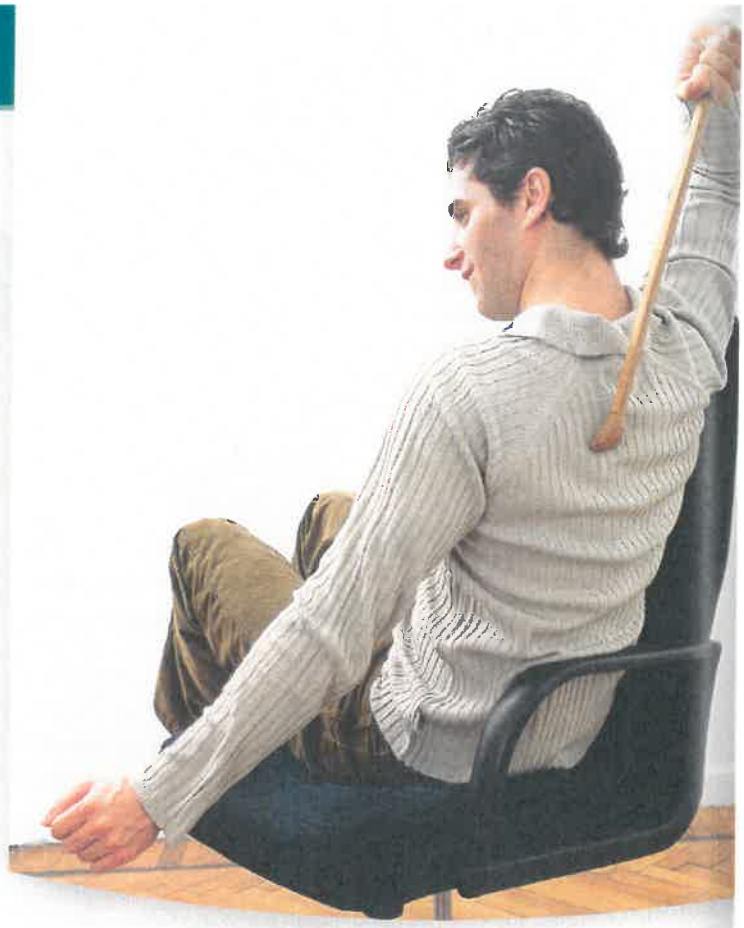
6

Integumentary System



Scratching is a common response to an itch.

Itching. Few sensations are as intense as an itch. For millions of people, itching is much more than an annoyance. Each year in the United States, nearly 33 million people consult dermatologists about itchy skin rashes.

Itching occurs in more than fifty diseases, from psychiatric conditions to cancer. It may also happen in response to an insect bite or exposure to a poisonous plant, or arise as a side effect of taking a particular drug. Itching may interfere significantly with quality of life, and even hasten death by chronically disturbing sleep. A case report in a medical journal describes a woman who, unable to feel pain due to shingles, actually scratched through her skull in response to intense itching. Nearly half of all people undergoing hemodialysis to treat kidney failure experience severe itching.

Why do we itch? It may be a holdover from long-ago times when scratching an itch was a way of ridding the outside of the body of disease-carrying insects. Whatever the reason, itching is more than just a less intense form of pain, as has been thought. It involves fewer nerve fibers over a larger area than a typical pain response.

Itching has been difficult to study for several reasons. Our reporting of the intensity of itching is highly subjective. Another problem is that testing treatments may cause pain. Most small animal models, such as rodents, itch from different stimuli than do humans. For this reason, some researchers study itching and scratching in monkeys. In one set of experiments, researchers induced itching in the animals' feet, then traced the responding neurons to a specific site at the base of the spinal cord where certain cells sense pain and itch. Scratching the itch quieted these nerve cells—but only for 5 to 10 seconds. Learning how scratching affects nerve cells might provide a new target for drug developers.

While researchers are still unsure of the origins of itching, sufferers can seek topical relief with oatmeal baths and lubricating creams. Antihistamine drugs work only on hives, which are a rare cause of itching. Drugs used to treat seizures and depression may help some severe cases of itching. The International Forum for the Study of Itch, founded in 2005, brings together dermatologists and neurologists to tackle the problem.

Learning Outcomes

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

6.1 Introduction

1. Describe what constitutes an 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. 120)

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. 125)

6.5 Healing of Wounds

7. Describe wound healing. (p. 125)

Module 4: Integumentary System

Aids to Understanding Words

(Appendix A on page 564 has a complete list of Aids to Understanding Words.)

cut- [skin] *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 types of tissues grouped together and performing specialized functions constitute an **organ** (see fig. 1.3, p. 4). The skin is the largest organ in the body by weight. Skin and its various accessory structures (hair, fingernails, 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 is a strong yet flexible covering for our bodies.

