UNIT

II

Support and Movement

CHAPTER

6

Integumentary System

OBJECTIVES

After studying this chapter, readers should be able to

1. Explain the structure of the dermis and epidermis.
2. Describe the normal and pathological colors skin can have.
3. List the functions of the skin.
4. Describe the structure of nails.
5. Discuss the various kinds of glands in the skin and the secretions of each.
6. Explain how the sweat glands play a major role in regulating body temperature.
7. Describe the three most common forms of skin cancer.
8. Describe the location and function of sebaceous and ceruminous glands.
9. Explain the anatomic parts of a hair.
10. Describe the effects of aging on the integumentary system.

OUTLINE

Overview

The **integumentary system**, which consists of the skin (cutaneous membrane) and accessory structures, accounts for approximately 16% of the total body weight of an adult. Its surface area covers from 1.5 to 2 m^2. The skin, which is the largest organ of the body in surface area and weight, is continually bombarded by all sorts of environmental components, including attack by microorganisms, radiation from sunlight, and exposure to chemicals. The accessory integumentary system structures include hairs, nails, sweat glands, and oil glands. The integumentary system is the first line of defense against the environment. The skin, as well as the deeper *hypodermis*, has many functions, such as protection, excretion, temperature maintenance, melanin production, keratin production, vitamin D_3 (cholecalciferol) synthesis, lipid storage, and sensory detection.

Skin

The skin is also known as the *integument*, which means "covering." This is where the name *integumentary system* is derived. The skin varies in thickness between 1.5 and 4 mm, depending on which part of the body it covers. The two main layers of skin are the epidermis and dermis. The **epidermis**, the outer layer, is made up of keratinized stratified squamous epithelium (**FIGURE 6-1**). The epidermis is also called the *superficial epithelium*. It has four primary cell types and four or five layers, depending on body location (four layers in most body areas and five layers on the palms, fingertips, and soles of the feet). Unlike the dermis, the epidermis is not vascularized. Nutrients must diffuse through dermal blood vessels and tissue fluid to reach the epidermis. The **dermis**, the inner layer, is much thicker than the epidermis and consists of papillary and reticular regions. The papillary region contains fine elastic fibers and dermal papillae. The reticular region is composed of connective tissue containing collagen, elastic fibers, fat tissue, hair follicles, nerves, sebaceous (oil) glands, and the ducts of sweat glands. The epidermis is connected to the dermis by a basement membrane.

Loose connective tissue below the dermis binds the skin to the organs underneath. This tissue, which is predominantly adipose (fatty), forms the **subcutaneous layer**, also known as the *hypodermis* or *superficial fascia*. It is deep below the dermis and not actually part of the skin. This adipose tissue insulates the body, conserving inner heat and helping to keep excessive heat from outside the body from entering.

