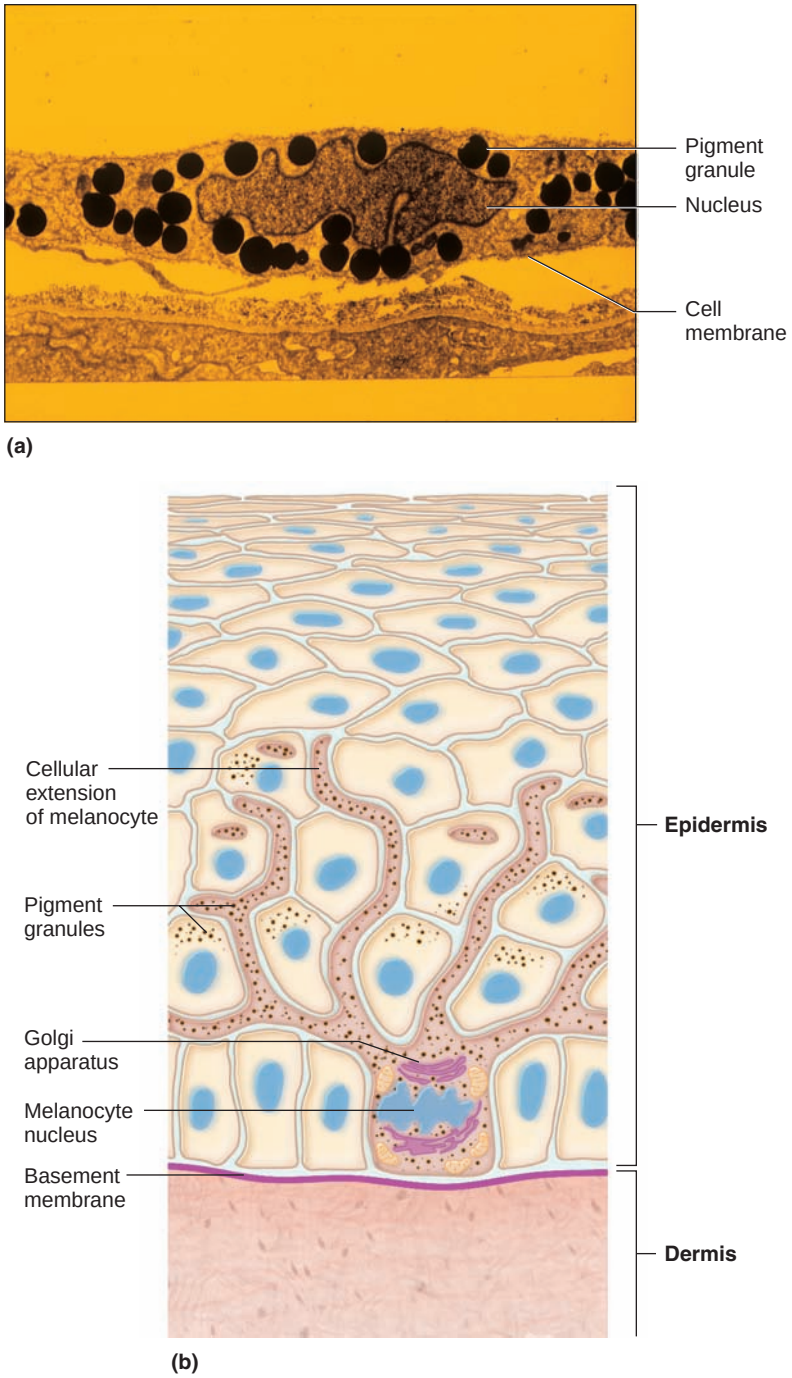


Figure 6.3

Melanocytes produce melanin. (*a*) This transmission electron micrograph shows 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. Note that much of the melanin is deposited above the nucleus, where the pigment can absorb UV radiation from outside before the DNA is damaged.

appears bluish—a condition called *cyanosis*. Other physiological factors affect skin color. For example, a diet high in yellow vegetables may turn skin orange-yellow, because these foods are rich in a pigment called β-carotene. Biochemical imbalances may also affect skin color. In newborns who have jaundice, for example, build-up of a substance called bilirubin turns the skin yellowish.

Check Your Recall

6. Explain how the epidermis is formed.
7. Distinguish between the stratum basale and the stratum corneum.
8. What is the function of melanin?
9. What factors influence skin color?