If the skin of a 150-pound person were spread out flat, it would cover approximately 20 square feet.

6.2 SKIN AND ITS TISSUES

The skin is one of the most versatile organs of the body. It 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 amounts of wastes.

The skin plays a role in the production of 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.

The skin includes two distinct layers (fig. 6.1). 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. It includes connective tissue consisting of collagen 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.

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 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.

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 collagen 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.

Practice

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?

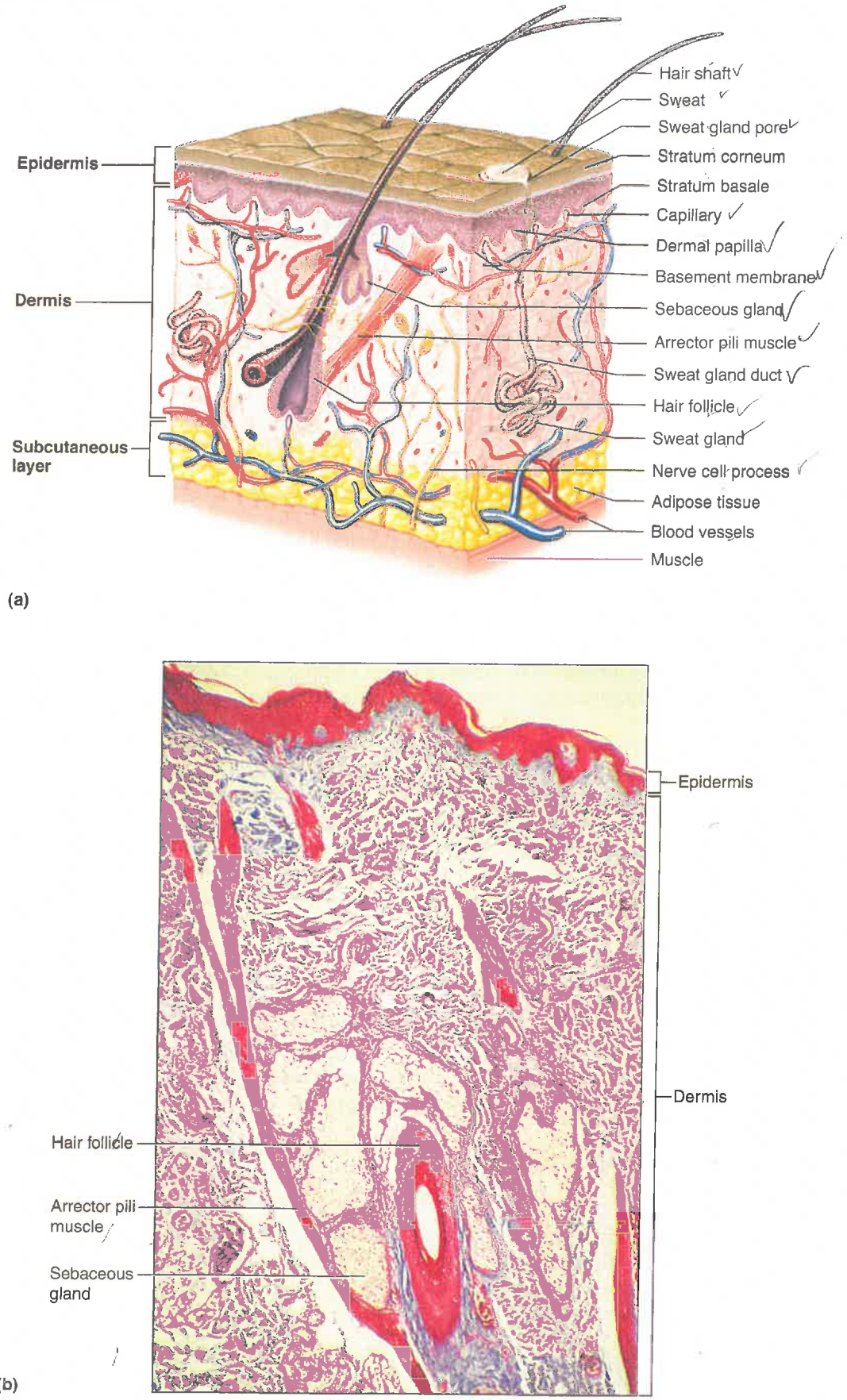


Figure 6.1 APIR

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 (100×).

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.

Epidermis

The epidermis lacks blood vessels because it is composed entirely of stratified squamous epithelium. 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). These dead cells 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 and hairless (glabrous) 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 generally 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 also absorbs ultraviolet radiation in sunlight, preventing it from causing mutations in the DNA of skin cells and other damaging effects. Melanocytes lie in the deepest portion of the epidermis. They are the only cells that can produce melanin, but the pigment may also appear in nearby epidermal cells. Melanocytes have long, pigment-containing cellular extensions that pass upward between neighboring epidermal cells. These extensions transfer melanin granules into neighboring cells by a process called *cytocrine secretion*.