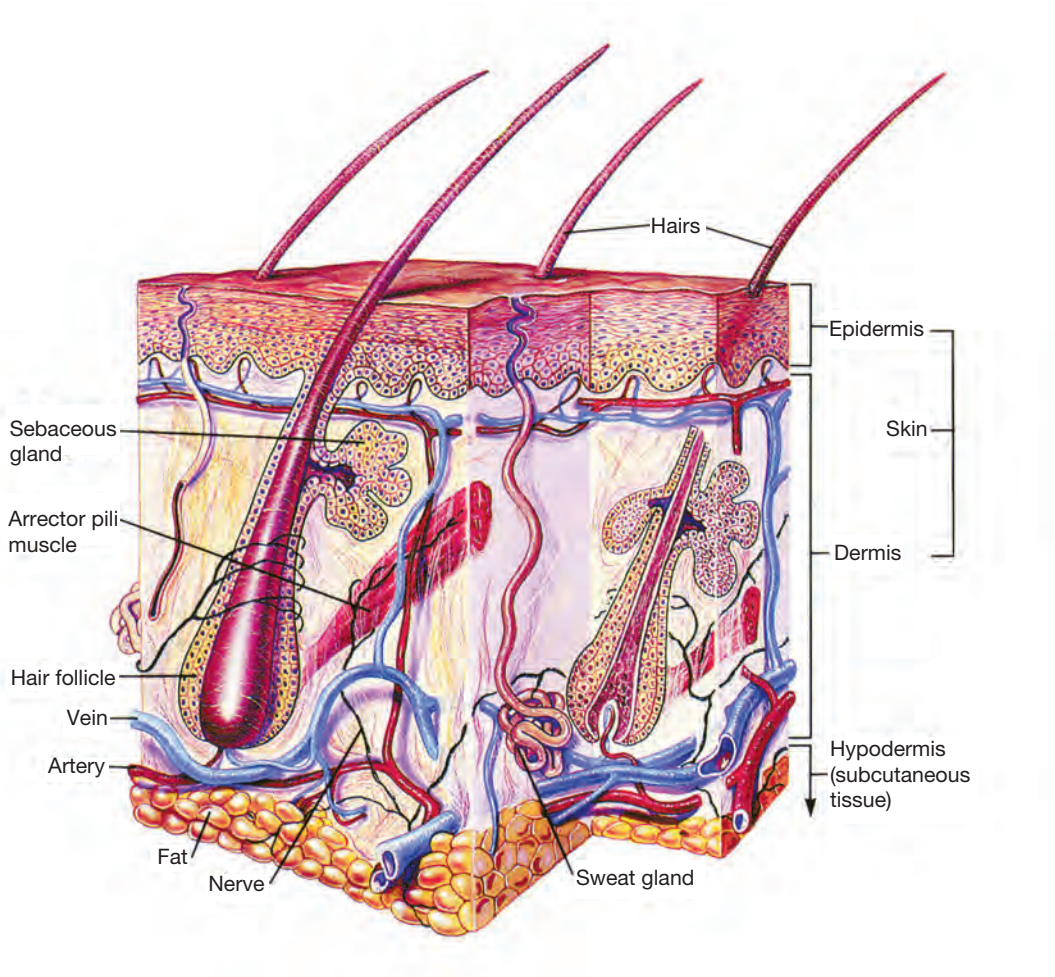


FIGURE 6-1 Anatomy of the skin.

The major blood vessels that supply the skin and adipose tissue are contained within the subcutaneous layer. The hypodermis is loose enough that the skin slides with ease over its underlying structures. It also acts as a shock absorber and becomes much thicker when weight is gained. This tissue first accumulates in the anterior abdomen in males and in the thighs and breasts in females. The hypodermis lends its name to the term "hypodermic," which is where subcutaneous injections are made via *hypodermic needles*.

FOCUS ON PATHOLOGY

Liposuction is a procedure that removes excessive amounts of adipose tissue. Because of the obesity epidemic, it has become a relatively common procedure. Liposuction is also called *lipoplasty*. Subcutaneous adipose tissue is removed through a tube inserted deep to the skin. The complications of liposuction include bleeding, infection, fluid loss, sensory loss, and risks related to anesthesia.

Epidermis

The epidermis is the outermost layer of the skin and is composed of stratified squamous epithelium. The epidermis does not contain blood vessels, although its deepest layer, the stratum basale, receives blood via the dermal blood vessels. Epidermal cells require diffusion of oxygen and nutrients from the capillaries within the dermis. Cells that have a higher metabolic demand are located closer to the basement membrane. Cells in this layer of the epidermis divide and grow, moving toward the skin surface and away from the dermis below. As they move upward, they receive fewer nutrients and eventually die. Older cells are called **keratinocytes**, which harden with age in the process known as *keratinization*. Keratin protein fills the cytoplasm of these skin cells, which collectively form a layer called the *stratum corneum*. Dead skin cells in this layer are eventually shed from the body.