Topic of Interest

Skin Cancer

Skin cancer usually arises from nonpigmented epithelial cells within the deep layer of the epidermis or from melanocytes. Skin cancers originating from epithelial cells are called *cutaneous carcinomas* (squamous cell carcinoma or basal 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, occurring most frequently in light-skinned people over forty years of age. These cancers usually appear in individuals who are regularly exposed to sunlight, such as farmers, sailors, athletes, and sunbathers, and may result because normally protective apoptosis—peeling of sun-damaged cells—fails to occur.

Cutaneous carcinomas often develop from hard, dry, scaly growths (lesions) that have reddish bases. Such lesions may be either flat or raised and usually firmly adhere to the skin, appearing most often on the neck, face, or scalp. Cutaneous carcinomas are typically slow growing and can usually be cured completely by surgical removal or radiation treatment.

Cutaneous melanomas are pigmented with melanin, often with a variety of colored areas, such as variegated brown, black, gray, or blue. Melanomas usually have irregular rather than smooth outlines, and may feel bumpy.

People of any age may develop cutaneous melanomas. These cancers seem to be caused by short, intermittent exposure to high-intensity sunlight. Thus, risk of melanoma increases in persons who stay indoors but occasionally sustain blistering sunburns. Melanoma is not associated with sustained sun exposure, as are the other types of skin cancers.

A cutaneous melanoma, usually appearing on the back or limbs, may arise from normal-appearing skin or from a mole (nevus). The lesion spreads horizontally through the skin, but eventually may thicken and grow downward, invading deeper tissues. If the melanoma is surgically removed while it is in its horizontal growth phase, it may be arrested. Once it thickens and spreads into deeper tissues, it becomes difficult to treat, and survival rate is very low.

To reduce the chances of developing skin cancer, avoid exposing the skin to high-intensity sunlight, use sunscreens and sunblocks, and examine the skin regularly. Report any unusual lesions—particularly those that change in color, shape, or surface texture—to a physician at once.

(a) (b) (c)

Figure 6A
Skin cancer. (*a*) Squamous cell carcinoma. (*b*) Basal cell carcinoma. (*c*) Melanoma.

Dermis

The boundary between the epidermis and dermis is uneven because epidermal ridges project inward and conical projections of dermis, called dermal papillae, extend into the spaces between the ridges (see fig. 6.1*a*). Dermal papillae can be found in skin all over the body, but they are most abundant in the hands and feet. Fingerprints form from these undulations of the skin at the distal end of the palmar surface of a finger. Genes determine fingerprint patterns, but the patterns can change slightly as a fetus moves and presses the forming ridges against the uterine wall. For this reason, even the fingerprints of identical twins are not exactly alike.

The dermis binds the epidermis to underlying tissues (see fig. 6.1*a*). It is largely composed of dense connective

tissue that includes tough collagenous fibers and elastic fibers within a gel-like ground substance. Networks of these fibers give the skin toughness and elasticity.

Dermal blood vessels supply nutrients to all skin cells. These vessels also help regulate body temperature, as explained later in this chapter on pages 124–125.

Because dermal blood vessels supply nutrients to the epidermis, interference with blood flow may kill epidermal cells. For example, when a 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 begin to 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.

Nerve cell processes are scattered throughout the dermis. Motor processes carry impulses out from the brain or spinal cord to dermal muscles and glands. Sensory processes carry impulses away from specialized sensory receptors, such as touch receptors in the dermis, and into the brain or spinal cord. The dermis also contains accessory structures including hair follicles, sebaceous (oil-producing) glands, and sweat glands (see fig. 6.1*a*).

To create a tattoo, very fine needles inject inks into the dermis. The color is permanent, because dermis cells are not shed, as are 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.

Check Your Recall

10. What kinds of tissues make up the dermis?
11. What are the functions of these tissues?

6.3 ACCESSORY STRUCTURES OF THE SKIN

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 that are 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 covers the most actively 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. 6.4).

The thumbnail grows the slowest; the middle nail grows the fastest.