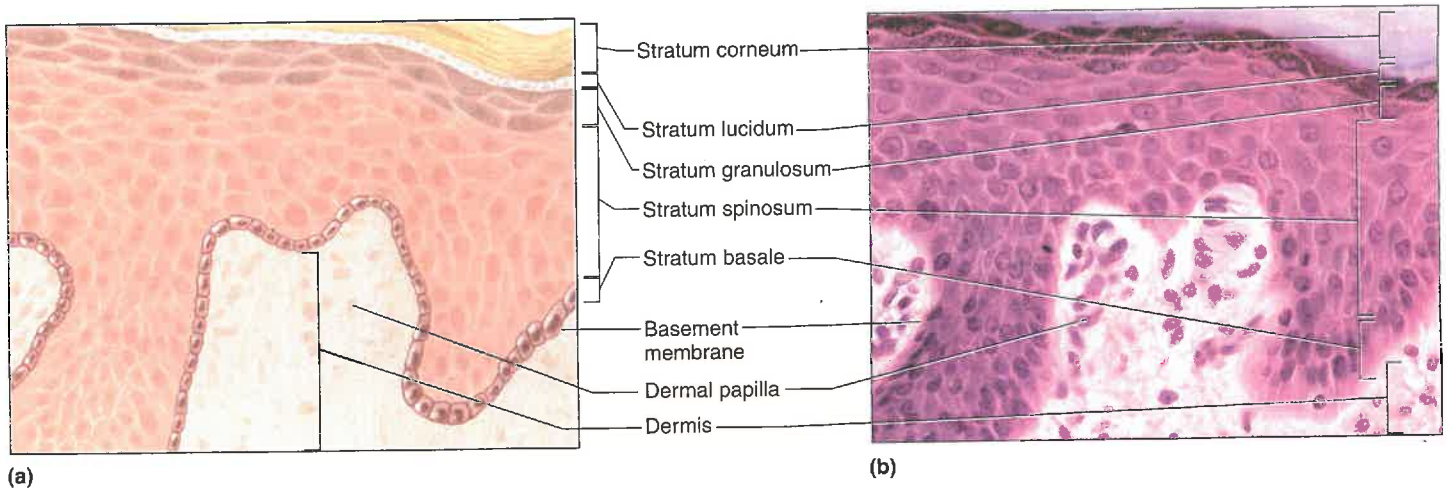


Figure 6.2 AP|R

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 (500×).

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

Answer can be found in Appendix E on page 568.