Epidermis Layers

There are basically five layers of the epidermis: stratum germinativum (stratum basale), stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum. Most of the body surface is covered by *thin skin*, consisting of four layers of keratinocytes that total only 0.08 mm in thickness. Areas of *thick skin* (the palms and soles) contain a fifth layer, the stratum lucidum, and the stratum corneum in these areas is much thicker. Therefore, on the palms and soles, the epidermal layers total about 0.5 mm in thickness. The five individual layers are explained as follows:

- The **stratum germinativum** (the "germinative or basal layer") is the innermost epidermal layer and is also known as the **stratum basale** (basal layer). It is interlocked with the underlying dermis via *hemidesmosomes*, which are tiny pin-like structures. This layer forms the epidermal ridges, extending into the dermis, which are adjacent to dermal projections (dermal papillae). The attachment of the stratum basale to the dermis is along a wavy borderline. Epidermal ridges are important because the strength of the attachment of the layer is proportional to the surface area of the **basal lamina**. Ridge shapes are genetically determined, and the pattern of epidermal ridges does not change during the entire life span of an individual (**FIGURE 6-2**). The ridge patterns on the tip of each finger are instrumental in the forming of fingerprints. Each person's fingerprints are unique, including those of identical twins. As a result, fingerprints are commonly used in criminal cases to identify individuals. Large basal (germinative) cells dominate the stratum germinativum. Stem cells are usually in single rows, with divisions that replace superficial keratinocytes that are lost or shed on the epithelial surface. When a stem cell divides into daughter cells, they are pushed from the stratum germinativum upward into the next layer, the stratum spinosum. There are many mitotic cell nuclei in this layer, reflecting rapid cell division. Approximately 10% to 25% of these cells are melanocytes that reach into the stratum spinosum. The ridges on the palms and soles also increase the surface area of the skin and help us to grip objects due to the increased friction. In areas where the skin surface does not have hair, there are specialized epithelial cells known as *Merkel* or *tactile* cells. They are sensitive to touch, releasing chemicals that stimulate sensory nerve endings when they are compressed. The brownish color of the skin comes from *melanocytes*, distributed in the stratum germinativum. They have cell processes that extend into the more superficial layers.
- The **stratum spinosum** (the "spinous or prickle cell layer") is made up of 8 to 10 layers of keratinocytes that are bound together by **desmosomes**. It contains cells that look like tiny pin cushions because of exposure to chemicals that caused the keratinocyte cytoplasm to shrink slightly. However, the desmosomes and elements of the cytoskeleton remained intact. Some entering cells from the stratum basale continue dividing, which increases the thickness of the epithelium. This layer also contains Langerhans cells, also known as *dendritic cells*, which stimulate immune defenses against microorganisms and superficial skin cancers.
- The **stratum granulosum** (the "granular layer") is the third layer and consists of only three to six layers of keratinocytes. Cells in this layer have mostly stopped dividing and begin to make the proteins keratin and keratohyalin. Keratin is tough and fibrous, making up hairs and nails. Developing keratin fibers become flatter and thinner, as their

FIGURE 6-2 A fingerprint. (© AbleStock)

membranes thicken and lose permeability. Keratohyalin forms cytoplasmic granules that dehydrate cells and aggregate and cross-link keratin fibers. The cells die as the nuclei and other organelles disintegrate. Continued dehydration causes this layer to become extremely interlocked. Nutrients are brought via capillaries in the dermis. However, above this layer, the cells are too distant from the dermal capillaries and glycolipids coating them keep nutrients from being supplied, hence their normal death.

- The **stratum lucidum** (the "clear layer") is the fourth region, which is only found on the palms of the hands and soles of the feet, with a glassy or clear appearance. Therefore, the overall skin of the palms and soles is thicker than on other parts of the body. In this layer, the cells are flattened and densely packed, have few organelles, and are filled with keratin. The stratum lucidum is microscopically viewed only in thick skin, appearing as a thin translucent band above the stratum granulosum. It consists only of two or three rows of flat and dead keratinocytes that have indistinct boundaries.
- The **stratum corneum** (the "horny layer") makes up the surface of the skin and contains 15 to 30 layers of keratinized cells that are protective and filled with keratin. The process of keratinization is also known

