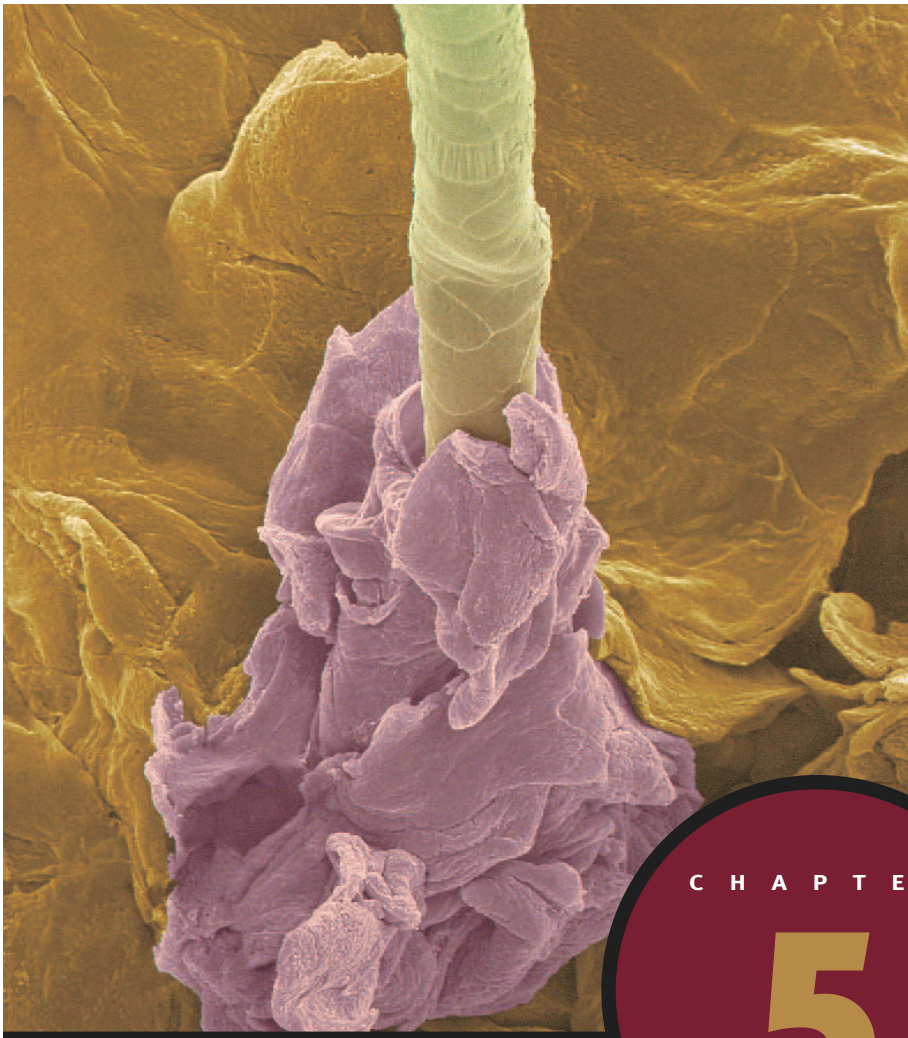




Colorized scanning electron micrograph (SEM) of the shaft of a hair protruding through the surface of the skin. Note the flat, scalelike epithelial cells of the skin.

C H A P T E R

5

Integumentary System

The **integumentary system** consists of the skin and accessory structures such as hair, nails, and glands. Integument means covering, and the integumentary system is familiar to most people because it covers the outside of the body and is easily observed. In addition,

humans are concerned with the appearance of the integumentary system. Skin without blemishes is considered attractive, whereas acne is a source of embarrassment for many teenagers. The development of wrinkles and the graying or loss of hair is a sign of aging that some people find unattractive. Because of these feelings, much time, effort, and money are spent on changing the appearance of the integumentary system. For example, people apply lotion to their skin, color their hair, and trim their nails. They also try to prevent sweating with antiperspirants and body odor with washing, deodorants, and perfumes.

The appearance of the integumentary system can indicate physiological imbalances in the body. Some disorders like acne or warts affect just the integumentary system. Disorders of other parts of the body can be reflected there, and thus the integumentary system is useful for diagnosis. For example, reduced blood flow through the skin during a heart attack can cause a pale appearance, whereas increased blood flow as a result of fever can cause a flushed appearance. Also, the rashes of some diseases are very characteristic, such as the rashes of measles, chicken pox, and allergic reactions.

This chapter provides an *overview of the integumentary system* (144) and an explanation of the *hypodermis* (144), the *skin* (145), and the *accessory skin structures* (150). A *summary of integumentary system functions* (156) and the *effects of aging on the integumentary system* (157) are also presented.

Overview of the Integumentary System

Objective

- Describe the functions of the integumentary system.

Although we are often concerned with how the integumentary system looks, it has many important functions that go beyond appearance. The integumentary system forms the boundary between the body and the external environment, thereby separating us from the external environment while allowing us to interact with it. Major functions of the integumentary system include:

1. **Protection.** The skin provides protection against abrasion and ultraviolet light. It also prevents the entry of microorganisms and prevents dehydration by reducing water loss from the body.
2. **Sensation.** The integumentary system has sensory receptors that can detect heat, cold, touch, pressure, and pain.
3. **Temperature regulation.** Body temperature is regulated by controlling blood flow through the skin and the activity of sweat glands.
4. **Vitamin D production.** When exposed to ultraviolet light, the skin produces a molecule that can be transformed into vitamin D.

5. **Excretion.** Small amounts of waste products are lost through the skin and in gland secretions.

- 1. Provide an example for each function of the integumentary system.

Hypodermis

Objective

- Describe the structure and function of the hypodermis.

Just as a house rests on a foundation, the skin rests on the **hypodermis** (hī-pō-der'mis), which attaches it to underlying bone and muscle and supplies it with blood vessels and nerves (figure 5.1). The hypodermis consists of loose connective tissue with collagen and elastin fibers. The main types of cells within the hypodermis are fibroblasts, adipose cells, and macrophages. The hypodermis, which is not part of the skin, is sometimes called **subcutaneous** (süb-koo-tā'nē-ŭs) **tissue**, or **superficial fascia** (fash'ē-ä).

Approximately half the body's stored fat is in the hypodermis, although the amount and location vary with age, sex, and diet. For example, newborn infants have a large amount of fat, which accounts for their chubby appearance; and women have more fat than men, especially over the thighs, buttocks, and breasts. Fat in the hypodermis functions as padding and insulation and is respon-

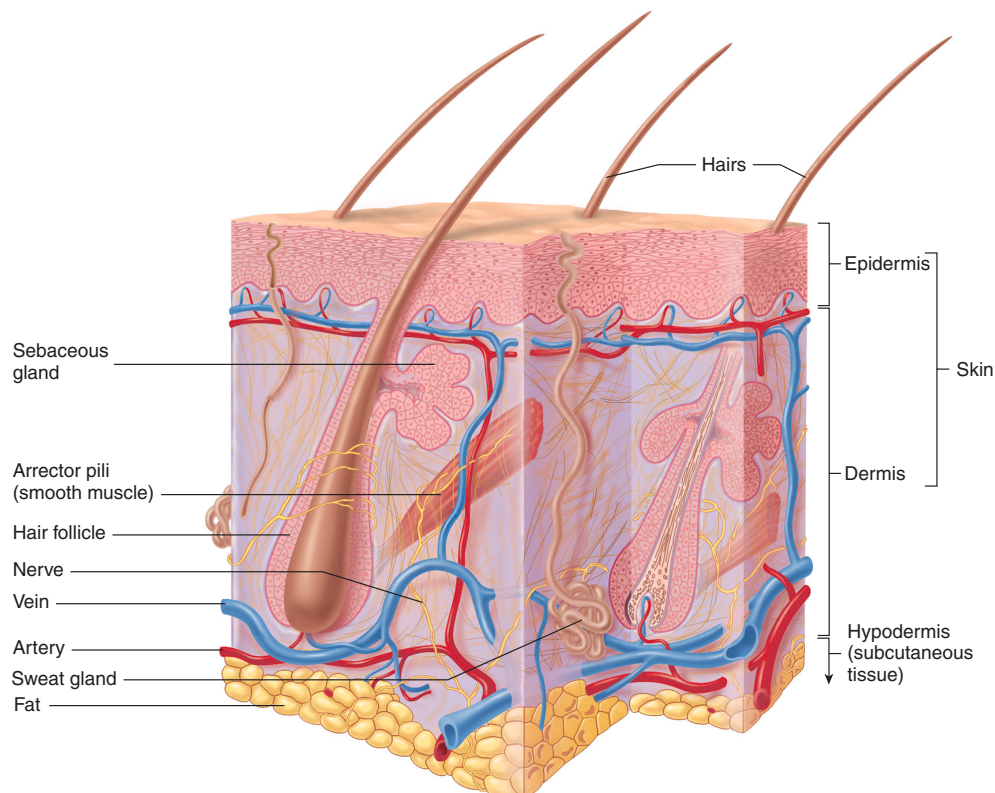


Figure 5.1 Skin and Hypodermis

The figure represents a block of skin (dermis and epidermis), hypodermis, and accessory structures (hairs and glands).

Chapter 5 Integumentary System

145

sible for some of the differences in body shape between men and women.

2. Name the types of tissue forming the hypodermis.
3. How is the hypodermis related to the skin?
4. List the functions of fat contained within the hypodermis.

Uses of the Hypodermis

The hypodermis can be used to estimate total body fat. The skin is pinched at selected locations, and the thickness of the fold of skin and underlying hypodermis is measured. The thicker the fold, the greater is the amount of total body fat. Clinically, the hypodermis is the site of subcutaneous injections.



Skin

Objectives

- Describe the parts of the skin and their functions.
- Explain the factors affecting skin color.

The skin is made up of two major tissue layers. The **dermis** (derm'is; skin) is a layer of connective tissue that is connected to the hypodermis. The **epidermis** (ep-i-derm'is; on the dermis) is a layer of epithelial tissue that rests on the dermis (see figure 5.1). If the hypodermis is the foundation on which the house rests, the dermis forms most of the house, and the epidermis is its roof.

Dermis

The dermis is responsible for most of the structural strength of the skin. It is connective tissue with fibroblasts, a few adipose cells, and macrophages. Collagen is the main connective tissue fiber, but elastin and reticular fibers are also present. Adipose cells and blood vessels are scarce in the dermis compared to the hypodermis. Nerve endings, hair follicles, smooth muscles, glands, and lymphatic vessels are also in the dermis (see figure 5.1). The nerve endings are varied in structure and function: free nerve endings for pain, itch, tickle, and temperature sensations; hair follicle receptors for light touch; pacinian corpuscles for deep pressure; Meissner's corpuscles for the ability to detect simultaneous stimulation at two points on the skin; and Ruffini's end organs for continuous touch or pressure (see figure 14.1). Nerve endings are described in chapter 14.



Uses of the Dermis

The dermis is that part of an animal hide from which leather is made. The epidermis of the skin is removed, and the dermis is treated with chemicals in a process called tanning. Clinically the dermis in humans is sometimes the site of such injections as the tuberculin skin test.

The dermis is divided into two layers (see figure 5.1, and figure 5.2): the deeper **reticular** (re-tik'ū-lār) **layer** and the more superficial **papillary** (pap'i-lār-ē) **layer**. The reticular layer, which is dense irregular connective tissue, is the main layer of the dermis. It is continuous with the hypodermis and forms a mat of irregularly arranged fibers that are resistant to stretching in many directions. The elastin and collagen fibers are oriented more in some directions than in others and produce **cleavage**, or **tension, lines** in the skin

(figure 5.3). Knowledge of cleavage line directions is important because an incision made parallel to the cleavage lines is less likely to gap than is an incision made across them. The closer together the edges of a wound, the less likely is the development of infections and the formation of considerable scar tissue.

If the skin is overstretched, the dermis may rupture and leave lines that are visible through the epidermis. These lines, called **striae** (strī'ē), or **stretch marks**, can develop on the abdomen and breasts of a woman during pregnancy.

The papillary layer derives its name from projections called **papillae** (pā-pil'ē) that extend toward the epidermis (see figure 5.2). The papillary layer is less dense than the reticular layer and is sometimes called loose connective tissue because it has thin fibers that are somewhat loosely arranged. The papillary layer also contains a large number of blood vessels that supply the overlying epidermis with nutrients, remove waste products, and aid in regulating body temperature.

5. Name and compare the two layers of the dermis. Which layer is responsible for most of the structural strength of the skin?
6. What are cleavage lines and striae?

Epidermis

The epidermis is stratified squamous epithelium, and it is separated from the papillary layer of the dermis by a basement membrane. The epidermis is not as thick as the dermis, contains no blood vessels, and is nourished by diffusion from capillaries of the papillary layer (see figures 5.1 and 5.2). Most cells of the epidermis are called **keratinocytes** (ke-rat'i-nō-sitz) because they produce a protein mixture called **keratin** (ker'ā-tin). Keratinocytes are responsible for the structural strength and permeability characteristics of the epidermis. Other cells of the epidermis include **melanocytes** (mel'ā-nō-sitz), which contribute to skin color, **Langerhans' cells**, which are part of the immune system (see chapter 22), and **Merkel's cells**, which are specialized epidermal cells associated with nerve endings responsible for detecting light touch and superficial pressure (see chapter 14).