Hair Follicles

Hair is present on all skin surfaces except the palms, soles, lips, nipples, and parts of the external reproductive organs. Each hair develops from a group of epidermal cells at the base of a tubelike depression called a **hair follicle** (hār fol'i-kl) (figs. 6.1 and 6.5). This follicle extends from the surface into the dermis and contains the *hair root*. The epidermal cells at its base are nourished from dermal blood vessels in a projection of connective tissue at the deep end of the follicle. As these epidermal cells divide and grow, older cells are pushed toward the surface. The cells that move upward and away from their nutrient supply become keratinized and die. Their remains constitute the structure of a developing *hair shaft* that extends away from the skin surface (fig. 6.6). In other words, a hair is composed of dead epidermal cells.

Genes determine hair color by directing the type and amount of pigment that epidermal melanocytes produce. Dark hair has more of the brownish-black

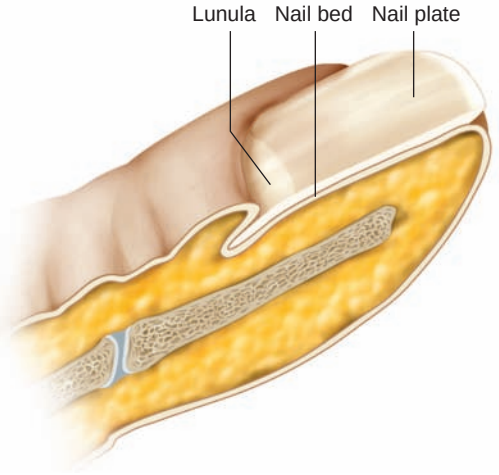


Figure 6.4
Nails grow from epithelial cells that divide and become keratinized, forming the rest of the nail.

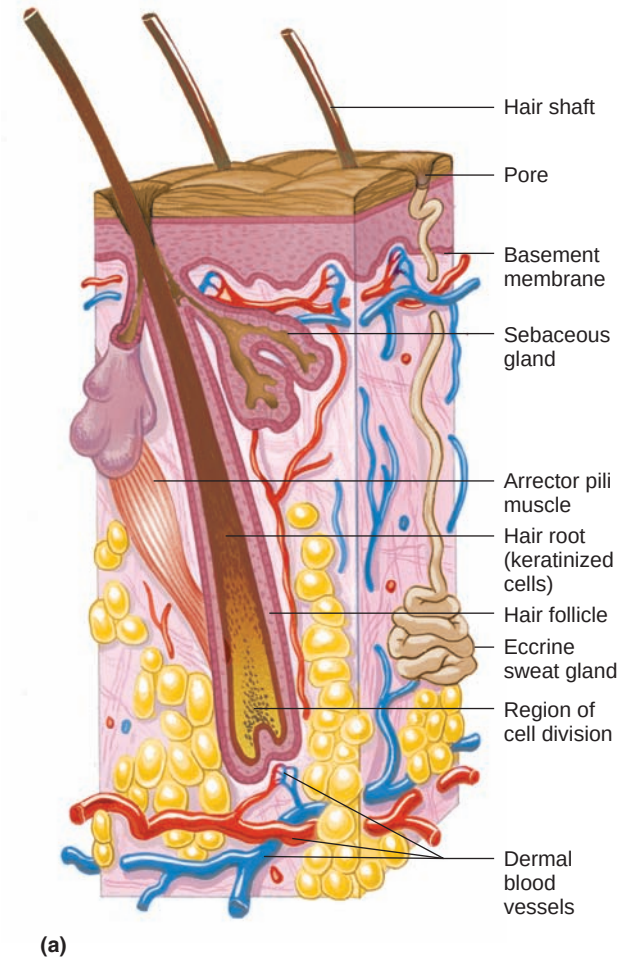


Figure 6.5

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. Stem cells keep the hair growing. (*b*) Light micrograph of a hair follicle (160×).

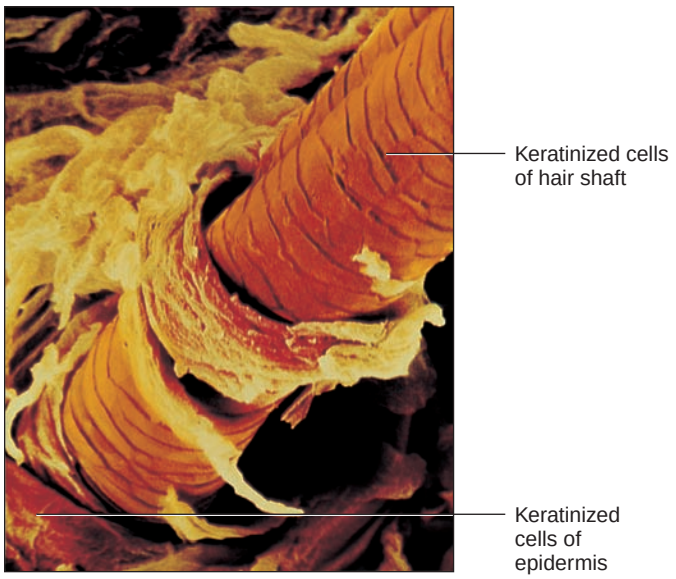


Figure 6.6

This scanning electron micrograph shows a hair emerging from the epidermis (875×).