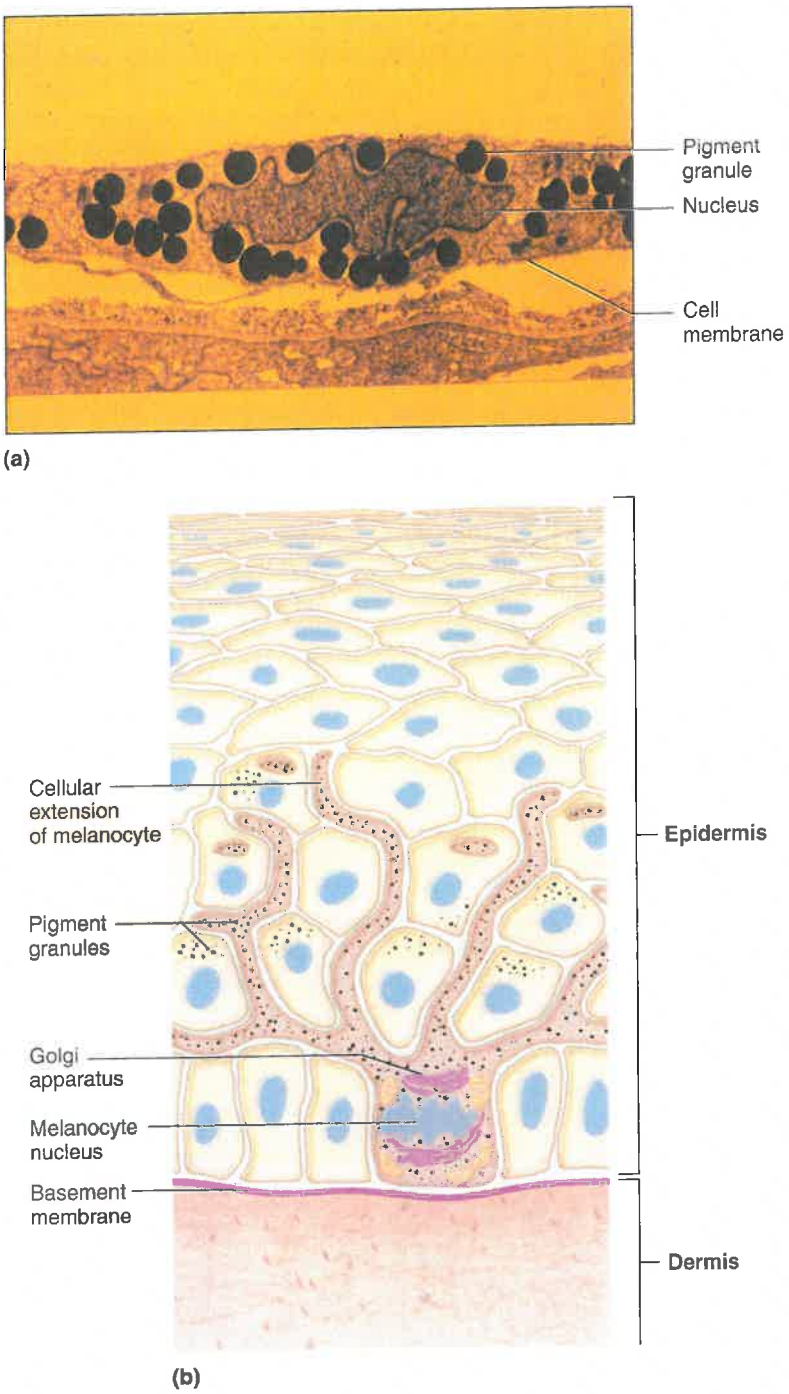


Figure 6.3

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.

The neighboring epidermal cells may actually contain more melanin than the melanocytes (fig. 6.3*b*). When melanin reaches the keratinized cells, it breaks into pieces, which provide the pigmentation. Clinical Application 6.1 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

Clinical Application 6.1

Skin Cancer

Skin cancer usually arises in nonpigmented epithelial cells in 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. Those who are regularly exposed to sunlight, such as farmers, sailors, athletes, and sun worshippers, are at increased risk. Cutaneous carcinomas may result from failure of apoptosis, which normally peels away sun-damaged cells.

Cutaneous carcinomas often develop from hard, dry, scaly growths (lesions) that have reddish bases. They may be flat or raised and usually firmly adhere to the skin. They are most common on the neck, face, or scalp. Cutaneous carcinomas grow slowly and are usually cured with 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. 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.

People of any age may develop cutaneous melanomas. These cancers are caused by short, intermittent exposure to high-intensity sunlight, such as a severe sunburn in a person who usually stays indoors. 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 may thicken and grow downward, invading deeper tissues. A melanoma surgically removed while in its horizontal growth phase may be arrested, but once it thickens and spreads into deeper tissues, it becomes difficult to treat.

To reduce the risk of developing skin cancer, avoid exposing the skin to high-intensity sunlight, use sunscreens and sunblocks, and examine the skin regularly. Report any "ABCDE" lesions to a physician at once.

(a) (b) (c)

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

is mostly genetically determined. If genes instruct melanocytes to produce abundant melanin, the skin is dark.

More than a hundred genes affect pigmentation of the skin, hair, and irises.

Environmental and physiological factors also influence skin color. Sunlight, ultraviolet light from sunlamps, and 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 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 beta-carotene. Biochemical imbalances may also affect skin color. In newborns who have jaundice, for example, buildup of a substance called bilirubin turns the skin yellowish.

Practice

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?

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. The friction ridges formed by the dermal papillae leave a patterned impression when a finger is pressed against a surface—a fingerprint. Genes determine fingerprint patterns, but the environment can alter them in a few situations. Fingerprint patterns can change slightly as a fetus presses the forming ridges against the uterine wall, which is why the fingerprints of identical twins are not exactly alike. Certain drugs used to treat cancer can erase fingerprints.

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 page 125.

Epidermal cells can die if their blood supply from the dermis, which brings nutrients, is blocked. 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 cell processes carry impulses out from the brain or spinal cord to dermal muscles and glands. Sensory cell processes carry impulses away from specialized sensory receptors, such as touch receptors in the dermis, and into the brain or spinal cord. Specialized sensory receptors are discussed in chapter 10 (p. 264). 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, 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

10. What types 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. The keratin of nails is harder than that produced by the epidermal stratum corneum. In time, the nail 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