Cells are produced by mitosis in the deepest layers of the epidermis. As new cells are formed, they push older cells to the surface where they slough off, or **desquamate** (des'kwā-māt). The outermost cells in this stratified arrangement protect the cells underneath, and the deeper replicating cells replace cells lost from the surface. As they move from the deeper epidermal layers to the surface, the cells change shape and chemical composition. This process is called **keratinization** (ker'ā-tin-i-zā'shūn) because the cells become filled with keratin. During keratinization, these cells eventually die and produce an outer layer of cells that resists abrasion and forms a permeability barrier.

Keratinization and Disease

The study of keratinization is important because many skin diseases result from malfunctions in this process. For example, large scales of epidermal tissue are sloughed off in **psoriasis** (sō-rī'ā-sis; see "Clinical Focus: Clinical Disorders of the Integumentary System" on p. 158). By comparing normal and abnormal keratinization, scientists may be able to develop effective therapies.



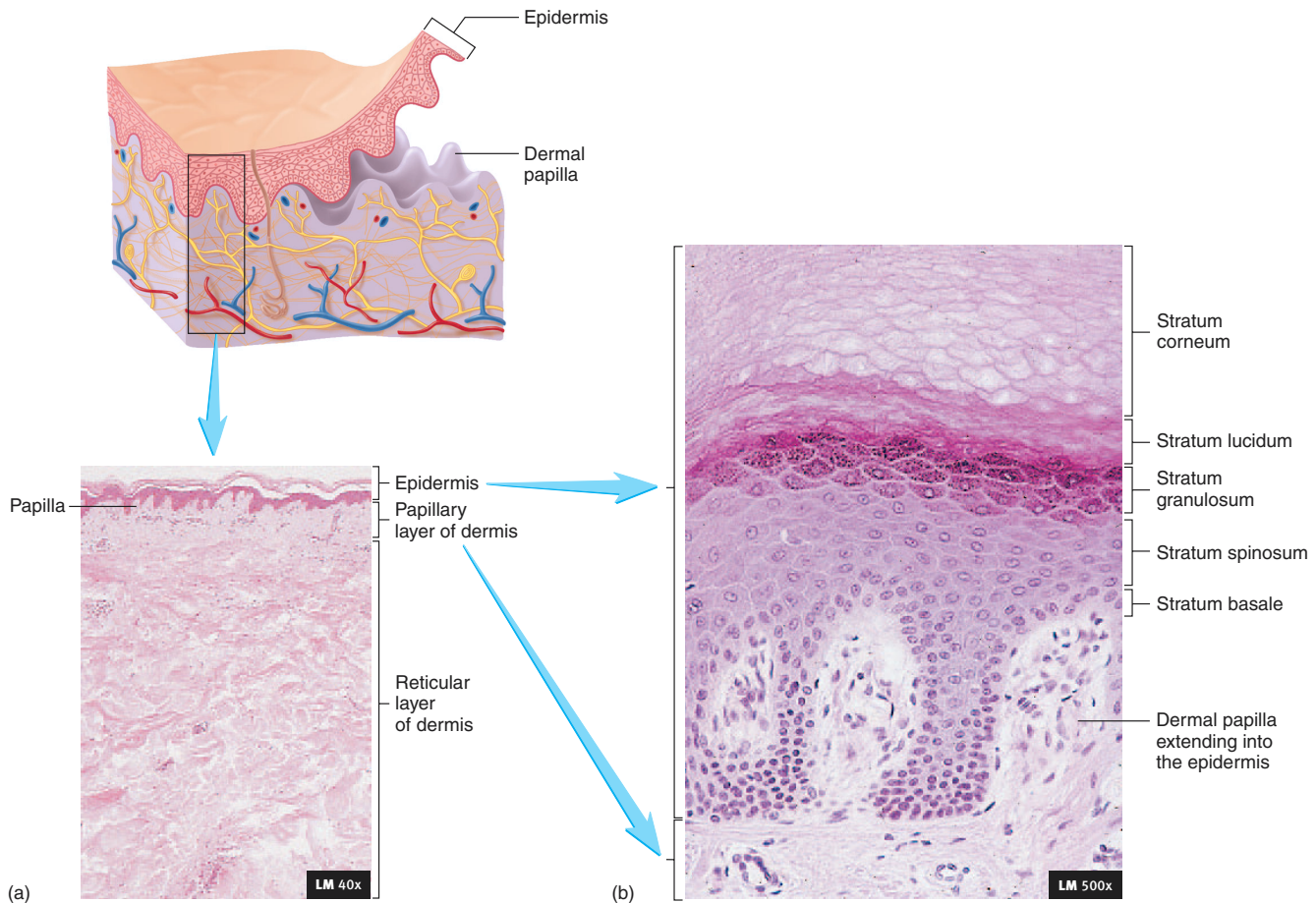


Figure 5.2 Dermis and Epidermis

(a) Photomicrograph of dermis covered by the epidermis. The dermis consists of the papillary and reticular layers. The papillary layer has projections called papillae that extend into the epidermis. (b) Higher magnification photomicrograph of the epidermis resting on the papillary layer of the dermis. Note the strata of the epidermis.

Although keratinization is a continual process, distinct transitional stages can be recognized as the cells change. On the basis of these stages, the many layers of cells in the epidermis are divided into regions, or **strata** (sing., stratum) (see figure 5.2 and figure 5.4). From the deepest to the most superficial, these five strata are observed: stratum basale, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum. The number of cell layers in each stratum and even the number of strata in the skin vary, depending on their location in the body.

Stratum Basale

The deepest portion of the epidermis is a single layer of cuboidal or columnar cells, the **stratum basale** (bā'sā-lē) (see figures 5.2 and 5.4). Structural strength is provided by hemidesmosomes, which anchor the epidermis to the basement membrane, and by

desmosomes, which hold the keratinocytes together (see chapter 4). Keratinocytes are strengthened internally by keratin fibers (intermediate filaments) that insert into the desmosomes. Keratinocytes undergo mitotic divisions approximately every 19 days. One daughter cell becomes a new stratum basale cell and divides again, but the other daughter cell is pushed toward the surface and becomes **keratinized** (ker'ă-ti-nīzd). It takes approximately 40–56 days for the cell to reach the epidermal surface and desquamate.

Stratum Spinosum

Superficial to the stratum basale is the **stratum spinosum** (spī-nō'sūm), consisting of 8–10 layers of many-sided cells (see figures 5.2 and 5.4). As the cells in this stratum are pushed to the surface, they flatten; desmosomes are broken apart, and new

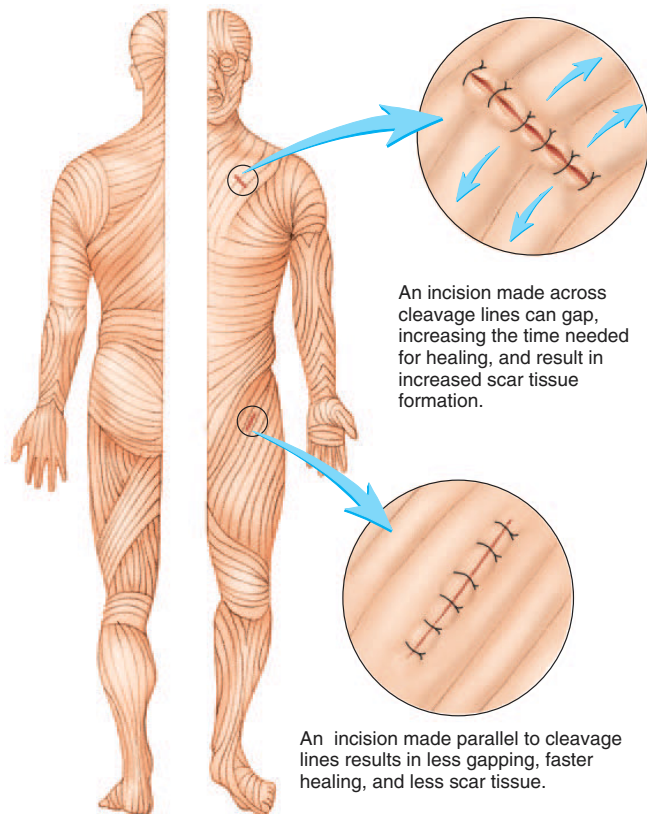


Figure 5.3 Cleavage Lines

The orientation of collagen fibers produces cleavage, or tension, lines in the skin.

desmosomes are formed. During preparation for microscopic observation, the cells usually shrink from one another, except where they are attached by desmosomes, causing the cells to appear spiny—hence the name stratum spinosum. Additional keratin fibers and lipid-filled, membrane-bounded organelles called **lamellar** (lam'ě-lăr, lă-mel'ăr) **bodies** are formed inside the keratinocytes. A limited amount of cell division takes place in this stratum, and for this reason the stratum basale and stratum spinosum are sometimes considered a single stratum called the **stratum germinativum** (jer'mi-nă-tīv'ŭm). Mitosis does not occur in the more superficial strata.

Stratum Granulosum

The **stratum granulosum** (gran-ŭ-lō'sŭm) consists of two to five layers of somewhat flattened, diamond-shaped cells with long axes that are oriented parallel to the surface of the skin (see figures 5.2 and 5.4). This stratum derives its name from the nonmembrane-bounded protein granules of **keratohyalin** (ker'ă-tō-hī'ă-lin), which accumulate in the cytoplasm of the cell. The lamellar bodies

of these cells move to the plasma membrane and release their lipid contents into the intercellular space. Inside the cell, a protein envelope forms beneath the plasma membrane. In the most superficial layers of the stratum granulosum, the nucleus and other organelles degenerate, and the cell dies. Unlike the other organelles, however, the keratin fibers and keratohyalin granules do not degenerate.

Stratum Lucidum

The **stratum lucidum** (loo'si-dŭm) appears as a thin, clear zone above the stratum granulosum (see figures 5.2 and 5.4) and consists of several layers of dead cells with indistinct boundaries. Keratin fibers are present, but the keratohyalin, which was evident as granules in the stratum granulosum, has dispersed around the keratin fibers, and the cells appear somewhat transparent. The stratum lucidum is present in only a few areas of the body (see “Thick and Thin Skin” below).

Stratum Corneum

The last and most superficial stratum of the epidermis is the **stratum corneum** (kōr'nē-ŭm) (see figures 5.2 and 5.4). This stratum is composed of approximately 25 or more layers of dead squamous cells joined by desmosomes. Eventually the desmosomes break apart, and the cells are desquamated from the surface of the skin. Dandruff is an example of desquamation of the stratum corneum of the scalp. Less noticeably, cells are continually shed as clothes rub against the body or as the skin is washed.

The stratum corneum consists of **cornified cells**, which are dead cells with a hard protein envelope that are filled with the protein keratin. **Keratin** is a mixture of keratin fibers and keratohyalin. The envelope and the keratin are responsible for the structural strength of the stratum corneum. The type of keratin found in the skin is soft keratin. Another type of keratin, hard keratin, is found in nails and the external parts of hair. Cells containing hard keratin are more durable than cells with soft keratin and do not desquamate.

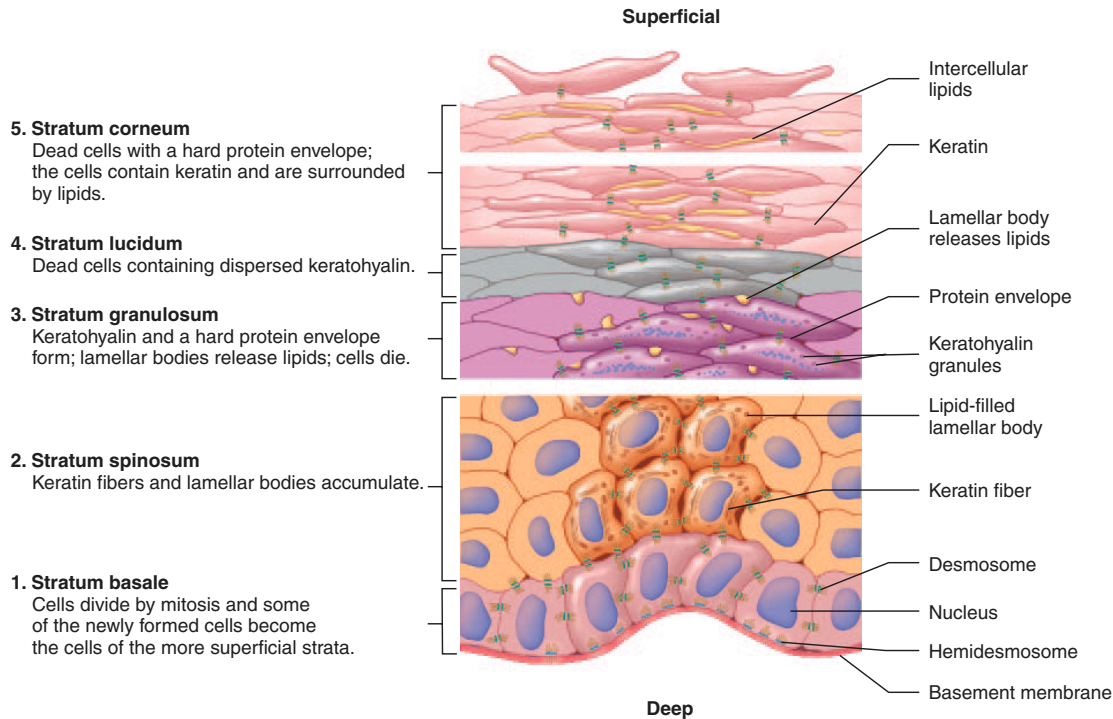
Surrounding the cells are the lipids released from lamellar bodies. The lipids are responsible for many of the permeability characteristics of the skin. Table 5.1 summarizes the structures and functions of the skin and hypodermis.