as *cornification*. It occurs on all exposed body surfaces except the anterior eye surfaces. The dead cells of the stratum corneum are tightly interconnected by desmosomes. Because of this interconnection, keratinized cells of this layer are shed in large sheets rather than individually. Cells move from the stratum germinativum to the stratum corneum in 7 to 30 days, remaining in the stratum corneum for about 2 weeks before being washed away or naturally shed. The dryness of the stratum corneum reduces the amount of potential microbial growth, and this layer is coated with lipid secretions from the sebaceous glands. This layer is water resistant but not waterproof. Water from the interstitial fluids eventually penetrates to the surface. About 500 mL of water is lost from this layer via evaporation every day in a process known as *insensible perspiration*. This differs from *sensible perspiration*, which is produced by active sweat glands. The rate of insensible perspiration may be increased when the epidermis is damaged and sometimes can be dangerous, such as when severe burns excessively damage the epidermis. Oppositely, being immersed in fresh (hypotonic) water for a long time causes the epidermal cells to swell up to four times their normal volume. This is most noticeable on the palms and soles. Immersion in ocean (hypertonic) water causes water to leave the epidermal cells, eventually resulting in dehydration. **FIGURE 6-3** shows how healthy skin balances the production of epidermal cells with the loss of dead cells. The stratum corneum makes up nearly three-fourths of the total epidermal thickness. Keratin protects it against abrasion, and glycolipids cause its water resistance. Approximately 50,000 dead cells are shed from this layer every minute. In an average lifetime, you will lose 40 pounds of these dead skin cells.

FOCUS ON PATHOLOGY

Psoriasis is a chronic inflammatory autoimmune condition of the skin characterized by thickened areas of silver-colored scales. The epidermal cells proliferate, and the condition is most common on the knees, elbows, scalp, lower back, face, palms, and soles. Psoriasis is most prevalent in Caucasians between the ages of 15 and 25, with one in three patients having a family member with the condition. Physicians can diagnose psoriasis simply by visualizing the lesions. Psoriasis may seem similar to eczema, but its scales have well-defined edges.

Psoriasis. (Courtesy of Yale Residents' Slide Collection, Dermatology Department, Yale University School of Medicine.)

Epidermal Cells

The epidermis protects the underlying tissues against the effects of harmful chemicals, excess water loss, mechanical injury, and pathogenic microorganisms. Layers of pigment in the epidermis help protect both epidermal and dermal tissues. **Melanin** is a brown, yellow-brown, or black pigment produced by spider-shaped **melanocytes** located in the stratum germinativum, either between or deeply rooted in the epithelial cells (**FIGURE 6-4**). It is made of tyrosine amino acids and has two forms that range in color (from red-yellow to brown-black). Synthesis of melanin is based on an enzyme called **tyrosinase**. Melanin accumulates in granules that are bound to membranes, called *melanosomes*. Lysosomes eventually break down **melanosomes**, meaning that melanin pigment is found only in the deeper layers of the epidermis. Motor proteins move down actin filaments to reach the ends of each melanocyte's processes. They then move to nearby keratinocytes, accumulating on the superficial side of the keratinocyte nucleus. Normal exposure of the skin to sunlight causes the keratinocytes to secrete chemicals that stimulate the melanocytes. Melanin absorbs *ultraviolet (UV) radiation* from sunlight, protecting the epidermis and dermis from its harmful effects. It builds up from sun exposure, absorbing rays, dissipating this energy as heat, and protecting DNA of viable skin cells from UV radiation. However, sunlight contains extremely significant amounts of UV radiation. Although small amounts of UV radiation are beneficial because they stimulate the epidermal production