eumelanin (u-mel′ah-nin), while blonde hair and red hair have more of the reddish-yellow **pheomelanin** (fe″o-mel′ah-nin). The white hair of a person with the inherited condition *albinism* lacks melanin altogether. A mixture of pigmented and unpigmented hair usually appears gray.

A bundle of smooth muscle cells, forming the *arrector pili muscle,* attaches to each hair follicle (see figs. 6.1*a* and 6.5*a*). This muscle is positioned so that a short hair within the follicle stands on end when the muscle contracts. If a person is emotionally upset or very cold, nerve impulses may stimulate the arrector pili muscles to contract, causing gooseflesh, or goose bumps.

Just above the "bulge" region at the base of a hair follicle are stem cells that can give rise to hair as well as epidermal cells. The first clue to the existence of these "young transient amplifying cells" was that new skin in burn patients arises from hair follicles. Then, experiments in mice that mark stem cells and their descendants showed that the young transient amplifying cells give rise to both hair and skin. Manipulating these stem cells could someday treat baldness or extreme hairiness (hirsutism).

Sebaceous Glands

Sebaceous glands (se-ba′shus glandz) contain groups of specialized epithelial cells and are usually associated with hair follicles (figs. 6.5*a* and 6.7). They are holocrine glands (see chapter 5, p. 101) that secrete an oily mixture of fatty material and cellular debris called *sebum* through small ducts into the hair follicles. Sebum helps keep the hair and skin soft, pliable, and waterproof.

Figure 6.7
A sebaceous gland secretes sebum into a hair follicle, shown here in oblique section (300×).

Many teens are all too familiar with a disorder of the sebaceous glands called *acne* (acne vulgaris). Overactive and inflamed glands in some body regions become plugged and surrounded by small, red elevations containing blackheads (comedones) or pimples (pustules).

Sweat Glands

Sweat (swet) **glands,** or sudoriferous glands, are exocrine glands that 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 abundant sweat glands, the **eccrine** (ek′rin) **glands,** respond throughout life to body temperature elevated by environmental heat or physical exercise (see fig. 6.5*a*). These glands are common on the forehead, neck, and back, where they produce profuse sweat on hot days or during intense physical activity.

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

Other sweat glands, known as **apocrine glands,** become active at puberty. Although they are currently called apocrine, these glands secrete by the same mechanism as eccrine glands, usually when a person is emotionally upset, frightened, in pain, or during sexual arousal. They are most numerous in the axillary regions and groin. Ducts of these glands open into hair follicles. The secretions of these glands develop a scent as they are metabolized by skin bacteria.

Other sweat glands are structurally and functionally modified to secrete specific fluids, such as the *ceruminous glands* of the external ear canal that secrete earwax. The female *mammary glands* that secrete milk are another example of modified sweat glands.

The average square inch (6.45 square centimeters) of skin holds 650 sweat glands, 20 blood vessels, 60,000 melanocytes, and more than a thousand nerve endings.

Check Your Recall

12. Describe the structure of a nail bed.
13. Explain how a hair forms.
14. What is the function of the sebaceous glands?
15. Distinguish between the eccrine and apocrine sweat glands.

6.4 REGULATION OF BODY TEMPERATURE

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). 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.

Heat is a product of cellular metabolism; thus, the more active cells of the body are the major heat producers. These cells include skeletal and cardiac muscle cells and the cells of certain glands, such as the liver.

As body temperature rises, nerve impulses stimulate 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 that the skin loses heat, the nervous system stimulates the eccrine sweat glands to become active and to release sweat onto the skin surface. As this fluid evaporates (changes from a liquid to a gas), it carries heat away from the surface, cooling the skin further.