P R E D I C T 1

Some drugs are administered by applying them to the skin (e.g., a nicotine skin patch to help a person stop smoking). The drug diffuses through the epidermis to blood vessels in the dermis. What kind of substances can pass easily through the skin by diffusion? What kind have difficulty?

Thick and Thin Skin

When we say a person has thick or thin skin, we are usually referring metaphorically to the person's ability to take criticism. However, all of us in a literal sense have both thick and thin skin. Skin is classified as thick or thin on the basis of the structure of the epidermis. **Thick skin** has all five epithelial strata, and the stratum corneum has many layers of cells. Thick skin is found in areas



Process Figure 5.4 Epidermal Layers and Keratinization

subject to pressure or friction, such as the palms of the hands, the soles of the feet, and the fingertips. The papillae of the dermis underlying thick skin are in parallel, curving ridges that shape the overlying epidermis into fingerprints and footprints. The ridges increase friction and improve the grip of the hands and feet.

Fingerprints and Criminal Investigations

Fingerprints were first used in criminal investigation in 1880 by Henry Faulds, a Scottish medical missionary. Faulds used a greasy fingerprint left on a bottle to identify a thief who had been drinking purified alcohol from the dispensary.

Thin skin covers the rest of the body and is more flexible than thick skin. Each stratum contains fewer layers of cells than are found in thick skin; the stratum granulosum frequently consists of only one or two layers of cells, and the stratum lucidum generally is absent. The dermis under thin skin projects upward as separate papillae and does not produce the ridges seen in thick skin. Hair is found only in thin skin.

The entire skin, including both the epidermis and the dermis, varies in thickness from 0.5 mm in the eyelids to 5.0 mm for the back and shoulders. The terms *thin* and *thick*, which refer to the epidermis only, should not be used when total skin thickness is considered. Most of the difference in total skin thickness results from variation in the thickness of the dermis. For example, the skin of the back is thin skin, whereas that of the palm is thick skin; however, the total skin thickness of the back is greater than that of the palm because more dermis exists in the skin of the back.

In skin subjected to friction or pressure, the number of layers in the stratum corneum greatly increases to produce a thickened area called a **callus** (kal'ūs). The skin over bony prominences may develop a cone-shaped structure called a **corn**. The base of the cone is at the surface, but the apex extends deep into the epidermis, and pressure on the corn may be quite painful. Calluses and corns can develop in both thin and thick skin.

7. From deepest to most superficial, name and describe the five strata of the epidermis. In which strata are new cells formed by mitosis? Which strata have live cells, and which have dead cells?
8. Describe the structural features resulting from keratinization that make the epidermis structurally strong and resistant to water loss.
9. Compare the structure and location of thick skin and thin skin. Is hair found in thick or thin skin?

Skin Color

Pigments in the skin, blood circulating through the skin, and the thickness of the stratum corneum together determine skin color. **Melanin** (mel'ā-nin) is the term used to describe a group of pigments responsible for skin, hair, and eye color. Melanin is believed to provide protection against ultraviolet light from the sun. Large amounts of melanin are found in certain regions of the skin, such as freckles, moles, nipples, areolae of the breasts, the axillae, and the genitalia. Other areas of the body, such as the lips, the palms of the hands, and the soles of the feet, contain less melanin.

Table 5.1 Comparison of the Skin (Epidermis and Dermis) and Hypodermis

Part	Structure	Function
Epidermis	Superficial part of skin; stratified squamous epithelium; composed of four or five strata	Barrier that prevents water loss and the entry of chemicals and microorganisms; protects against abrasion and ultraviolet light; produces vitamin D; gives rise to hair, nails, and glands
Stratum corneum	Most superficial strata of the epidermis; 25 or more layers of dead squamous cells	Provision of structural strength by keratin within cells; prevention of water loss by lipids surrounding cells; desquamation of most superficial cells resists abrasion
Stratum lucidum	Three to five layers of dead cells; appears transparent; present in thick skin, absent in most thin skin	Dispersion of keratohyalin around keratin fibers
Stratum granulosum	Two to five layers of flattened, diamond-shaped cells	Production of keratohyalin granules; lamellar bodies release lipids from cells; cells die
Stratum spinosum	A total of 8–10 layers of many-sided cells	Production of keratin fibers; formation of lamellar bodies
Stratum basale	Deepest strata of the epidermis; single layer of cuboidal or columnar cells; basement membrane of the epidermis attaches to the dermis	Production of cells of the most superficial strata; melanocytes produce and contribute melanin, which protects against ultraviolet light
Dermis	Deep part of skin; connective tissue composed of two layers	Responsible for the structural strength and flexibility of the skin; the epidermis exchanges gases, nutrients, and waste products with blood vessels in the dermis
Papillary layer	Papillae project toward the epidermis; loose connective tissue	Brings blood vessels close to the epidermis; papillae form fingerprints and footprints
Reticular layer	Mat of collagen and elastin fibers; dense, irregular connective tissue	Main fibrous layer of the dermis; strong in many directions; forms cleavage lines
Hypodermis	Not part of the skin; loose connective tissue with abundant fat deposits	Attaches the dermis to underlying structures; fat tissue provides energy storage, insulation, and padding; blood vessels and nerves from the hypodermis supply the dermis

In the production of melanin, the enzyme tyrosinase (tī' rō-si-nās, tīr'ō-si-nās) converts the amino acid tyrosine to dopaquinone (dō'pā-kwin'ōn, dō'pā-kwī-nōn). Dopaquinone can be converted to a variety of related molecules, most of which are brown to black pigments, but some of which are yellowish or reddish.

Melanin is produced by **melanocytes** (mel'ā-nō-sītz), irregularly shaped cells with many long processes that extend between the keratinocytes of the stratum basale and the stratum spinosum (figure 5.5). The Golgi apparatuses of the melanocytes package melanin into vesicles called **melanosomes** (mel'ā-nō-sōmz), which move into the cell processes of the melanocytes. Keratinocytes phagocytize (see chapter 3) the tips of the melanocyte cell processes, thereby acquiring melanosomes. Although all keratinocytes can contain melanin, only the melanocytes produce it.

Melanin production is determined by genetic factors, hormones, and exposure to light. Genetic factors are primarily responsible for the variations in skin color between different races and among people of the same race. The amount and types of melanin produced by the melanocytes, and the size, number, and distribution of the melanosomes, is genetically determined. Skin colors are not determined by the number of melanocytes because all races have essentially the same number. Although many genes are responsible for skin color, a single mutation (see chapter 29) can prevent the manufacture of melanin. **Albinism** (al'bi-nizm) usually is a recessive ge-

netic trait causing an inability to produce tyrosinase. The result is a deficiency or absence of pigment in the skin, hair, and eyes.

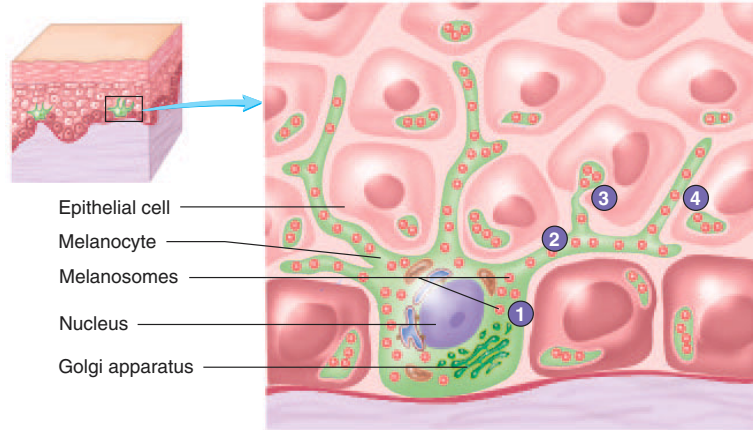
During pregnancy, certain hormones cause an increase in melanin production in the mother, which in turn causes darkening of the nipples, areolae, and genitalia. The cheekbones, forehead, and chest also may darken, resulting in the “mask of pregnancy,” and a dark line of pigmentation may appear on the midline of the abdomen. Diseases like Addison’s disease that cause an increased secretion of certain hormones also cause increased pigmentation.

Exposure to ultraviolet light darkens melanin already present and stimulates melanin production, resulting in tanning of the skin.

The location of pigments and other substances in the skin affects the color produced. If a dark pigment is located in the dermis or hypodermis, light reflected off the dark pigment can be scattered by collagen fibers of the dermis to produce a blue color. The same effect produces the blue color of the sky as light is reflected from dust particles in the air. The deeper within the dermis or hypodermis any dark pigment is located, the bluer the pigment appears because of the light-scattering effect of the overlying tissue. This effect causes the blue color of tattoos, bruises, and some superficial blood vessels.

Carotene (kar'ō-tēn) is a yellow pigment found in plants such as carrots and corn. Humans normally ingest carotene and use it as a source of vitamin A. Carotene is lipid-soluble, and, when

1. Melanosomes are produced by the Golgi apparatus of the melanocyte.
2. Melanosomes move into melanocyte cell processes.
3. Epithelial cells phagocytize the tips of the melanocyte cell processes.
4. These melanosomes are within epithelial cells.



Process Figure 5.5 Melanin Transfer from Melanocyte to Keratinocytes

Melanocytes make melanin, which is packaged into melanosomes and transferred to many keratinocytes.

large amounts of carotene are consumed, the excess accumulates in the stratum corneum and in the adipose cells of the dermis and hypodermis, causing the skin to develop a yellowish tint that slowly disappears once carotene intake is reduced.

Blood flowing through the skin imparts a reddish hue, and, when blood flow increases (e.g., during blushing, anger, and the inflammatory response), the red color intensifies. A decrease in blood flow such as occurs in shock can make the skin appear pale, and a decrease in the blood oxygen content produces **cyanosis** (sī-ā-nō'sis), a bluish skin color.

10. Which cells of the epidermis produce melanin? What happens to the melanin once it is produced?
11. How do genetic factors, hormones, and exposure to light determine the amount of melanin in the skin?
12. How do melanin, carotene, and blood affect skin color?

P R E D I C T 2

Explain the differences in skin color between (a) the palms of the hands and the lips, (b) the palms of the hands of a person who does heavy manual labor and one who does not, (c) the anterior and posterior surfaces of the forearm, and (d) the genitals and the soles of the feet.

Accessory Skin Structures

Objectives

- Describe the types of hair and the structure of a hair and its follicle. Discuss the stages of hair growth.
- Describe the glands of the skin and their secretions.
- Describe the parts of a nail, and explain how the nails are produced.

Hair

The presence of **hair** is one of the characteristics common to all mammals; if the hair is dense and covers most of the body surface, it is called fur. In humans, hair is found everywhere on the skin except the palms, soles, lips, nipples, parts of the external genitalia, and the distal segments of the fingers and toes.

By the fifth or sixth month of fetal development, delicate unpigmented hair called **lanugo** (lā-noo'gō) develops and covers the fetus. Near the time of birth, **terminal hairs**, which are long, coarse, and pigmented, replace the lanugo of the scalp, eyelids, and eyebrows. **Vellus** (vel'ūs) **hairs**, which are short, fine, and usually unpigmented, replace the lanugo on the rest of the body. At puberty, terminal hair, especially in the pubic and axillary regions, replaces much of the vellus hair. The hair of the chest, legs, and arms is approximately 90% terminal hair in males compared with approximately 35% in females. In males, terminal hairs replace the vellus hairs of the face to form the beard. The beard, pubic, and axillary hair are signs of sexual maturity. In addition, pubic and axillary hair may function as wicks for dispersing odors produced by secretions from specialized glands in the pubic and axillary regions. It also has been suggested that pubic hair provides protection against abrasion during intercourse, and axillary hair reduces friction when the arms move.

Hair Structure

A hair is divided into the **shaft** and **root** (figure 5.6a). The shaft protrudes above the surface of the skin, and the root is located below the surface. The base of the root is expanded to form the **hair bulb** (figure 5.6b). Most of the root and the shaft of the hair are composed of columns of dead keratinized epithelial cells arranged in three concentric layers: the medulla, the cortex, and the cuticle (figure 5.6c). The **medulla** (me-dool'ā) is the central axis of the hair and consists of two or three layers of cells containing soft keratin. The **cortex** forms the bulk of the hair and consists of cells containing hard keratin. The **cuticle** (kū'ti-kl) is a single layer of cells that forms the hair surface. The cuticle cells contain hard keratin, and the edges of the cuticle cells overlap like shingles on a roof.