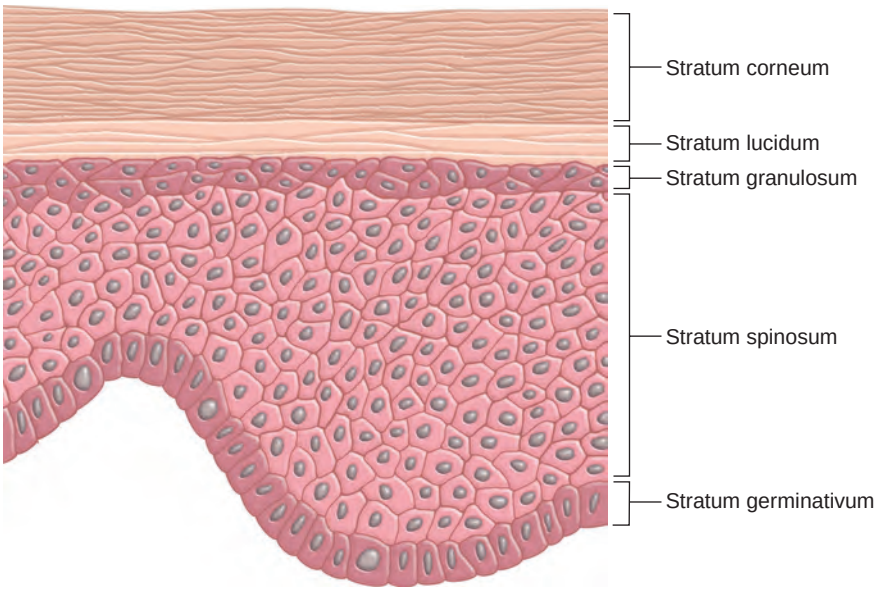


FIGURE 6-3 The epidermal layers of the skin.

of a compound required for calcium ion homeostasis (the production of vitamin D), larger amounts damage DNA. This causes mutations, promoting the development of cancer. UV radiation can also produce burns. When severe, they can damage the epidermis and the dermis.

Keratinocytes produce *keratin*, which is the fibrous protein that aids the epidermis in protecting the body. Most epidermal cells are keratinocytes, which arise in the stratum basale. Upon reaching the skin surface, they are already dead. At this time, they have a scale-like appearance and are basically plasma membranes filled with keratin. Every day, millions of dead keratinocytes rub off. Therefore, the epidermis is totally replaced every 25 to 45 days.

Star-shaped **dendritic cells**, or *Langerhans cells,* from the bone marrow eventually move to the epidermis. They consume foreign substances and play a key role in activating