If too much heat is lost and body temperature drops, 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 decreases the flow of heat-carrying blood through the skin and helps reduce heat loss. Also, the sweat glands remain inactive, decreasing heat loss by evaporation. If body temperature continues to drop, the nervous system may stimulate muscle fibers in the skeletal muscles throughout the body to contract slightly. This action requires an increase in the rate of cellular respiration and produces heat as a by-product. If this response does not raise body temperature to normal, small groups of muscles may contract rhythmically with greater force, and the person begins to shiver, generating more heat. Chapter 1 introduced this type of homeostatic mechanism (fig. 1.7, p. 8).

Most of the body's heat (80%) escapes through the head.

Deviation from the normal range for body temperature impairs health and may be lethal. People with severe spinal cord injuries can no longer control body temperature, which fluctuates depending upon the environment.

In hypothermia, core body temperature falls below 95°F. The body becomes so cold that it cannot maintain function. Symptoms of worsening hypothermia include a gradual loss of coordination, stiffening muscles, confusion, fatigue, and slow, shallow breathing. When core temperature falls to 87.8°F, the skin turns a bluish-gray, weakness intensifies, and consciousness ebbs away.

In hyperthermia, core body temperature exceeds 106°F. The skin becomes hot, dry, and flushed, and the person becomes weak, dizzy, and nauseous, with headache and a rapid, irregular pulse. The vignette that opens chapter 18 (p. 491) describes a fatal case of hyperthermia in an athlete.

Check Your Recall

16. Why is regulation of body temperature so important?
17. How does the body lose excess heat?
18. Which actions help the body conserve heat?

6.5 HEALING OF WOUNDS

A wound and the area surrounding it usually become red and painfully swollen. This is the result of *inflammation,* which 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, warm, swollen, and painful to touch (table 6.1). However, the dilated blood vessels provide the tissues with more nutrients and oxygen, which aids healing.

Table 6.1 Inflammation

Symptom	Cause
Redness	Vasodilation, more blood in area
Heat	Large amount of blood accumulating in area and as a by-product of increased metabolic activity in tissue
Swelling	Increased permeability of blood vessels, fluids leaving blood go into tissue spaces (edema)
Pain	Injury to neurons and increased pressure from edema

The specific events in healing depend on the nature and extent of the injury. If a break in the skin is shallow, epithelial cells along its margin are stimulated to divide more rapidly than usual, and the newly formed cells fill the gap.

If the injury extends into the dermis or subcutaneous layer, blood vessels break, and the escaping blood forms a clot in the wound. The blood clot and dried tissue fluids form a *scab* that covers and protects underlying tissues. Before long, fibroblasts migrate into the injured region and begin forming new collagenous fibers that bind the edges of the wound together. Suturing or otherwise closing a large break in the skin speeds this process.

As healing continues, blood vessels extend into the area 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 extensive, the newly formed connective tissue may appear on the surface as 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 that is largely composed of collagenous fibers. The Topic of Interest on page 126 includes descriptions of healing that occurs following tissue damage resulting from a burn.

Check Your Recall

19. What is the tissue response to inflammation?
20. Distinguish between the activities necessary to heal a wound in the epidermis and those necessary to heal a wound in the dermis.
21. Explain the role of phagocytic cells in wound healing.
22. Define granulation.

Topic of Interest

Burns

Slightly burned skin, as from a minor sunburn, may become warm and reddened (erythema) as dermal blood vessels dilate. This response may be accompanied by mild edema, and in time, the surface layer of skin may be shed. A burn injuring the epidermis alone is called a *superficial partial-thickness* (first degree) *burn*. Healing usually occurs within a few days to two weeks, with no scarring.

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, and as it accumulates beneath the outer layer of epidermal cells, blisters appear. The injured region becomes moist and firm and may vary from dark red to waxy white. Such a burn most commonly occurs from exposure to hot objects, hot liquids, flames, or burning clothing.

Healing of a deep partial-thickness burn depends upon accessory structures of the skin that survive the injury because they are deep in the dermis. These structures, which include hair follicles, sweat glands, and sebaceous glands, include epithelial cells that divide and extend onto the surface of the injured dermis, spread over it, and form new epidermis.