Hard keratin contains more sulfur than does soft keratin. When hair burns, the sulfur combines with hydrogen to form hydrogen sulfide, which produces the unpleasant odor of rotten eggs. In some animals such as sheep, the cuticle edges of the hair are raised and during textile manufacture catch each other and hold together to form threads.

Chapter 5 Integumentary System

151

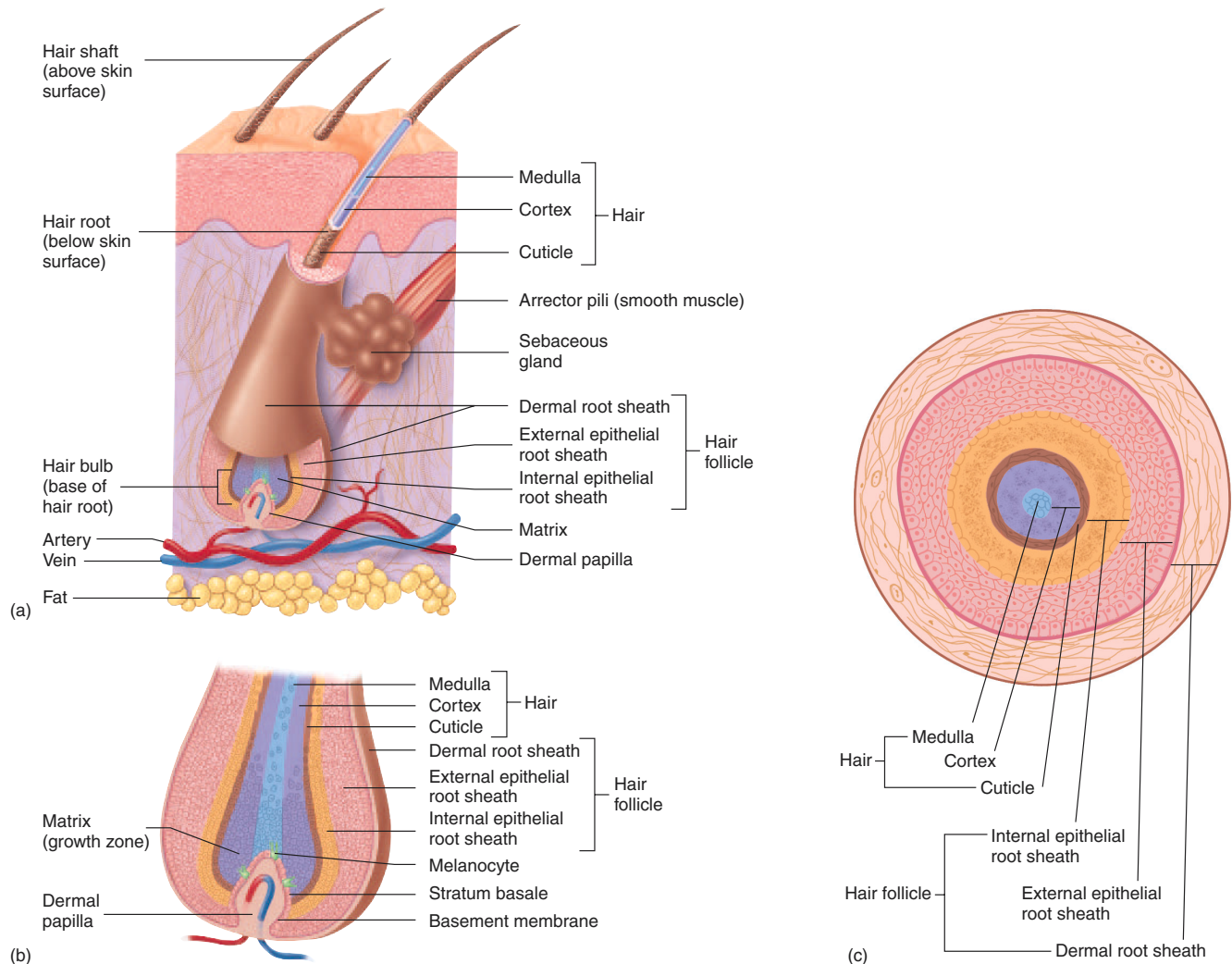


Figure 5.6 Hair Follicle

(a) The hair follicle contains the hair and consists of a dermal and epithelial root sheath. (b) Enlargement of the hair follicle wall and hair bulb. (c) Cross section of a hair within a hair follicle.

The **hair follicle** consists of a **dermal root sheath** and an **epithelial root sheath**. The dermal root sheath is the portion of the dermis that surrounds the epithelial root sheath. The epithelial root sheath is divided into an external and an internal part (see figure 5.6b). At the opening of the follicle, the external epithelial root sheath has all the strata found in thin skin. Deeper in the hair follicle, the number of cells decreases until at the hair bulb only the stratum germinativum is present. This has important consequences for the repair of the skin. If the epidermis and the superficial part of the dermis are damaged, the undamaged part of the hair follicle that lies deep in the dermis can be a source of new epithelium. The internal epithelial root sheath has raised edges that mesh closely with the raised edges of the hair cuticle and hold the hair in place. When a hair is pulled out, the internal epithelial root sheath usually comes out as well and is plainly visible as whitish tissue around the root of the hair.

The hair bulb is an expanded knob at the base of the hair root (see figure 5.6a and b). Inside the hair bulb is a mass of undifferentiated epithelial cells, the **matrix**, which produces the hair and the internal epithelial root sheath. The dermis of the skin projects into the hair bulb as a papilla and contains blood vessels that provide nourishment to the cells of the matrix.

Hair Growth

Hair is produced in cycles that involve a **growth stage** and a **resting stage**. During the growth stage, hair is formed by cells of the matrix that differentiate, become keratinized, and die. The hair grows longer as cells are added at the base of the hair root. Eventually hair growth stops; the hair follicle shortens and holds the hair in place. A resting period follows after which a new cycle begins, and a new hair replaces the old hair, which falls out of the hair follicle. Thus loss of hair normally means that the hair is being

Clinical Focus Burns

Burns are classified according to the extent of surface area involved and the depth of the burn. For an adult, the surface area that is burned can be conveniently estimated by “the rule of nines,” in which the body is divided into areas that are approximately 9% or multiples of 9% of the total body surface (figure A). For younger patients, surface area relationships are different. For example, in an infant, the head and neck are 21% of total surface area, whereas in an adult they are 9%. For burn victims younger than age 15, a table specifically developed for them should be consulted.

On the basis of depth, burns are classified as either partial-thickness or full-

thickness burns (figure B). **Partial-thickness burns** are divided into first- and second-degree burns. **First-degree burns** involve only the epidermis and are red and painful, and slight edema (swelling) may occur. They can be caused by sunburn or brief exposure to hot or cold objects, and they heal in a week or so without scarring.

Second-degree burns damage the epidermis and the dermis. Minimal dermal damage causes redness, pain, edema, and blisters. Healing takes approximately 2 weeks, and no scarring results. If the burn goes deep into the dermis, however, the wound appears red, tan, or white; may take several months to

heal; and might scar. In all second-degree burns the epidermis regenerates from epithelial tissue in hair follicles and sweat glands, as well as from the edges of the wound.

Full-thickness burns are also called **third-degree burns**. The epidermis and dermis are completely destroyed, and deeper tissue may also be involved. Third-degree burns are often surrounded by first- and second-degree burns. Although the areas that have first- and second-degree burns are painful, the region of third-degree burn is usually painless because of destruction of sensory receptors. Third-degree burns appear white, tan,

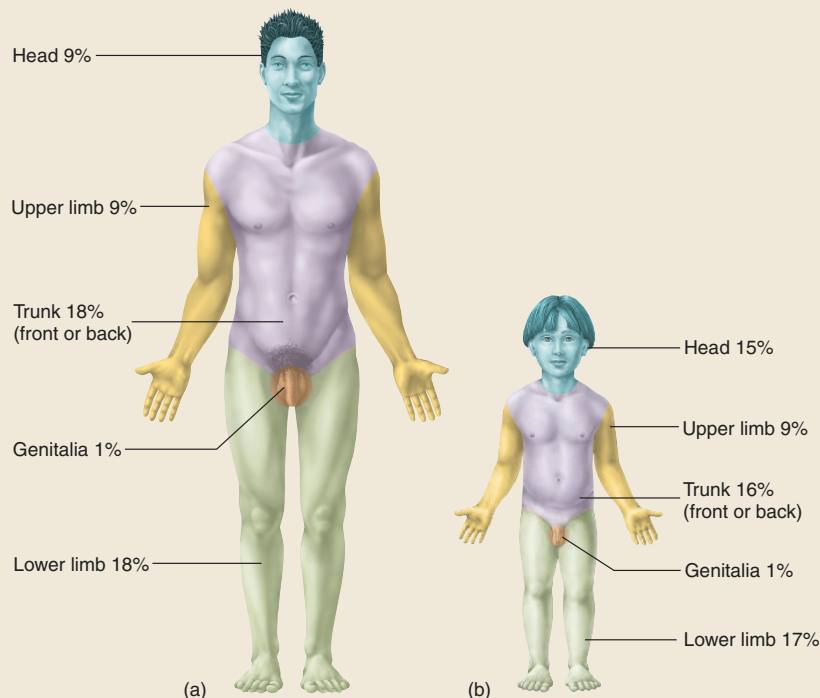


Figure A The Rule of Nines

(a) In an adult, surface areas can be estimated using the rule of nines: each major area of the body is 9%, or a multiple of 9%, of the total body surface area. (b) In infants and children the head represents a larger proportion of surface area. The rule of nines is not as accurate for children, as can be seen in this 5-year-old child.

replaced. The length of each stage depends on the hair—eyelashes grow for approximately 30 days and rest for 105 days, whereas scalp hairs grow for a period of 3 years and rest for 1–2 years. At any given time an estimated 90% of the scalp hairs are in the growing stage, and loss of approximately 100 scalp hairs per day is normal.

The most common kind of permanent hair loss is “pattern baldness.” Hair follicles are lost, and the remaining hair follicles revert to producing vellus hair, which is very short, transparent, and for practical purposes invisible. Although more common and more pronounced in certain men, baldness can also occur in

brown, black, or deep cherry red in color. Skin can regenerate in a third-degree burn only from the edges, and skin grafts are often necessary.

Deep partial-thickness and full-thickness burns take a long time to heal and form scar tissue with disfiguring and debilitating wound contracture. Skin grafts are performed to prevent these complications and to speed healing. In a split skin graft, the epidermis and part of the dermis

are removed from another part of the body and are placed over the burn. Interstitial fluid from the burned area nourishes the graft until it becomes vascularized. Meanwhile, the donor tissue produces new epidermis from epithelial tissue in the hair follicles and sweat glands such as occurs in superficial second-degree burns.

Other types of grafts are possible, and in cases in which a suitable donor site is not practical, artificial skin or grafts from hu-

man cadavers or from pigs are used. These techniques are often unsatisfactory because the body's immune system recognizes the graft as a foreign substance and rejects it. A solution to this problem is laboratory-grown skin. A piece of healthy skin from the burn victim is removed and placed into a flask with nutrients and hormones that stimulate rapid growth. The skin that is produced consists only of epidermis and does not contain glands or hair.

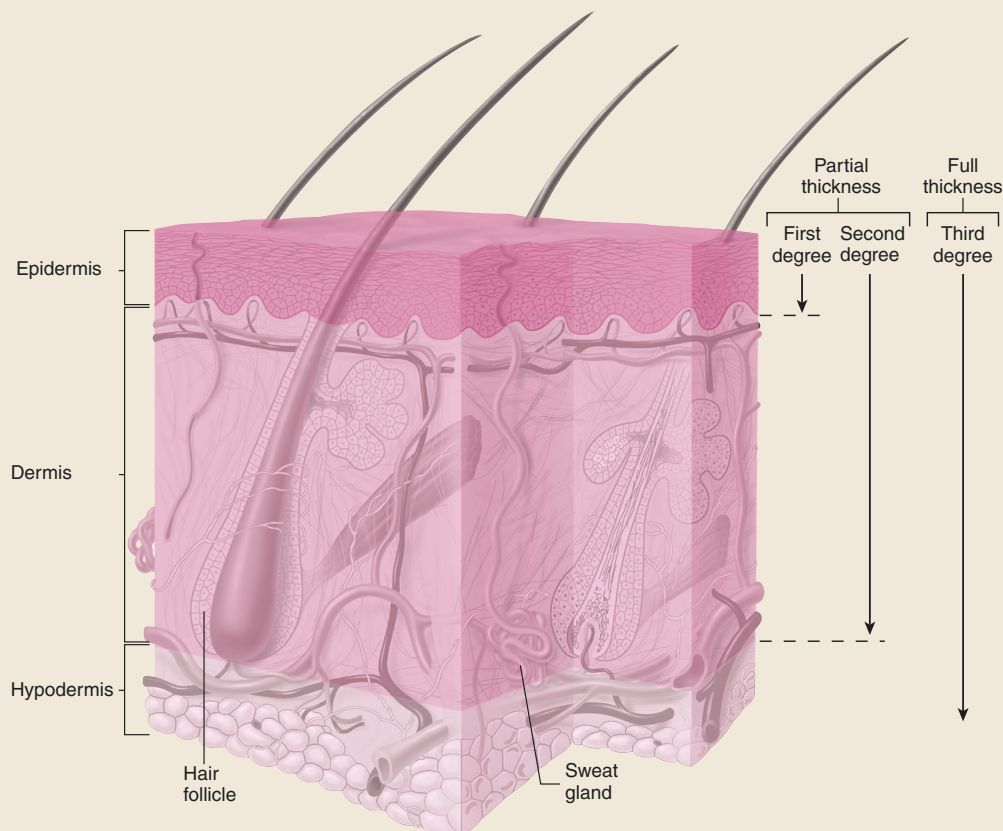


Figure B Burns

Parts of the skin damaged by burns of different degrees.

women. Genetic factors and the hormone testosterone are involved in causing pattern baldness.