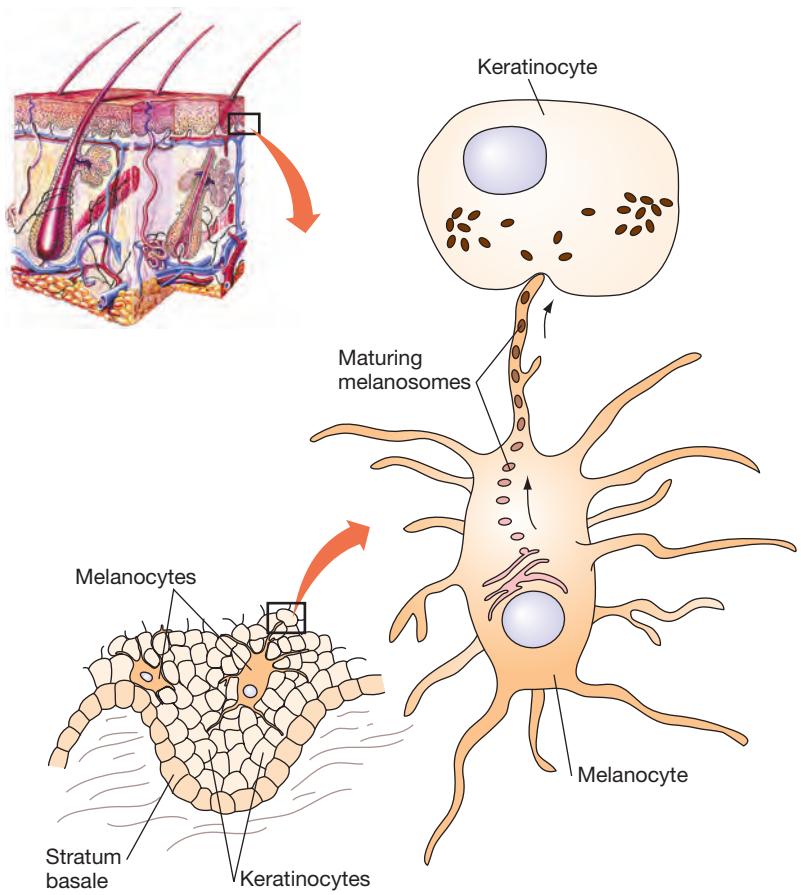


FIGURE 6-4 Melanocytes produce melanin, the pigment of skin, package it in melanosomes, and transfer it to keratinocytes.

the immune system. **Tactile cells**, or *Merkel cells,* are located at the epidermal–dermal junction. They have spiked shapes and combine with disc-like sensory nerve endings to form *tactile discs*, which are receptors for the sense of touch.

Differences in skin color are based on the amount of melanin produced and how it is distributed throughout the skin. Skin color is based on a person's genetics, which regulates the amount of melanin produced by the melanocytes. Other factors that affect skin color include sunlight, UV light, and x-rays. Dermal vessel blood also affects the color of the skin. Well-oxygenated blood makes light-skinned people appear pinker, whereas poorly oxygenated blood makes them appear bluer, as in the condition known as *cyanosis*. Diet also affects skin color, as do biochemical imbalances. For example, the buildup of the substance known as *bilirubin* makes the skin appear yellowish, as in the condition called *jaundice*.

Also contributing to skin color are the pigments *carotene* and *hemoglobin*. Carotene is a yellow to orange pigment that primarily accumulates in the stratum corneum and the hypodermic fatty tissue. It is also found in plant products such as carrots and other orange-colored vegetables. The color of carotene is most easily seen in the palms and soles, especially in lighter skinned individuals, where the stratum corneum is present in thicker cellular levels. It intensifies in the body when large amounts of foods rich in carotene are consumed. Carotene can be converted to vitamin A (essential for normal vision), which aids in the health of the epidermis. Carotene, along with variations in melanin, contributes to the skin color of people from certain Asian countries. *Hemoglobin* is the red pigment inside red blood cells. As it circulates throughout the dermal capillaries, it gives off a pink color that is easily seen in people with fairer skin.

TEST YOUR UNDERSTANDING

1. List and discuss the five layers of the epidermis.
2. Explain melanin, melanocytes, and melanosomes.
3. Which layer of the epidermis is vascular?

FOCUS ON PATHOLOGY

The skin is eventually damaged by excessive sun exposure, regardless of the protective abilities of melanin. Elastic fibers clump together, and the skin becomes "leathery." The immune system is depressed, which can lead to skin cancer by altering skin cell DNA. Dark-skinned people get skin cancer less often than light-skinned people, and when they develop it, cancerous lesions usually occur on areas of lighter skin, such as the palms or soles. UV radiation also destroys stores of folic acid in the body, which can lead to developmental defects in pregnant women.

Dermis

The *dermis* lies between the epidermis and the subcutaneous layer and has two major components: a superficial papillary layer and a deeper reticular layer. The dermis also contains all cells of connective tissue proper. Epidermal accessory organs extend into the dermis, and both the papillary and reticular layers of the dermis contain many blood vessels, lymph vessels, and nerve fibers. The dermis is the second major skin structure and is a strong and flexible connective tissue. Dermal cells contain fibroblasts, macrophages, and smaller amounts of mast cells and white blood cells. The major portions of hair follicles, oil glands, and sweat glands are found in the dermis, even though they derive from epidermal tissue.