A burn that destroys the epidermis, the dermis, and the accessory structures of the skin is a *full-thickness* (third degree) *burn*. The injured skin becomes dry and leathery, and may vary from red to black to white. A full-thickness burn usually is caused by immersion in hot liquids or prolonged exposure to hot objects, flames, or corrosive chemicals. Typically, most of the epithelial cells in the affected region are destroyed, and healing occurs only if epithelial cells divide and grow inward from the margin of the burn. If the injured area is extensive, it may require a transplant, using a thin layer of skin from an unburned region of the body (an autograft), cadaveric skin (a homograft), or a skin substitute (amniotic membrane from a human fetus, artificial membranes, or a tissue-engineered skin).

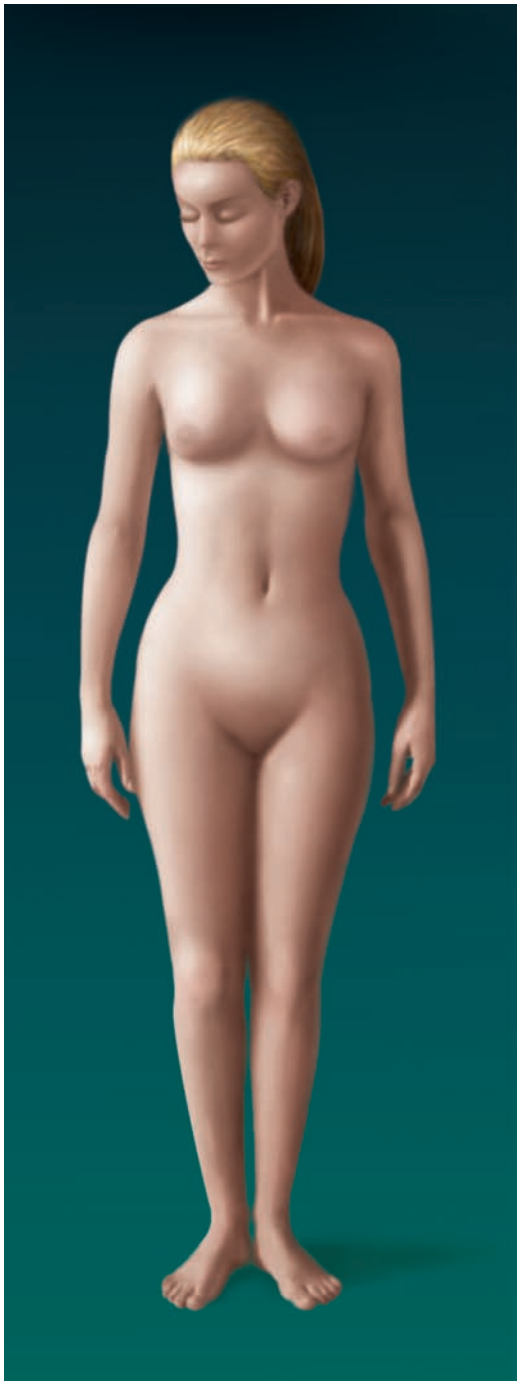
Common Skin Disorders

acne (ak′ne) Disease of the sebaceous glands that produces blackheads and pimples.
alopecia (al″o-pe′she-ah) Hair loss, usually sudden.
athlete's foot (ath′-lētz foot) Fungus (*Tinea pedis*) infection usually in the skin of the toes and soles.
birthmark (berth′ mark) Congenital blemish or spot on the skin, visible at birth or soon after.
boil (boil) Bacterial infection (furuncle) of the skin, produced when bacteria enter a hair follicle.
carbuncle (kar′bung-kl) Bacterial infection, similar to a boil, that spreads into the subcutaneous tissues.
cyst (sist) Liquid-filled sac or capsule.
dermatitis (der″mah-ti′tis) Inflammation of the skin.
eczema (ek′zĕ-mah) Noncontagious skin rash that produces itching, blistering, and scaling.
erythema (er″ĭ-the′mah) Reddening of the skin due to dilation of dermal blood vessels in response to injury or inflammation.
herpes (her′pēz) Infectious disease of the skin, caused by the herpes simplex virus and characterized by recurring formations of small clusters of vesicles.
impetigo (im″pĕ-ti′go) Contagious disease of bacterial origin, characterized by pustules that rupture and become covered with loosely held crusts.
keloid (ke′loid) Elevated, enlarging fibrous scar usually initiated by an injury.
mole (mōl) Fleshy skin tumor (nevus) that is usually pigmented; colors range from brown to black.
pediculosis (pĕ-dik″u-lo′sis) Disease produced by an infestation of lice.
pruritus (proo-ri′tus) Itching of the skin.
psoriasis (so-ri′ah-sis) Chronic skin disease characterized by red patches covered with silvery scales.
pustule (pus′tūl) Elevated, pus-filled area on the skin.
scabies (ska′bēz) Disease resulting from an infestation of mites.
seborrhea (seb″o-re′ah) Hyperactivity of the sebaceous glands, causing greasy skin and dandruff.
ulcer (ul′ser) Open sore.
urticaria (ur″tĭ-ka′re-ah) Allergic reaction of the skin that produces reddish, elevated patches (hives).
vitiligo (vit″ĭ-li′go) Loss of melanocytes in parts of the epidermis, producing whitened areas of skin.
wart (wort) Flesh-colored, raised area caused by a viral infection.