The average rate of hair growth is approximately 0.3 mm per day, although hairs grow at different rates even in the same approximate location. Cutting, shaving, or plucking hair does not al-

ter the growth rate or the character of the hair, but hair can feel coarse and bristly shortly after shaving because the short hairs are less flexible. Maximum hair length is determined by the rate of hair growth and the length of the growing phase. For example, scalp hair can become very long, but eyelashes are short.

Hair Color

Melanin is produced by melanocytes within the hair bulb matrix and passed to keratinocytes in the hair cortex and medulla. As with the skin, varying amounts and types of melanin cause different shades of hair color. Blonde hair has little black-brown melanin, whereas jet black hair has the most. Intermediate amounts of melanin account for different shades of brown. Red hair is caused by varying amounts of a red type of melanin. Hair sometimes contains both black-brown and red melanin. With age, the amount of melanin in hair can decrease, causing the color of the hair to fade or become white (i.e., no melanin). Gray hair is usually a mixture of unfaded, faded, and white hairs. Hair color is controlled by several genes, and dark hair color is not necessarily dominant over light.

P R E D I C T 3

Marie Antoinette's hair supposedly turned white overnight after she heard she would be sent to the guillotine. Explain why you believe or disbelieve this story.

Muscles

Associated with each hair follicle are smooth muscle cells, the **arrector pili** (ă-rek'tôr pī'li), that extend from the dermal root sheath of the hair follicle to the papillary layer of the dermis (see figure 5.6a). Normally, the hair follicle and the hair inside it are at an oblique angle to the surface of the skin. When the arrector pili muscles contract, however, they pull the follicle into a position more perpendicular to the surface of the skin, causing the hair to “stand on end.” Movement of the hair follicles produces raised areas called “gooseflesh,” or “goose bumps.”

Contraction of the arrector pili muscles occurs in response to cold or to frightening situations, and in animals with fur the response increases the thickness of the fur. When the response results from cold temperatures, it is beneficial because the fur traps more air and thus becomes a better insulator. In a frightening situation the animal appears larger and more ferocious, which might deter an attacker. It is unlikely that humans, with their sparse amount of hair, derive any important benefit from either response and probably retain this trait as an evolutionary holdover.

13. When and where are lanugo, vellus, and terminal hairs found in the skin?
14. Define the root, shaft, and hair bulb of a hair. Describe the three parts of a hair seen in cross section.
15. Describe the parts of a hair follicle. How is the epithelial root sheath important in the repair of the skin?
16. In what part of a hair does growth take place? What are the stages of hair growth?
17. Explain the location and action of arrector pili muscles.

Glands

The major glands of the skin are the sebaceous glands and the sweat glands (figure 5.7).

Sebaceous Glands

Sebaceous (sē-bā'shŭs) **glands**, located in the dermis, are simple or compound alveolar glands that produce **sebum** (sē'bŭm), an

oily, white substance rich in lipids. Because sebum is released by the lysis and death of secretory cells, sebaceous glands are classified as holocrine glands (see chapter 4). Most sebaceous glands are connected by a duct to the upper part of the hair follicles from which the sebum oils the hair and the skin surface. This prevents drying and provides protection against some bacteria. A few sebaceous glands located in the lips, in the eyelids (meibomian glands), and in the genitalia are not associated with hairs but open directly onto the skin surface.

Sweat Glands

Two types of **sweat**, or **sudoriferous** (soo-dō-rif'er-ŭs), **glands** exist, and at one time it was believed that one released its secretions in a merocrine fashion and the other in an apocrine fashion (see chapter 4). Accordingly, they were called merocrine and apocrine sweat glands. It is now known that apocrine sweat glands also release some of their secretions in a merocrine fashion, and possibly some in a holocrine fashion. Traditionally, they are still referred to as apocrine sweat glands.

Merocrine (mer'ō-krin, mer'ō-krīn, mer'ō-krēn), or **eccrine** (ek'rīn), **sweat glands** are the most common type of sweat gland. They are simple coiled tubular glands that open directly onto the surface of the skin through sweat pores (see figure 5.7). Merocrine sweat glands can be divided into two parts: the deep coiled portion, which is located mostly in the dermis, and the duct, which passes to the surface of the skin. The coiled part of the gland produces an isotonic fluid that is mostly water but also contains some salts (mainly sodium chloride) and small amounts of ammonia, urea, uric acid, and lactic acid. As this fluid moves through the duct, sodium chloride moves by active transport from the duct

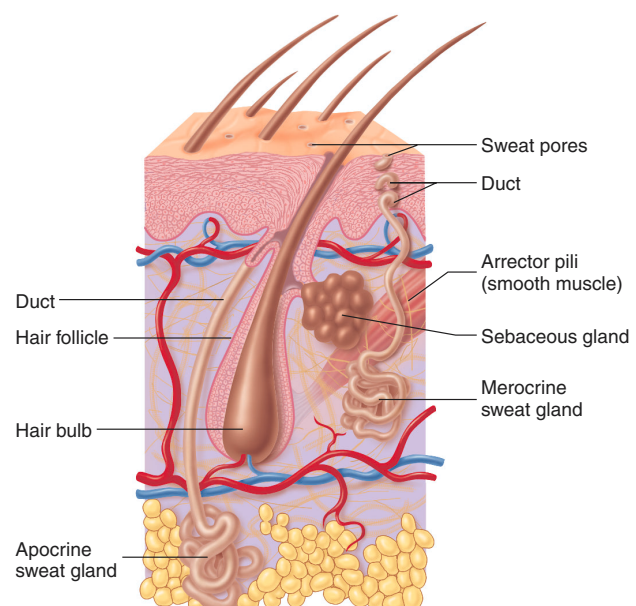


Figure 5.7 Glands of the Skin

Merocrine sweat glands open to the surface of the skin. Apocrine sweat glands and sebaceous glands open into hair follicles.

Chapter 5 Integumentary System

155

back into the body, thereby conserving salts. The resulting hypotonic fluid that leaves the duct is called **sweat**. When the body temperature starts to rise above normal levels, the sweat glands produce sweat, which evaporates and cools the body. Sweat also can be released in the palms, soles, and axillae as a result of emotional stress.

Detecting Lies

Emotional sweating is used in lie detector (polygraph) tests because sweat gland activity can increase when a person tells a lie. The sweat produced, even in small amounts, can be detected because the salt solution conducts electricity and lowers the electric resistance of the skin.



Merocrine sweat glands are most numerous in the palms of the hands and the soles of the feet but are absent from the margin of the lips, the labia minora, and the tips of the penis and clitoris. Only a few mammals such as humans and horses have merocrine sweat glands in hairy skin. Dogs, on the other hand, keep cool by water lost through panting instead of sweating.

Apocrine (ap'ō-krin) **sweat glands** are compound coiled tubular glands that usually open into hair follicles superficial to the opening of the sebaceous glands (see figure 5.7). In other mammals, these glands are widely distributed throughout the skin and help to regulate temperature. In humans, apocrine sweat glands are found in the axillae and genitalia (scrotum and labia majora) and around the anus and do not help to regulate temperature. In humans, apocrine sweat glands become active at puberty as a result of the influence of sex hormones. Their secretions contain organic substances, such as 3-methyl-2-hexenoic acid, that are essentially odorless when first released but that are quickly metabolized by bacteria to cause what commonly is known as body odor. Many mammals use scent

as a means of communication, and it has been suggested that the activity of apocrine sweat glands may be a sign of sexual maturity.

Other Glands

Other skin glands include the ceruminous glands and the mammary glands. The **ceruminous** (sě-roo'mi-nūs) **glands** are modified merocrine sweat glands located in the ear canal (external auditory meatus). **Cerumen**, or earwax, is the combined secretions of ceruminous glands and sebaceous glands. Cerumen and hairs in the ear canal protect the eardrum by preventing the entry of dirt and small insects. An accumulation of cerumen, however, can block the ear canal and make hearing more difficult.

The **mammary glands** are modified apocrine sweat glands located in the breasts. They function to produce milk. The structure and regulation of mammary glands is discussed in chapter 29.

- 18. What secretion is produced by the sebaceous glands? What is the function of the secretion?
- 19. Which glands of the skin are responsible for cooling the body? Which glands are involved with the production of body odor?

Nails

The distal ends of primate digits have nails, whereas most other mammals have claws or hooves. Nails protect the ends of the digits, aid in manipulation and grasping of small objects, and are used for scratching.

A **nail** consists of the proximal **nail root** and the distal **nail body** (figure 5.8a). The nail root is covered by skin, and the nail body is the visible portion of the nail. The lateral and proximal edges of the nail are covered by skin called the **nail fold**, and the edges are held in place by the **nail groove** (figure 5.8b). The

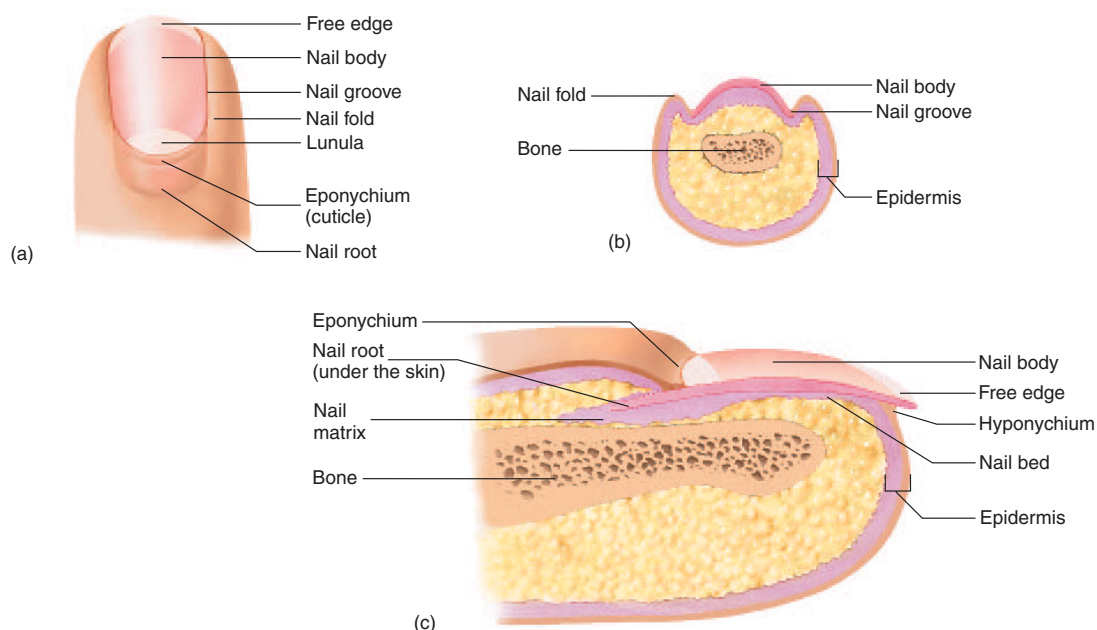


Figure 5.8 Nail

(a) Dorsal view. (b) Cross section. (c) Longitudinal section.

stratum corneum of the nail fold grows onto the nail body as the **eponychium** (ep-ō-nik'ē-ūm), or cuticle. Beneath the free edge of the nail body is the **hyponychium** (hi'pō-nik'ē-ūm), a thickened region of the stratum corneum (figure 5.8c).

The nail root and the nail body attach to the **nail bed**, the proximal portion of which is the **nail matrix**. Only the stratum germinativum is present in the nail bed and nail matrix. The nail matrix is thicker than the nail bed and produces most of the nail, although the nail bed does contribute. The nail bed is visible through the clear nail and appears pink because of blood vessels in the dermis. A small part of the nail matrix, the **lunula** (loo'noo-lā), is seen through the nail body as a whitish, crescent-shaped area at the base of the nail. The lunula, seen best on the thumb, appears white because the blood vessels cannot be seen through the thicker nail matrix.

The nail is stratum corneum. It contains a hard keratin which makes the nail hard. The nail cells are produced in the nail matrix and pushed distally over the nail bed. Nails grow at an average rate of 0.5–1.2 mm per day, and fingernails grow more rapidly than toenails. Nails, like hair, grow from the base. Unlike hair, they grow continuously throughout life and do not have a resting phase.