The **papillary layer** consists of areolar tissue and contains capillaries, lymphatics, and sensory neurons. The papillary layer is named for the dermal papillae that project between the epidermal ridges. It is thin and superficial areolar connective tissue with interwoven collagen and elastic fibers. The papillary layer is loose, allowing phagocytes and various defensive cells to move freely, searching for bacteria that have gotten through the skin. Dermal papillae often contain loops of capillaries or may contain pain receptors and touch receptors. In the thicker skin of the palms or soles, these papillae are above larger *dermal ridges*, which then cause the epidermis to form its *epidermal ridges*. These ridges leave pressure marks that are commonly referred to as *fingerprints*, unique to every individual human being.

The deeper *reticular layer* is made up of connective tissue containing collagen and elastic fibers. The boundary between the papillary and reticular layers is not distinct. The reticular layer makes up approximately 80% of the overall thickness of the dermis. It is nourished by the *cutaneous plexus*. Collagen fibers mostly run parallel to the skin surface, with less dense regions known as *separations* forming **cleavage lines** in the skin. Also known as *tension lines*, these lines are used for surgeries to make parallel incisions, meaning better healing afterward. A third type of skin marking, **flexure lines**, occur close to joints, where the dermis is more tightly secured to deeper structures. Examples include the creases on the palms of the hands. In the papillary layer, small arteries form a branched network known as the *papillary plexus*, which provides arterial blood to the capillaries along the epidermis–dermis boundary.

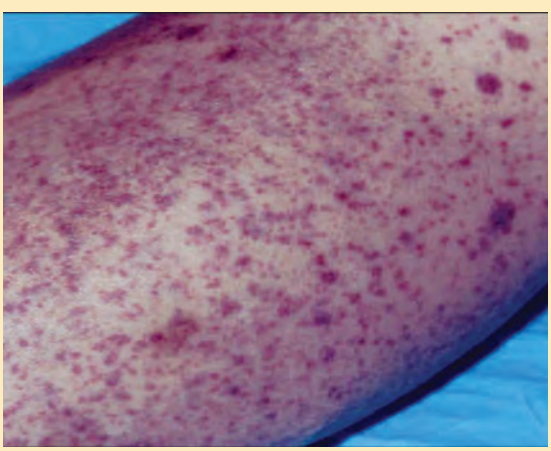
The collagenous and elastic fibers of the dermis make it both tough and elastic. The skin's water content helps it to be flexible and resilient, which is known as *skin turgor*. A sign of dehydration is the loss of skin turgor. Processes from nerve cells are located throughout the dermis. Motor processes carry impulses to the dermal glands and muscles, whereas sensory processes carry impulses back to the brain and spinal cord. Cutaneous sensations include touch, hot, cold, and pain.

FOCUS ON PATHOLOGY

Excessive stretching of the skin can tear the dermis, leaving silver-white scars known as *striae* or "stretch marks." These are often due to events such as pregnancy. Also, acute trauma that is short term may cause a *blister*, a fluid-filled pocket between the epidermal and dermal layers.

FOCUS ON PATHOLOGY

Petechiae are small hemorrhages in the skin caused by decreased amounts of platelets, resulting in bleeding from capillaries. Sometimes, petechiae occur after application of a tourniquet. Petechiae may be caused by platelet abnormalities such as thrombocytopenia or platelet dysfunction, vasculitis, and infections such as meningococcemia or Rocky Mountain spotted fever.



Petechiae.

TEST YOUR UNDERSTANDING

1. Describe the layer of the dermis that determines a person's fingerprints.
2. What forms cleavage lines in the skin?

Accessory Structures

The accessory structures of the integumentary system include nails, hair and hair follicles, and sebaceous and sweat glands. These glands are multicellular and have exocrine functions. Most accessory structures are located in the dermis and protrude through the epidermis to reach the surface of the skin.