Clinical Connection

When a mammal is hurt, it licks the wound—for good reason. Saliva is rich in epidermal growth factor (EFG), a protein that speeds healing. EGF stimulates fibroblasts in the skin to secrete collagen, which helps to fill in the damaged area. An experiment with people who have leg ulcers demonstrated another effect of EGF—proliferation of stem cells. Researchers compared the skin of patients with leg ulcers given EGF to patients who did not receive the treatment and to healthy individuals. The healthy people and untreated patients had very few skin stem cells, located near hair follicles and at the bottom of the basement membrane. The treated patients, however, had many more stem cells, grouped into "islands" that traversed more than one layer, particularly where the epidermis dips down into the dermis.

Integumentary System



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

Skeletal System

Vitamin D activated by the skin helps provide calcium needed for bone matrix.

Lymphatic System

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

Muscular System

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

Digestive System

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

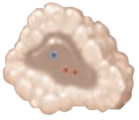
Nervous System

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

Respiratory System

Stimulation of skin receptors may alter respiratory rate.

Endocrine System

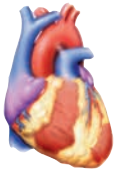


Hormones help to increase skin blood flow during exercise. Other hormones stimulate either the synthesis or the decomposition of subcutaneous fat.

Urinary System

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

Cardiovascular System



Skin blood vessels play a role in regulating body temperature.

Reproductive System

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

SUMMARY OUTLINE

6.1 Introduction (p. 117)

An organ is formed by two or more tissues grouped together and performing specialized functions. The skin, the largest organ in the body, is part of the integumentary system.

6.2 Skin and Its Tissues (p. 117)

Skin is a protective covering, helps regulate body temperature, retards water loss, houses sensory receptors, synthesizes various biochemicals, and excretes wastes. It is composed of an epidermis and a dermis separated by a basement membrane. Beneath the skin is the subcutaneous layer that binds the skin to underlying organs, stores fat, and contains blood vessels that supply the skin.

1. Epidermis
   a. The deepest layer of the epidermis, called the stratum basale, contains cells that divide.
   b. Epidermal cells undergo keratinization as they mature and are pushed toward the surface.
   c. The outermost layer, called the stratum corneum, is composed of dead epidermal cells.
   d. The epidermis protects underlying tissues against water loss, mechanical injury, and the effects of harmful chemicals.
   e. Melanin protects underlying cells from the effects of ultraviolet light.
   f. Melanocytes transfer melanin to nearby epidermal cells.
   g. Melanin provides skin color.
      (1) All people have about the same number of melanocytes.
      (2) Skin color is due largely to the amount of melanin and the distribution and size of pigment granules in the epidermis.
      (3) Environmental and physiological factors, as well as genes, influence skin color.
2. Dermis
   a. The dermis binds the epidermis to underlying tissues.
   b. Dermal blood vessels supply nutrients to all skin cells and help regulate body temperature.
   c. Nerve fibers are scattered throughout the dermis.
      (1) Some dermal nerve fibers carry impulses to muscles and glands of the skin.
      (2) Other dermal nerve fibers are associated with sensory receptors in the skin, and carry impulses to the brain and spinal cord.
   d. The dermis also has hair follicles, sebaceous glands, and sweat glands.