- 20. Name the parts of a nail. Which part produces most of the nail? What is the lunula?
- 21. What makes a nail hard? Do nails have growth stages?

Summary of Integumentary System Functions

Objective

- Discuss the functions of the skin, hair, nails, and glands.

Protection

The integumentary system is the body's fortress, defending it from harm. It performs many protective functions.

1. The stratified squamous epithelium of the skin protects underlying structures against abrasion. As the outer cells of the stratum corneum are desquamated, they are replaced by cells from the stratum basale. Calluses develop in areas subject to heavy friction or pressure.
2. The skin prevents the entry of microorganisms and other foreign substances into the body. Secretions from skin glands produce an environment unsuitable for some microorganisms. The skin contains components of the immune system that act against microorganisms (see chapter 22).
3. Melanin absorbs ultraviolet light and protects underlying structures from its damaging effects.
4. Hair provides protection in several ways. The hair on the head acts as a heat insulator and protects against ultraviolet light and abrasion. The eyebrows keep sweat out of the eyes, eyelashes protect the eyes from foreign objects, and hair in the nose and ears prevents the entry of dust and other materials. Axillary and pubic hair are a sign of sexual maturity and protect against abrasion.
5. Nails protect the ends of the digits from damage and can be used in defense.

6. The intact skin plays an important role in preventing water loss because its lipids act as a barrier to the diffusion of water.

Administering Medications Through the Skin



Some lipid-soluble substances readily pass through the epidermis. Lipid-soluble medications can be administered by applying them to the skin, after which the medication slowly diffuses through the skin into the blood. For example, nicotine patches are used to help reduce withdrawal symptoms in those attempting to quit smoking.

Sensation

The body feels pain, heat, and cold because the integumentary system has sensory receptors in all its layers. For example, the epidermis and dermal papillae are well supplied with touch receptors. The dermis and deeper tissues contain pain, heat, cold, touch, and pressure receptors. Hair follicles (but not the hair) are well innervated, and movement of hair can be detected by sensory receptors surrounding the base of hair follicles. Sensory receptors are discussed in more detail in chapter 14.

Temperature Regulation

Body temperature tends to increase as a result of exercise, fever, or an increase in environmental temperature. Homeostasis is maintained by the loss of excess heat. The blood vessels (arterioles) in the dermis dilate and allow more blood to flow through the skin, thus transferring heat from deeper tissues to the skin (figure 5.9a). To counteract environmental heat gain or to get rid of excess heat produced by the body, sweat is produced. The sweat spreads over the surface of the skin, and as it evaporates, heat is lost from the body.

If body temperature begins to drop below normal, heat can be conserved by a decrease in the diameter of dermal blood vessels, thus reducing blood flow to the skin (figure 5.9b). With less warm blood flowing through the skin, however, the skin temperature decreases. If the skin temperature drops below approximately 15°C (59°F), blood vessels dilate, which helps to prevent tissue damage from the cold.

Contraction of the arrector pili muscles causes hair to stand on end, but with the sparse amount of hair covering the body, this does not significantly reduce heat loss in humans. Hair on the head, however, is an effective insulator. General temperature regulation is considered in chapter 25.

P R E D I C T 4

You may have noticed that on very cold winter days, people's ears and noses turn red. Can you explain why this happens?

Vitamin D Production

Vitamin D functions as a hormone to stimulate uptake of calcium and phosphate from the intestines, to promote their release from bones, and to reduce calcium loss from the kidneys, resulting in increased blood calcium and phosphate levels. Adequate levels of these minerals are necessary for normal bone metabolism (see chapter 6), and calcium is required for normal nerve and muscle function (see chapter 9).

Vitamin D synthesis begins in skin exposed to ultraviolet light, and humans can produce all the vitamin D they require by this process if enough ultraviolet light is available. Because humans live indoors and wear clothing, however, their exposure to ultraviolet

light may not be adequate for the manufacture of sufficient vitamin D. This is especially likely for people living in cold climates because they remain indoors or are covered by warm clothing when outdoors. Fortunately, vitamin D can also be ingested and absorbed in the intestine. Natural sources of vitamin D are liver (especially fish liver), egg yolks, and dairy products (e.g., butter, cheese, and milk). In addition, the diet can be supplemented with vitamin D in fortified milk or vitamin pills.

Vitamin D synthesis begins when the precursor molecule, 7-dehydrocholesterol (7-dē-hī'drō-kō-les'ter-ol), is exposed to ultraviolet light and is converted into cholecalciferol (kō'lē-kal-sif'er-ol). Cholecalciferol is released into the blood and modified by hydroxylation (hydroxide ions are added) in the liver and kidneys to form active vitamin D (calcitriol; kal-si-trī'ol).

Excretion

Excretion is the removal of waste products from the body. In addition to water and salts, sweat contains a small amount of waste products, such as urea, uric acid, and ammonia. Compared to the kidneys, however, the quantity of waste products eliminated in the sweat is insignificant, even when large amounts of sweat are lost.

22. In what ways does the skin provide protection?
23. What kind of sensory receptors are found in the skin, and why are they important?
24. How does the skin assist in the regulation of body temperature?
25. Name the locations where cholecalciferol is produced and then modified into vitamin D. What are the functions of vitamin D?
26. What substances are excreted in sweat? Is the skin an important site of excretion?

Effects of Aging on the Integumentary System

Objective

- Describe the changes that occur in the integumentary system with increasing age.

As the body ages, the skin is more easily damaged because the epidermis thins and the amount of collagen in the dermis decreases. Skin infections are more likely, and repair of the skin occurs more slowly. A decrease in the number of elastic fibers in the dermis and loss of fat from the hypodermis cause the skin to sag and wrinkle.

The skin becomes drier with age as sebaceous gland activity decreases. A decrease in the activity of sweat glands and a decrease in the blood supply to the dermis result in a poor ability to regulate body temperature. Death from heat prostration can occur in elderly individuals who do not take proper precautions.

The number of functioning melanocytes generally decreases, but in some localized areas, especially on the hands and the face, melanocytes increase in number to produce age spots. (Age spots are different from freckles, which are caused by an increase in melanin production and not an increase in melanocyte numbers.) White or gray hairs also occur because of a decrease in or lack of melanin production.

Skin that is exposed to sunlight appears to age more rapidly than nonexposed skin. This effect is observed on areas of the body, such as the face and hands, that receive sun exposure (figure 5.10). The effects of chronic sun exposure on the skin, however, are different from the effects of normal aging. In skin exposed to sunlight, normal elastic fibers are replaced by an interwoven mat of thick, elasticlike material, the number of collagen fibers decreases, and the ability of keratinocytes to divide is impaired.

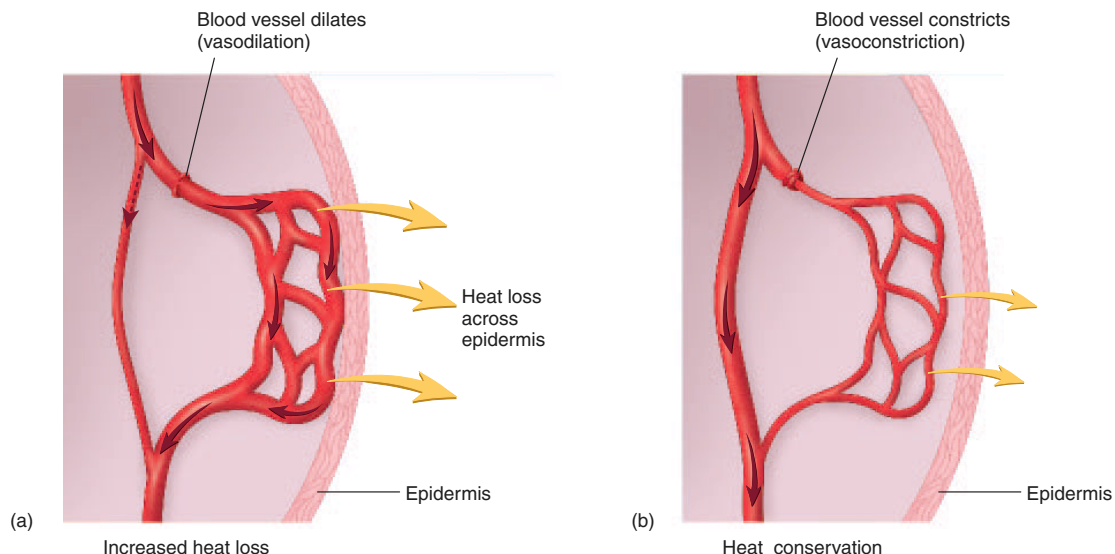


Figure 5.9 Heat Exchange in the Skin

(a) Blood vessels in the dermis dilate (vasodilate), thus allowing more blood to flow through the blood vessels close to the surface, where heat is lost from the body. (b) Blood vessels in the dermis constrict (vasoconstrict), thus reducing blood flow and heat loss.

Clinical Focus Clinical Disorders of the Integumentary System

The Integumentary System as a Diagnostic Aid

The integumentary system can be used in diagnosis because it is easily observed and often reflects events occurring in other parts of the body. For example, **cyanosis** (sī-ā-nō'sis), a bluish color to the skin that results from decreased blood oxygen content, is an indication of impaired circulatory or respiratory function. When red blood cells wear out, they are broken down, and part of their contents is excreted by the liver as bile pigments into the intestine. **Jaundice** (jawn'dis), a yellowish skin color, occurs when excess bile pigments accumulate in the blood. If a disease like viral hepatitis damages the liver, bile pigments are not excreted and accumulate in the blood.

Rashes and lesions in the skin can be symptomatic of problems elsewhere in the body. For example, scarlet fever results from a bacterial infection in the throat. The bacteria release a toxin into the blood that causes the pink-red rash for which this disease was named. In allergic reactions (see chapter 22), a release of histamine into the tissues produces swelling and reddening. The development of a rash (hives) in the skin can indicate an allergy to foods or drugs such as penicillin.

The condition of the skin, hair, and nails is affected by nutritional status. In vitamin A deficiency the skin produces excess keratin and assumes a characteristic sandpaper texture, whereas in iron-deficiency anemia the nails lose their normal contour and become flat or concave (spoon-shaped).

Hair concentrates many substances that can be detected by laboratory analysis, and comparison of a patient's hair to "normal" hair can be useful in certain diagnoses. For example, lead poisoning results in high levels of lead in the hair. The use of hair analysis as a screening test to determine the general health or nutritional status of an individual is unreliable, however.

Bacterial Infections

Staphylococcus aureus is commonly found in pimples, boils, and carbuncles and causes **impetigo** (im-pe-tī'gō), a disease of

the skin that usually affects children. It is characterized by small blisters containing pus that easily rupture and form a thick, yellowish crust. *Streptococcus pyogenes* causes **erysipelas** (er-i-sip'ē-las), swollen red patches in the skin. Burns are often infected by *Pseudomonas aeruginosa*, which produces a characteristic blue-green pus caused by bacterial pigment.

Acne is a disorder of the hair follicles and sebaceous glands that affects almost everyone at some time or another. Although the exact cause of acne is unknown, four factors are believed to be involved: hormones, sebum, abnormal keratinization within hair follicles, and the bacterium *Propionibacterium acnes*. The lesions apparently begin with a hyperproliferation of the hair follicle epidermis, and many cells are desquamated. These cells are abnormally sticky and adhere to one another to form a mass of cells mixed with sebum that blocks the hair follicle. During puberty, hormones, especially testosterone, stimulate the sebaceous glands to increase sebum production. Because both the adrenal gland and the testes produce testosterone, the effect is seen in both males and females. An accumulation of sebum behind the blockage produces a whitehead, which may continue to develop into a blackhead or a pimple. A blackhead results if the opening of the hair follicle is pushed open by the accumulating cornified cells and sebum. Although it is generally agreed that dirt is not responsible for the black color of blackheads, the exact cause of the black color is disputed. Once the wall of the follicle ruptures, *P. acnes* and other microorganisms stimulate an inflammatory response that results in the formation of a red pimple filled with pus. If tissue damage is extensive, scarring occurs.

Viral Infections

Some of the well-known viral infections of the skin include **chicken pox** (varicella-zoster), **measles**, **German measles** (rubella), and **cold sores** (herpes simplex). **Warts**, which are caused by a viral infection of the epidermis, are generally harmless and usually disappear without treatment.

Fungal Infections

Ringworm is a fungal infection that affects the keratinized portion of the skin, hair, and nails and produces patchy scaling and an inflammatory response. The lesions are often circular with a raised edge, and in ancient times they were thought to be caused by worms. Several species of fungus cause ringworm in humans and are usually described by their location on the body; in the scalp the condition is ringworm, in the groin it is jock itch, and in the feet it is athlete's foot.

Decubitus Ulcers

Decubitus (dē-kū'bi-tūs) **ulcers**, also known as bedsores or pressure sores, develop in patients who are immobile (e.g., bedridden or confined to a wheelchair). The weight of the body, especially in areas over bony projections such as the hipbones and heels, compresses tissues and causes **ischemia** (is-kē'mē-ā), or reduced circulation. The consequence is destruction, or **necrosis** (nē-krō'sis), of the hypodermis and deeper tissues, which is followed by necrosis of the skin. Once skin necrosis occurs, microorganisms gain entry to produce an infected ulcer.