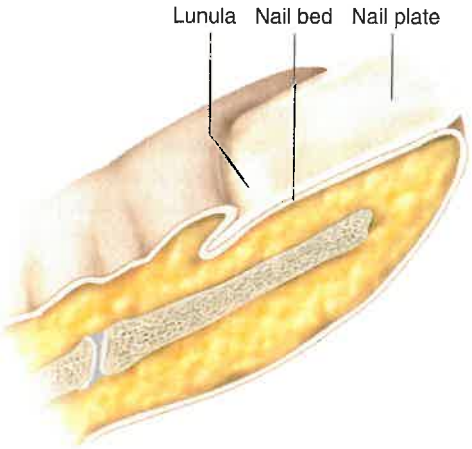


Figure 6.4 AP|R

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?*

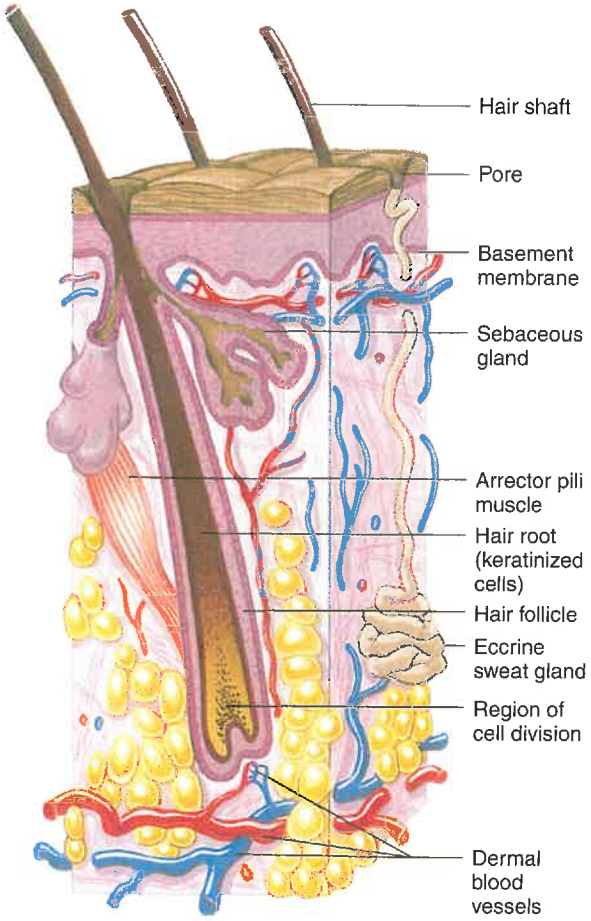
Answer can be found in Appendix E on page 568.

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.

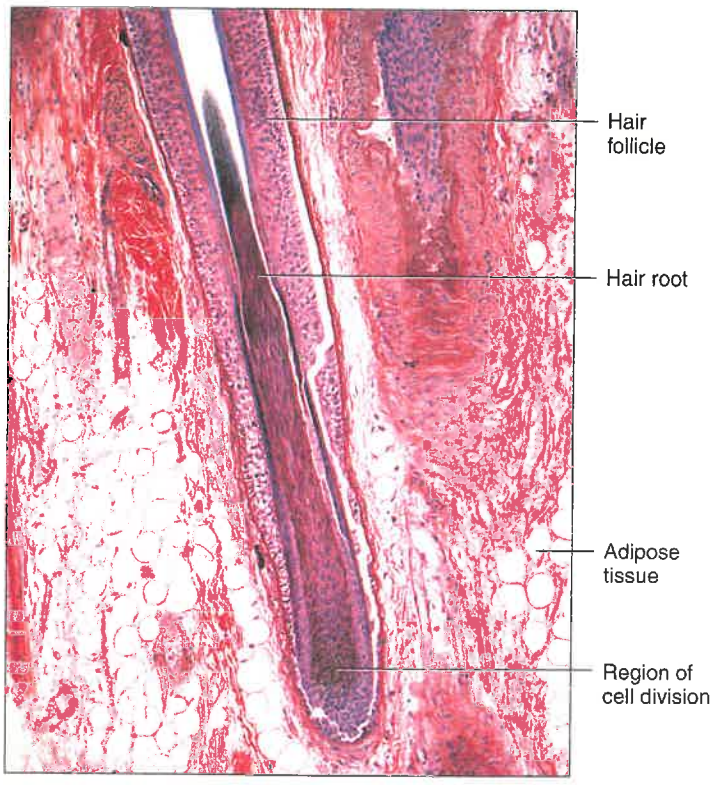
Genes determine hair color by directing the type and amount of pigment that epidermal melanocytes produce. Dark hair has more of the brownish-black **eumelanin** (u-mel′ah-nin), while blonde hair and red hair have more of the reddish-yellow **pheomelanin** (fe″o-mel′ah-nin). The white hair of a person 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 epidermal cells of hair or skin. The first clue to the existence of these cells was that new skin in burn patients arises from hair follicles. Manipulating these stem cells could someday treat baldness (alopecia) or extreme hairiness (hirsutism).