6.3 Accessory Structures of the Skin (p. 122)

1. Nails
   a. Nails are protective covers on the ends of fingers and toes.
   b. Specialized epidermal cells that are keratinized make up nails.
   c. The keratin of nails is harder than that produced by the skin's epidermal cells.
2. Hair follicles
   a. Each hair develops from epidermal cells at the base of a tubelike hair follicle.
   b. As newly formed cells develop and grow, older cells are pushed toward the surface and undergo keratinization.
   c. A bundle of smooth muscle cells is attached to each hair follicle.
   d. Hair color is determined by genes that direct the amount of eumelanin or pheomelanin that melanocytes associated with hair follicles produce.
3. Sebaceous glands
   a. Sebaceous glands are usually associated with hair follicles.
   b. Sebaceous glands secrete sebum, which helps keep the skin and hair soft and waterproof.
4. Sweat glands
   a. Each sweat gland is a coiled tube.
   b. Sweat is primarily water but also has salts and wastes.
   c. Eccrine sweat glands respond to elevated body temperature; apocrine glands respond to emotional stress.

6.4 Regulation of Body Temperature (p. 124)

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

1. When body temperature rises above the normal set point, dermal blood vessels dilate, and sweat glands secrete sweat.
2. If body temperature drops below the normal set point, dermal blood vessels constrict, and sweat glands become inactive.
3. Excessive heat loss stimulates skeletal muscles to contract involuntarily.

6.5 Healing of Wounds (p. 125)

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

1. Dividing epithelial cells fill in shallow cuts in the epidermis.
2. Clots close deeper cuts, sometimes leaving a scar where connective tissue replaces skin.
3. Granulations form in large, open wounds as part of the healing process.

CHAPTER ASSESSMENTS

6.1 Introduction

1. Two or more tissues grouped together and performing specialized functions defines a(n) _____. (p. 117)

a. organelle c. organ
b. cell d. organ system

2. The largest organ(s) in the body is (are) the _____. (p. 117)

a. liver c. lungs
b. intestines d. skin

6.2 Skin and Its Tissues

3. Functions of the skin include _____. (p. 117)

a. retarding water loss d. excretion
b. body temperature regulation e. all of the above
c. sensory reception

4. List the remaining functions of skin not mentioned in question 3. (p. 117)

5. The epidermis is composed of layers of _____ tissue. (p. 118)

6. The _____ layer of epidermal cells contains older keratinized cells and dead cells. (p. 118)

a. stratum corneum d. stratum spinosum
b. stratum lucidum e. stratum basale
c. stratum granulosum

7. Discuss the function of melanin, other than providing color to the skin. (p. 119)

8. List and describe the influence of each factor affecting skin color. (p. 119)

9. The dermis is composed primarily of what kind of tissue? (p. 121)

6.3 Accessory Structures of the Skin

10. Describe how nails are formed and relate the structure of nails to their function. (p. 122)
11. Distinguish between a hair and a hair follicle. (p. 122)
12. Sebaceous glands are _____ glands that secrete _____. (p. 123)
13. Compare and contrast eccrine and apocrine sweat glands. (p. 124)

6.4 Regulation of Body Temperature

14. Explain how body heat is produced. (p. 124)
15. Explain how sweat glands help regulate body temperature. (p. 124)
16. Describe the body's responses to decreasing body temperature. (p. 125)

6.5 Healing of Wounds

17. Explain how the healing of superficial breaks in the skin differs from the healing of deeper wounds. (p. 125)

INTEGRATIVE ASSESSMENTS/ CRITICAL THINKING

OUTCOME 6.2

1. Everyone's skin contains about the same number of melanocytes, even though people are of many different skin colors. How is this possible?
2. Which of the following would result in the more rapid absorption of a drug: a subcutaneous injection or an intradermal injection? Why?
3. How is it protective for skin to peel after a severe sunburn?

OUTCOMES 6.2, 6.4

4. A premature infant typically lacks subcutaneous adipose tissue and the small body has a relatively large surface area compared to its volume. How do these factors affect the ability of a premature infant to regulate its body temperature?

OUTCOMES 6.2, 6.5

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

OUTCOMES 6.2, 6.3, 6.4, 6.5

6. What special problems would result from the loss of 50% of a person's functional skin surface? How might this person's environment be modified to partially compensate for such a loss?

WEB CONNECTIONS

Visit the text website at **aris.mhhe.com** for additional quizzes, interactive learning exercises, and more.

AP R INTEGUMENTARY SYSTEM

Anatomy & Physiology | REVEALED includes cadaver photos that allow you to peel away layers of the human body to reveal structures beneath the surface. This program also includes animations, radiologic imaging, audio pronunciation, and practice quizzing. To learn more visit **www.aprevealed.com**.