Bullae

Bullae (bul'ē), or blisters, are fluid-filled areas in the skin that develop when tissues are damaged, and the resultant inflammatory response produces edema. Infections or physical injuries can cause bullae or lesions in different layers of the skin.

Psoriasis

Psoriasis (sō-nī'ā-sis) is characterized by a thicker-than-normal stratum corneum that sloughs to produce large, silvery scales. If the scales are scraped away, bleeding occurs from the blood vessels at the top of the dermal papillae. These changes result from increased cell division in the stratum basale, abnormal keratin production, and elongation of the dermal papillae toward the skin surface. Evidence suggests that the disease has a genetic component and that the immune system stimulates the increased cell divisions. Psoriasis is a chronic disease that can be controlled with drugs

and phototherapy (ultraviolet light) but as yet has no cure.

Eczema and Dermatitis

Eczema (ek'zē-mă, eg'zē-mă, eg-zē'mă) and **dermatitis** (der-mă-tī'tis) are inflammatory conditions of the skin. Cause of the inflammation can be allergy, infection, poor circulation, or exposure to physical factors, such as chemicals, heat, cold, or sunlight.

Birthmarks

Birthmarks are congenital (present at birth) disorders of the capillaries in the dermis of the skin. Usually they are only of concern for cosmetic reasons. A **strawberry birthmark** is a mass of soft, elevated tissue that appears bright red to deep purple in color. In 70% of patients, strawberry birthmarks disappear spontaneously by age 7. **Portwine stains** appear as flat, dull red or bluish patches that persist throughout life.

Vitiligo

Vitiligo (vit-i-lī'gō) is the development of patches of white skin because the melanocytes in the affected area are destroyed, apparently by an autoimmune response (see chapter 22).

Moles

A **mole** is an elevation of the skin that is variable in size and is often pigmented and hairy. Histologically, a mole is an aggregation, or “nest,” of melanocytes in the epidermis or dermis. They are a normal occurrence, and most people have 10–20 moles, which appear in childhood and enlarge until puberty.

Cancer

Skin cancer is the most common type of cancer (figure C). Although chemicals and radiation (x rays) are known to induce cancer, the development of skin cancer is most often associated with exposure to ultraviolet (UV) radiation from the sun, and, consequently, most skin cancers develop on the face or neck. The group of people most likely to have skin cancer are fair-skinned (i.e., they have less protection from the sun) or are older than 50 (i.e., they have had long exposure to the sun).

Basal cell carcinoma (kar-si-nō'mă), the most frequent skin cancer, begins in the stratum basale and extends into the dermis to produce an open ulcer. Surgical removal or radiation therapy cures this type of cancer, and fortunately little danger exists that the cancer will spread, or metastasize (mē-

tas'tă-sīz), to other areas of the body if treated in time. **Squamous cell carcinoma** develops from stratum spinosum keratinocytes that continue to divide as they produce keratin. Typically, the result is a nodular, keratinized tumor confined to the epidermis, but it can invade the dermis, metastasize, and cause death. **Malignant melanoma** (mel'ă-nō'mă) is a less common form of skin cancer that arises from melanocytes, usually in a preexisting mole. The melanoma can appear as a large, flat, spreading lesion or as a deeply pigmented nodule. Metastasis is common, and, unless diagnosed and treated early in development, this cancer is often fatal. Other types of skin cancer are possible (e.g., metastasis from other parts of the body to the skin).

Limiting exposure to the sun and using sunscreens can reduce the likelihood of developing skin cancer. Some concern over the use of sunscreens, however, has recently arisen because of the different types of UV radiation they can block. Exposure to UVB can cause sunburn and is associated with the development of basal cell and squamous cell carcinomas. The development of malignant melanoma is associated with exposure to UVA. Sunscreens that block primarily UVB allow longer exposure to the sun without sunburning but thereby increase exposure to UVA and the possible development of malignant melanoma. Sunscreens that effectively block UVB and UVA are advisable.



Figure C Cancer of the Skin

- (a) Basal cell carcinoma.
- (b) Squamous cell carcinoma.
- (c) Malignant melanoma.

Systems Pathology

Burns

Mr. S is a 23-year-old man who had difficulty falling asleep at night. He often stayed up late watching television or reading until he fell asleep. Mr. S was also a chain smoker. One night he took several sleeping pills. Unfortunately, he fell asleep before putting out his cigarette, which started a fire. As a result, Mr. S was severely burned and received full-thickness and partial-thickness burns (figure D*a*). He was rushed to the emergency room and was eventually transferred to a burn unit.

For the first day after his accident, his condition was critical because he went into shock. Administration of large volumes of intravenous fluid stabilized his condition. As part of his treatment, Mr. S was also given a high-protein, high-calorie diet.

A week later, dead tissue was removed from the most serious burns (figure D*b*), and a skin graft was performed. Despite the use of topical antimicrobial drugs and sterile bandages, some of the burns became infected. An additional complication was the development of a venous thrombosis in his leg.

Although the burns were painful and the treatment was prolonged, Mr. S made a full recovery. He no longer smokes.

Background Information

When large areas of skin are severely burned, systemic effects are produced that can be life-threatening. One effect is on capillaries, which are the small blood vessels in which fluid, gases, nutrients, and waste products are normally exchanged between the blood and tissues. Within minutes of a major burn injury, capillaries become more permeable at the burn site and throughout the body. As a result, fluid and electrolytes (see chapter 2) are lost from the burn wound and into tissue spaces. The loss of fluid decreases blood volume, which decreases the ability of the heart to pump blood. The resulting decrease in blood delivery to tissues can cause tissue damage, shock, and even death. Treatment consists of administering intravenous fluid at a faster rate than it leaks out of the capillaries. Although this can reverse the shock and prevent death, fluid continues to leak into tissue spaces causing pronounced **edema**, a swelling of the tissues.

Typically, after 24 hours, capillary permeability returns to normal, and the amount of intravenous fluid administered can be greatly decreased. How burns result in capillary permeability changes is not well understood. It is clear that following a burn, immunologic and metabolic changes occur that affect not only

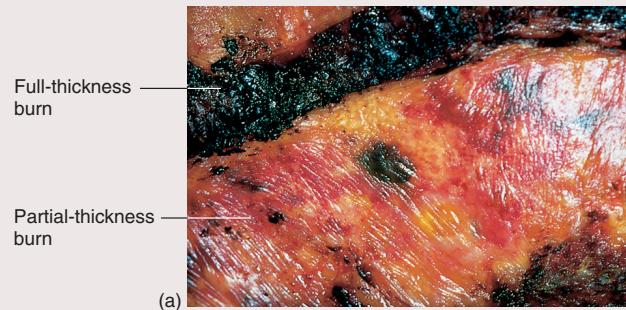


Figure D Burn Victim

(a) Partial and full-thickness burns. (b) Patient in a burn unit.

capillaries but the rest of the body as well. For example, mediators of inflammation (see chapter 4), which are released in response to the tissue damage, contribute to changes in capillary permeability throughout the body.

Substances released from the burn may also play a role in causing cells to function abnormally. Burn injuries result in an almost immediate hypermetabolic state that persists until wound closure. Also contributing to the increased metabolism is a resetting of the temperature control center in the brain to a higher temperature and an

System Interactions

System	Interactions
Skeletal	Red bone marrow replaces red blood cells destroyed in the burnt skin.
Muscular	Loss of muscle mass resulting from the hypermetabolic state caused by the burn.
Nervous	Pain is sensed in the partial-thickness burns. The temperature-regulatory center in the brain is set to a higher temperature, which contributes to increased body temperature. Abnormal K^+ concentrations disturb normal nervous system activity: elevated levels are caused by release of K^+ from damaged tissues; low levels can be caused by rapid loss of K^+ in fluid from the burn.
Endocrine	Increased secretion of epinephrine and norepinephrine from the adrenal gland in response to the injury contributes to increased body temperature by increasing cell metabolism.
Cardiovascular	Increased capillary permeability causes decreased blood volume, resulting in decreased blood delivery to tissues, edema, and shock. The pumping effectiveness of the heart is impaired by electrolyte imbalance and substances released from the burn. Increased blood clotting causes venous thrombosis. Preferential delivery of blood to the injury promotes healing.
Lymphatic and Immune	Inflammation increases in response to tissue damage. Later, depression of the immune system can result in infection.
Respiratory	Airway obstruction caused by edema. Increased respiration rate caused by increased metabolism and lactic acid buildup.
Digestive	Decreased blood delivery as a result of the burn causes degeneration of the intestinal lining and liver. Bacteria from the intestine can cause systemic infections. The liver releases blood-clotting factors in response to the injury. Increased nutrients necessary to support increased metabolism and for repair of the integumentary system are absorbed.
Urinary	The kidneys compensate for the increased fluid loss caused by the burn by greatly reducing or even stopping urine production. Decreased blood volume causes decreased blood flow to the kidneys, which reduces urine output but can cause kidney tissue damage. Hemoglobin, released from red blood cells damaged in the burnt skin, can obstruct urine flow in the kidneys.

increase in the hormones released by the endocrine system. For example, epinephrine and norepinephrine from the adrenal glands increase cell metabolism. Compared with a normal body temperature of approximately 37°C (98.6°F), a body temperature of 38.5°C (101.3°F) is typical in burn patients, despite the higher loss of water by evaporation from the burn.

In severe burns, the increased metabolic rate can result in weight loss as great as 30%–40% of the patient's preburn weight. To help compensate, caloric intake may double or even triple. In addition, the need for protein, which is necessary for tissue repair, is greater.

The skin normally maintains homeostasis by preventing the entry of microorganisms. Because burns damage and even completely destroy the skin, microorganisms can cause infections. For this reason, burn patients are maintained in an aseptic environment, which attempts to prevent the entry of microorganisms into the wound. They are also given antimicrobial drugs, which kill microorganisms or suppress their growth. **Debridement**, (dā-brēd-mon'), the removal of dead tissue from the burn, helps to prevent infections by cleaning the wound and removing tissue in which infections could develop. Skin grafts, performed within a week of the injury, also prevent infections by closing the wound and preventing the entry of microorganisms.

Despite these efforts, however, infections still are the major cause of death of burn victims. Depression of the immune system during the first or second week after the injury contributes to the high infection rate. The thermally altered tissue is recognized as a foreign substance that stimulates the immune system. As a result, the immune system is overwhelmed as immune system cells become less effective and production of the chemicals that normally provide resistance to infections decreases (see chapter 22). The greater the magnitude of the burn, the greater the depression of the immune system, and the greater the risk of infection.

Venous thrombosis, the development of a clot in a vein, is also a complication of burns. Blood normally forms a clot when exposed to damaged tissue, such as at a burn site, but the clot can block blood flow, resulting in tissue destruction. In addition, the concentration of chemicals in the blood that cause clotting increases for two reasons: loss of fluid from the burn and the increased release of clotting factors from the liver.

P R E D I C T 5

When Mr. S is first admitted to the burn unit, the nurses carefully monitor his urine output. Why does that make sense in light of his injuries?

- 27. Compared to young skin, why is aged skin more likely to be damaged, wrinkled, and dry?
- 28. Why is heat potentially dangerous to the elderly?
- 29. Explain age spots and white hair.
- 30. What effect does exposure to sunlight have on skin?

Treatment of Skin Wrinkles



Retin-A (tretinoin; tret'i-nō-in) is a vitamin A derivative that is being used to treat skin wrinkles. It appears to be effective in treating fine wrinkles on the face, such as those caused by long-term exposure to the sun, but is not effective in treating deep lines. One ironic side effect of Retin-A use is increased sensitivity to the sun's ultraviolet rays. Doctors prescribing this cream caution their patients to always use a sunblock when they are going to be outdoors.



(a)

Figure 5.10 Effects of Sunlight on Skin

(a) A 91 year old Japanese monk who has spent most of his life indoors.
(b) A 62 year old Native American woman who has spent most of her life outdoors.



(b)

S U M M A R Y

The integumentary system consists of the skin, hair, nails, and a variety of glands.

Overview of the Integumentary System (p. 144)

The integumentary system separates and protects us from the external environment. Other functions include sensation, temperature regulation, vitamin D production, and excretion of small amounts of waste products.

Hypodermis (p. 144)

1. Located beneath the dermis, the hypodermis is loose connective tissue that contains collagen and elastin fibers.
2. The hypodermis attaches the skin to underlying structures and is a site of fat storage.

Skin (p. 145)

Dermis

1. The dermis is connective tissue divided into two layers.
2. The reticular layer is the main layer. It is dense irregular connective tissue consisting mostly of collagen.
3. The papillary layer has projections called papillae and is loose connective tissue that is well supplied with capillaries.