(a)



(b)

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. **(b)** Light micrograph of a hair follicle (175×).

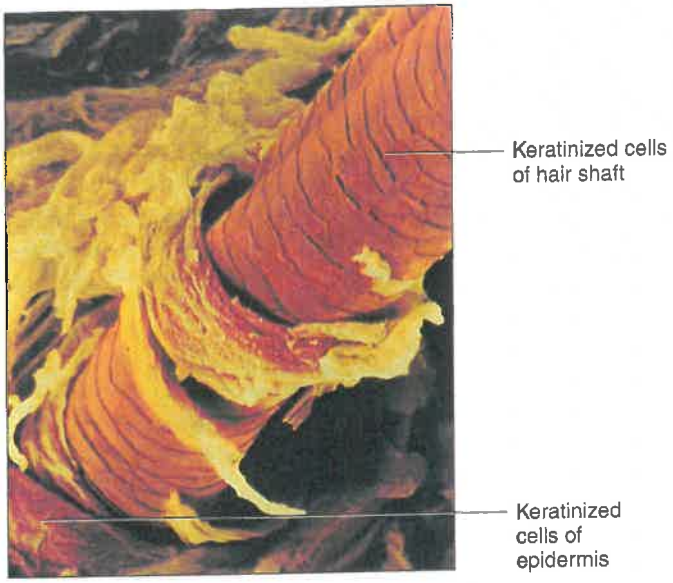


Figure 6.6
This scanning electron micrograph shows a hair emerging from the epidermis (875×).

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.

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, producing blackheads (comedones), or surrounded by small, red elevations producing 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 numerous 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. They also release moisture that appears on the palms and soles when a person is emotionally stressed.

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.

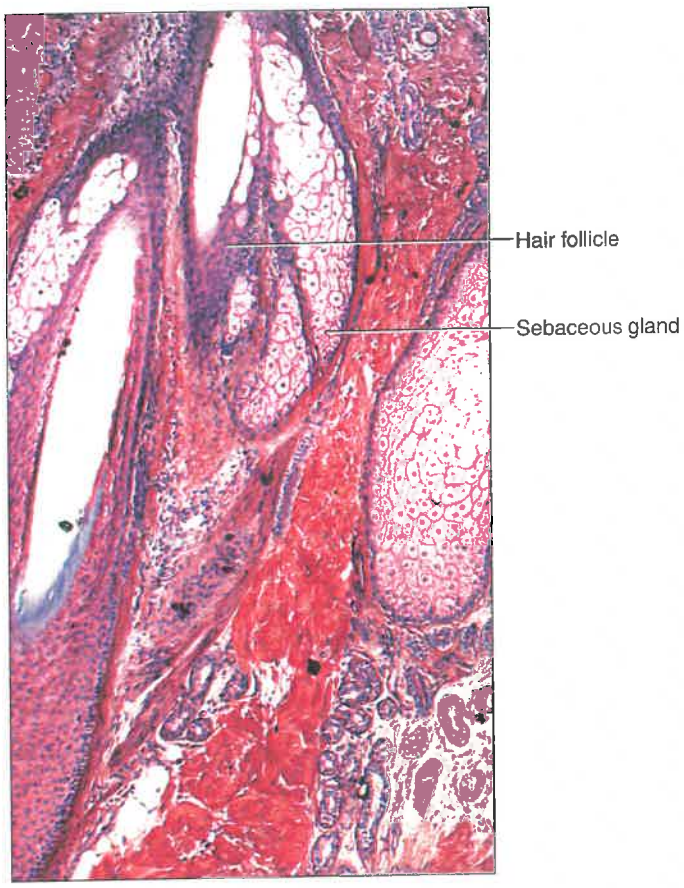


Figure 6.7
A sebaceous gland secretes sebum into a hair follicle, shown here in oblique section (200×).

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. In adults, the apocrine glands 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 (see chapter 20, p. 552).

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.

Practice

12. Describe the structure of the 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. Examples include 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 in the blood escapes to the outside.

At the same time as 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.

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 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 cells in the skeletal muscles throughout the body to contract slightly. This action requires an increase in the rate of cellular respiration and releases heat as a by-product. If this response does not raise body temperature to normal, small groups of muscles may rhythmically contract with greater force, causing the person to shiver, generating more heat. Chapter 1 introduced this type of homeostatic mechanism (fig. 1.7, p. 8).

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 fades.

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. 489) describes heatstroke.

Practice

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.

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 released blood forms a

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

Clinical Application 6.2

Burns

A few hours outside on a sunny summer day, without use of sunscreen, may result in a minor sunburn. The slightly burned skin warms and reddens (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.