Epidermis

1. The epidermis is stratified squamous epithelium divided into five strata.
2. The stratum basale consists of keratinocytes, which produce the cells of the more superficial strata.
3. The stratum spinosum consists of several layers of cells held together by many desmosomes. The stratum basale and the stratum spinosum are sometimes called the stratum germinativum.
4. The stratum granulosum consists of cells filled with granules of keratohyalin. Cell death occurs in this stratum.
5. The stratum lucidum consists of a layer of dead transparent cells.
6. The stratum corneum consists of many layers of dead squamous cells. The most superficial cells are desquamated.
7. Keratinization is the transformation of the living cells of the stratum basale into the dead squamous cells of the stratum corneum.
 - Keratinized cells are filled with keratin and have a protein envelope, both of which contribute to structural strength. The cells are also held together by many desmosomes.
 - Intercellular spaces are filled with lipids from the lamellae that contribute to the impermeability of the epidermis to water.
8. Soft keratin is found in skin and the inside of hairs, whereas hard keratin occurs in nails and the outside of hairs. Hard keratin makes cells more durable, and these cells do not desquamate.

Chapter 5 Integumentary System

163

Thick and Thin Skin

1. Thick skin has all five epithelial strata. The dermis under thick skin produces fingerprints and footprints.
2. Thin skin contains fewer cell layers per stratum, and the stratum lucidum is usually absent. Hair is found only in thin skin.

Skin Color

1. Melanocytes produce melanin inside melanosomes and then transfer the melanin to keratinocytes. The size and distribution of melanosomes determine skin color. Melanin production is determined genetically but can be influenced by hormones and ultraviolet light (tanning).
2. Carotene, an ingested plant pigment, can cause the skin to appear yellowish.
3. Increased blood flow produces a red skin color, whereas a decreased blood flow causes a pale skin. Decreased oxygen content in the blood results in a bluish color called cyanosis.

Accessory Skin Structures (p. 150)

Hair

1. Lanugo (fetal hair) is replaced near the time of birth by terminal hairs (scalp, eyelids, and eyebrows) and vellus hairs. At puberty vellus hairs can be replaced with terminal hairs.
2. Hair is dead keratinized epithelial cells consisting of a central axis of cells with soft keratin, known as the medulla, which is surrounded by a cortex of cells with hard keratin. The cortex is covered by the cuticle, a single layer of cells filled with hard keratin.
3. A hair has three parts: the shaft, the root, and the hair bulb.
4. The hair bulb produces the hair in cycles involving a growth stage and a resting stage.
5. Hair color is determined by the amount and kind of melanin present.
6. Contraction of the arrector pili muscles, which are smooth muscles, causes hair to “stand on end” and produces “gooseflesh.”

Glands

1. Sebaceous glands produce sebum, which oils the hair and the surface of the skin.
2. Merocrine sweat glands produce sweat that cools the body. Apocrine sweat glands produce an organic secretion that can be broken down by bacteria to cause body odor.
3. Other skin glands include ceruminous glands, which help to make cerumen (earwax), and the mammary glands, which produce milk.

Nails

1. The nail consists of a nail root and a nail body resting on the nail bed.
2. Part of the nail root, the nail matrix, produces the nail body, which is several layers of cells containing hard keratin.

Summary of Integumentary System Functions (p. 156) Protection

1. The skin provides protection against abrasion and ultraviolet light, prevents the entry of microorganisms, helps to regulate body temperature, and prevents water loss.
2. Hair protects against abrasion and ultraviolet light and is a heat insulator.
3. Nails protect the ends of the digits.

Sensation

The skin contains sensory receptors for pain, touch, hot, cold, and pressure that allow proper response to the environment.

Temperature Regulation

1. Through dilation and constriction of blood vessels, the skin controls heat loss from the body.
2. Sweat glands produce sweat which evaporates and lowers body temperature.

Vitamin D Production

1. Skin exposed to ultraviolet light produces cholecalciferol, which is modified in the liver and then in the kidneys to form active vitamin D.
2. Vitamin D increases blood calcium levels by promoting calcium uptake from the intestine, release of calcium from bone, and reduction of calcium loss from the kidneys.

Excretion

Skin glands remove small amounts of waste products (e.g., urea, uric acid, and ammonia) but are not important in excretion.

Effects of Aging on the Integumentary System (p. 157)

1. As the body ages, blood flow to the skin declines, the skin becomes thinner, and elasticity is lost.
2. Sweat and sebaceous glands are less active, and the number of melanocytes decreases.

R E V I E W A N D C O M P R E H E N S I O N

1. The hypodermis
 - a. is the layer of skin where the hair is produced.
 - b. is the layer of skin where nails are produced.
 - c. connects the dermis to the epidermis.
 - d. is dense irregular connective tissue.
 - e. contains approximately half of the body's stored fat.

For questions 2–5, match the layer of the dermis with the correct description or function:

- a. papillary layer
 - b. reticular layer
2. The layer of the dermis closest to the epidermis
 3. The layer of the dermis responsible for most of the structural strength of the skin
 4. The layer of the dermis responsible for fingerprints and footprints
 5. The layer of the dermis responsible for cleavage lines and striae
 6. A layer of skin (where mitosis occurs) that replaces cells lost from the outer layer of the epidermis is the

- a. stratum corneum.
- b. stratum basale.
- c. stratum lucidum.
- d. reticular layer.
- e. hypodermis.

7. If a splinter penetrates the skin of the palm of the hand to the second epidermal layer from the surface, the last layer damaged is the
 - a. stratum granulosum.
 - b. stratum basale.
 - c. stratum corneum.
 - d. stratum lucidum.
 - e. stratum spinosum.

For questions 8–12, match the layer of the epidermis with the correct description or function:

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

8. Production of keratin fibers; formation of lamellar bodies; limited amount of cell division
9. Desquamation occurs; 25 or more layers of dead squamous cells
10. Production of cells; melanocytes produce and contribute melanin; hemidesmosomes present
11. Production of keratohyalin granules; lamellar bodies release lipids; cells die
12. Dispersion of keratohyalin around keratin fibers; layer appears transparent; cells dead
13. In which of these areas of the body is thick skin found?
 - a. back of the hand
 - b. abdomen
 - c. over the shin
 - d. bridge of the nose
 - e. heel of the foot
14. The function of melanin in the skin is
 - a. lubrication of the skin.
 - b. prevention of skin infections.
 - c. protection from ultraviolet light.
 - d. to reduce water loss.
 - e. to help regulate body temperature.
15. Concerning skin color, which of these statements is *not* correctly matched?
 - a. skin appears yellow—carotene present
 - b. no skin pigmentation (albinism)—genetic disorder
 - c. skin tans—increased melanin production
 - d. skin appears blue (cyanosis)—oxygenated blood
 - e. African-Americans darker than Caucasians—more melanin in African-American skin
16. After birth, the type of hair on the scalp, eyelids, and eyebrows is
 - a. lanugo.
 - b. terminal hair.
 - c. vellus hair.
17. Hair
 - a. is produced by the dermal root sheath.
 - b. consists of living keratinized epithelial cells.
 - c. is colored by melanin.
 - d. contains mostly soft keratin.
 - e. grows from the tip.
18. Given these parts of a hair and hair follicle:
 1. cortex
 2. cuticle
 3. dermal root sheath
 4. epithelial root sheath
 5. medullaArrange the structures in the correct order from the outside of the hair follicle to the center of the hair.
 - a. 1,4,3,5,2
 - b. 2,1,5,3,4
 - c. 3,4,2,1,5
 - d. 4,3,1,2,5
 - e. 5,4,3,2,1
19. Concerning hair growth:
 - a. Hair falls out of the hair follicle at the end of the growth stage.
 - b. Most of the hair on the body grows continuously.
 - c. Cutting or plucking the hair increases its growth rate and thickness.
 - d. Genetic factors and the hormone testosterone are involved in “pattern baldness.”
 - e. Eyebrows have a longer growth stage and resting stage than scalp hair.
20. Smooth muscles that produce “goose bumps” when they contract and are attached to hair follicles are called

- a. external root sheaths.
- b. arrector pili.
- c. dermal papillae.
- d. internal root sheaths.
- e. hair bulbs.

For questions 21–23, match the type of gland with the correct description or function.

- a. apocrine sweat gland
 - b. merocrine sweat gland
 - c. sebaceous gland
21. Alveolar glands that produce a white, oily substance; usually open into hair follicles
 22. Coiled tubular glands that secrete a hyposmotic fluid that cools the body; most numerous in the palms of the hands and soles of the feet
 23. Secretions from these coiled tubular glands are broken down by bacteria to produce body odor; found in the axillae, genitalia, and around the anus
 24. The lunula of the nail appears white because
 - a. it lacks melanin.
 - b. blood vessels cannot be seen through the thick nail matrix.
 - c. the eponychium decreases blood flow to the area.
 - d. the nail root is much thicker than the nail body.
 - e. the hyponychium is thicker than the eponychium.
 25. The stratum corneum of the nail fold grows onto the nail body as the
 - a. eponychium.
 - b. hyponychium.
 - c. lunula.
 - d. nail bed.
 - e. nail matrix.
 26. Most of the nail is produced by the
 - a. eponychium.
 - b. hyponychium.
 - c. nail bed.
 - d. nail matrix.
 - e. dermis.
 27. The skin aids in maintaining the calcium and phosphate levels of the body at optimum levels by participating in the production of
 - a. vitamin A.
 - b. vitamin B.
 - c. vitamin D.
 - d. melanin.
 - e. keratin.
 28. Which of these processes increase(s) heat loss from the body?
 - a. dilation of dermal arterioles
 - b. constriction of dermal arterioles
 - c. increased sweating
 - d. both a and c
 - e. both b and c
 29. In third-degree (full-thickness) burns, both the epidermis and dermis of the skin are destroyed. Which of the following conditions would *not* occur as a result of a third-degree burn?
 - a. dehydration (increased water loss)
 - b. increased likelihood of infection
 - c. increased sweating
 - d. loss of sensation in the burned area
 - e. poor temperature regulation in the burned area
 30. Which of the following factors *increases* with age?
 - a. blood flow to the skin
 - b. number and diameter of elastic fibers in the skin
 - c. number of melanocytes in some localized areas of the skin
 - d. melanin production in the hair
 - e. activity of sebaceous and sweat glands in the skin

C R I T I C A L T H I N K I N G

1. A woman has stretch marks on her abdomen, yet she states that she has never been pregnant. Is this possible?
2. The skin of infants is more easily penetrated and injured by abrasion than that of adults. Based on this fact, which stratum of the epidermis is probably much thinner in infants than that in adults?
3. Melanocytes are found primarily in the stratum basale of the epidermis. In reference to their function, why does this location make sense?
4. Harry Fastfeet, a white man, jogs on a cold day. What color would you expect his skin to be (a) just before starting to run, (b) during the run, and (c) 5 minutes after the run?
5. Why are your eyelashes not a foot long? Your fingernails?
6. Given what you know about the cause of acne, propose some ways to prevent or treat the disorder.
7. A patient has an ingrown toenail, a condition in which the nail grows into the nail fold. Would cutting the nail away from the nail fold permanently correct this condition? Why or why not?

Answers in Appendix G

A N S W E R S T O P R E D I C T Q U E S T I O N S

1. Because the permeability barrier is mainly composed of lipids surrounding the epidermal cells, substances that are lipid-soluble easily pass through, whereas water-soluble substances have difficulty.
2. a. The lips are pinker or redder than the palms of the hand. Several explanations for this are possible: more blood vessels in the lips, increased blood flow could occur in the lips, or the blood vessels could be easier to see through the epidermis of the lips. The last possibility explains most of the difference in color between the lips and the palms. The epidermis of the lips is thinner and not as heavily keratinized as that of the palms. In addition, the papillae containing the blood vessels in the lips are “high” and closer to the surface.
b. A person who does manual labor has a thicker stratum corneum on the palms (and possibly calluses) than a person who does not perform manual labor. The thicker epidermis masks the underlying blood vessels, and the palms do not appear as pink. In addition, carotene accumulating in the lipids of the stratum corneum might impart a yellowish cast to the palms.
c. The posterior surface of the forearm appears darker because of the tanning effect of ultraviolet light from the sun.
d. The genitals normally have more melanin and appear darker than the soles of the feet.
3. The story is not true. Hair color results from the transfer of melanin from melanocytes to keratinocytes in the hair matrix as the hair grows. The hair itself is dead. To turn white, the hair must grow out without the addition of melanin, a process that takes weeks.
4. On cold days, skin blood vessels of the ears and nose can dilate, bringing warm blood to the ears and nose and thus preventing tissue damage from the cold. The increased blood flow makes the ears and nose appear red.
5. Reducing water loss is one of the normal functions of the skin. Loss of skin, or damage to the skin, can greatly increase water loss. In addition, burning large areas of the skin results in increased capillary permeability and additional loss of fluid from the burn and into tissue spaces. The loss of fluid reduces blood volume, which results in reduced blood flow to the kidneys. Consequently, urine output by the kidneys decreases, which reduces fluid loss and thereby helps to compensate for the fluid loss caused by the burn. The reduced blood flow to the kidneys can cause tissue damage, however. To counteract this effect, during the first 24 hours following the injury, part of the treatment for burn victims is the administration of large volumes of fluid. But, how much fluid should be given? The amount of fluid given should be sufficient to match that lost plus enough to prevent kidney damage and allow the kidneys to function. Urine output is therefore monitored. If it is too low, more fluid is administered, and if it is too high, less fluid is given. An adult receiving intravenous fluids should produce 30–50 mL of urine/hour, and children should produce 1 mL/kg of body weight/hour.

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