More serious is a burn that destroys some epidermis as well as some underlying dermis. This 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 from dark red to waxy white. Such a burn usually happens 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 which accessory structures of the skin survive the injury, which is possible if they are deep in the dermis. These structures include hair follicles, sweat glands, and sebaceous glands, as well as epithelial cells that divide and extend onto the surface of the injured dermis, spreading over it and forming new epidermis.

Most severe is a burn that destroys the epidermis, the dermis, and the accessory structures of the skin. This is a *full-thickness* (third degree) *burn*. The injured skin becomes dry and leathery, and may vary in color from red to black to white. A full-thickness burn usually occurs as a result of prolonged exposure to hot objects, flames, or corrosive chemicals. Most of the epithelial cells in the affected region are destroyed, and the skin heals 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 such as tissue-engineered skin.

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. 6B). 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.

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 secreting new collagenous fibers that bind the edges of the wound. 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 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 collagen fibers. Clinical Application 6.2 describes healing of burned tissue.

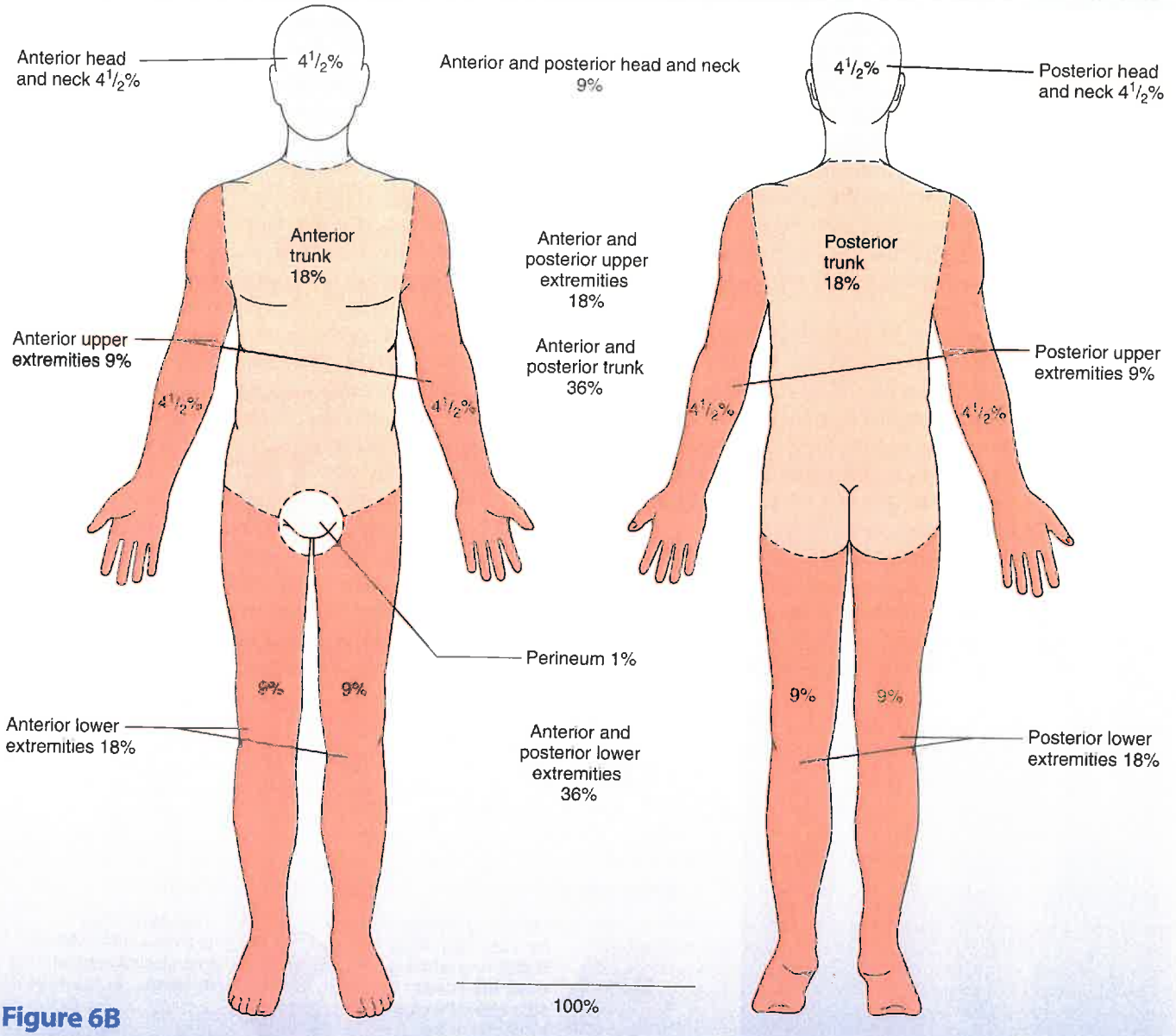


Figure 6B

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.

Practice

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*.

Common Skin Disorders

acne (ak′ne) Disease of the sebaceous glands that produces blackheads and pimples.

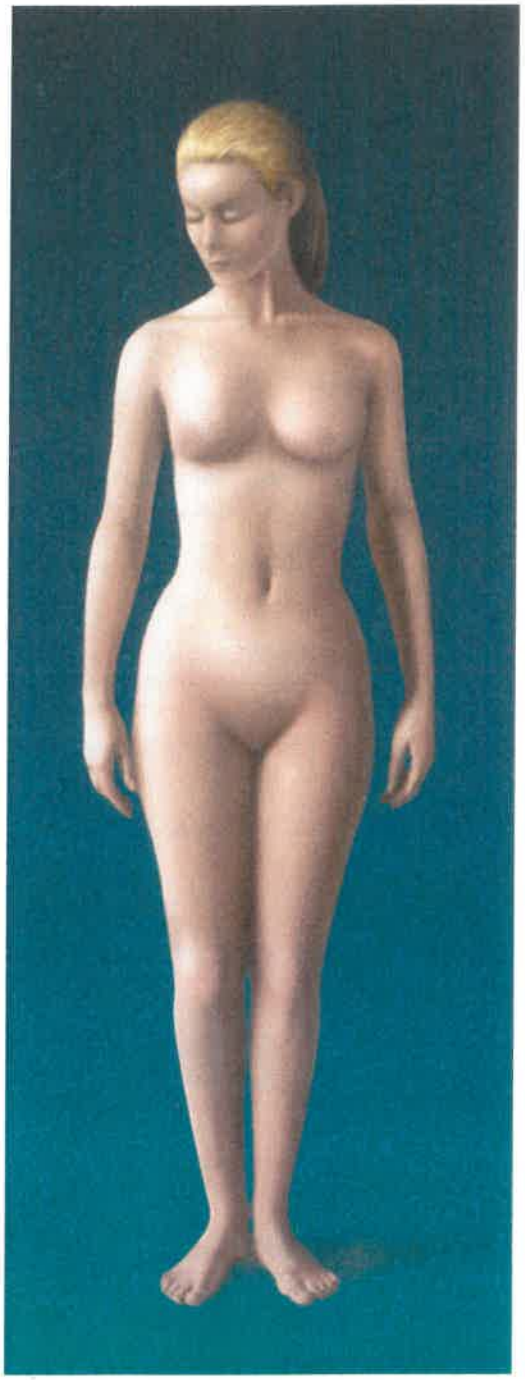
alopecia (al″o-pe′she-ah) Hair loss, usually sudden.

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.

Integumentary System



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.

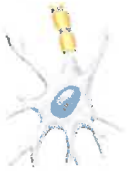
Muscular System

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.

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

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) Benign 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.

Summary Outline

6.1 Introduction (p. 117)

An organ is formed by two or more tissue types 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 epidermis is stratified squamous epithelium that lacks blood vessels.
   b. The deepest layer of the epidermis, called the stratum basale, contains cells that divide.
   c. Epidermal cells undergo keratinization as they mature and are pushed toward the surface.
   d. The outermost layer, called the stratum corneum, is composed of dead epidermal cells.
   e. The epidermis protects underlying tissues against water loss, mechanical injury, and the effects of harmful chemicals.
   f. Melanin protects underlying cells from the effects of ultraviolet light.
   g. Melanocytes transfer melanin to nearby epidermal cells.
   h. 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 cell processes are 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, 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. Hair color is determined by genes that direct the amount of eumelanin or pheomelanin produced by melanocytes associated with hair follicles.
   d. A bundle of smooth muscle cells is attached to each hair follicle.
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 contains salts and wastes.
   c. Eccrine sweat glands respond to elevated body temperature; apocrine glands respond to emotional upset.

6.4 Regulation of Body Temperature (p. 125)

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

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 types of tissues grouped together and performing specialized functions defines a(n) _____. (p. 117)

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

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

a. liver c. lungs e. brain
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. Describe how skin plays a role in the production of vitamin D. (p. 117)

5. The epidermis is composed of layers of _____ tissue. (p. 117)

6. The _____ layer of epidermal cells contains older keratinized cells and dead cells. (p. 119)

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. 120)

9. The dermis is composed primarily of what kind of tissue? (p. 122)

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. 124)

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. 125)

15. Explain how sweat glands help regulate body temperature. (p. 125)

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

OUTCOMES 5.3, 6.2, 6.4

1. 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?

OUTCOME 6.2

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

OUTCOMES 6.2, 6.5

4. How is it protective for skin to peel after a severe sunburn?
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?

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