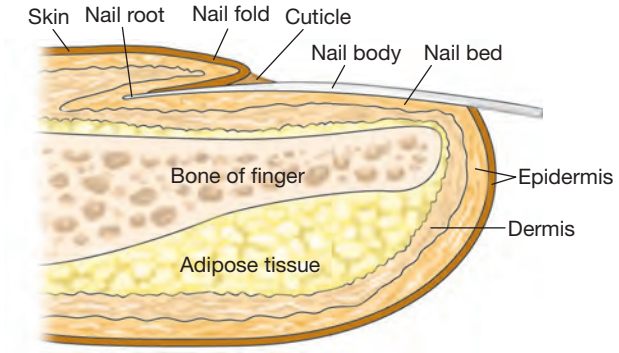


FIGURE 6-5 Fingernail anatomy.

Nails

Nails protect the ends of the fingers and toes, consisting of a nail plate above a skin surface called the *nail bed*. A *nail* is a modification of the epidermis that contains hard keratin. The part of the *nail plate* (*nail body*) that grows most actively is covered by a whitish, half-moon–shaped *lunula* or *lunule*, where epithelial cells divide and become keratinized. The nail cells push forward over the *nail bed*, causing the nail body to continually grow outward. The nail bed is surrounded on each side by depressions known as the *lateral nail grooves*. The thickened proximal part of the nail bed is called the *nail matrix*, which is the part that causes nail growth. The nail of the middle finger grows fastest, whereas the nail of the thumb grows slowest (**FIGURE 6-5**).

The free edge of each nail is the part that is trimmed when it extends to a sufficient length, with the thicker region underneath where dirt accumulates called the **hyponychium** or the "quick." The hyponychium secures the nail plate's free edge at the fingertip. Skin folds called **nail folds** overlap the proximal and lateral borders of each nail. The proximal nail fold attaches to the nail body as the **cuticle** (eponychium).

Nails begin growing at the nail root, which lies very close to the bone of the fingertip. A part of the stratum corneum forms the cuticle, with underlying blood vessels that give the nail a pinkish color. The nail body consists of dead, compressed cells packed with keratin. Changes in the nails can help to diagnose many different body conditions. Nails normally appear pink in color because of underlying capillaries, with the white crescent-shaped *lunula* above the nail matrix. Discoloration of a nail may indicate respiratory, thyroid, or immune disorders. A yellow tinge may indicate a respiratory or thyroid gland condition. Pitting or distortion of the shapes of the nails may indicate psoriasis, and a concave shape may indicate a blood disorder. Thickened yellow nails may indicate a fungal infection. If the nail is outwardly concaved (*spoon nail*), an iron deficiency may exist. Horizontal *Beau's lines* across the nails may signify malnutrition.

TEST YOUR UNDERSTANDING

1. Describe the substance that makes nails "hard."
2. Define the nail folds, cuticle, and lunula.

FOCUS ON PATHOLOGY

Paronychia is a condition wherein abscesses occur around the nails. When acute, the edges of the nails may swell because of a collection of pus. When chronic, paronychia is usually caused by jobs in which the hands remain wet on a regular basis. Chronic paronychia is also caused by diabetes or immunocompromised states. The condition may be an irritant dermatitis, with secondary fungal colonization.

Paronychia. (Courtesy of Yale Residents' Slide Collection, Dermatology Department, Yale University School of Medicine.)

Hairs

Hairs (*pili*) project above the skin surface over most of the body, except for the sides and soles of the feet, the palms of the hands, the sides of the fingers and toes, the lips, and parts of the external genitalia. They begin to form during embryologic development and are also known as *epidermal derivatives* because they arise from the epidermis. There are about 2.5 million hairs on the human body, of which over 75% is on the general body surface and not the head. Hairs are structures produced in organs called **hair follicles** (**FIGURE 6-6**). They consist of a large amount of dead keratinized cells, dominated by hard keratin. Hair follicles extend from the skin surface into the dermis, containing hair *roots* that are nourished with dermal blood. Each hair follicle is attached to an *arrector pili* muscle, which helps the hair *shaft* (in which keratinization is complete) to stand on end when it contracts. This occurs during emotional upset and cold temperatures. Hairs are pushed upward as epidermal hair cells divide and grow, becoming keratinized and then dying.

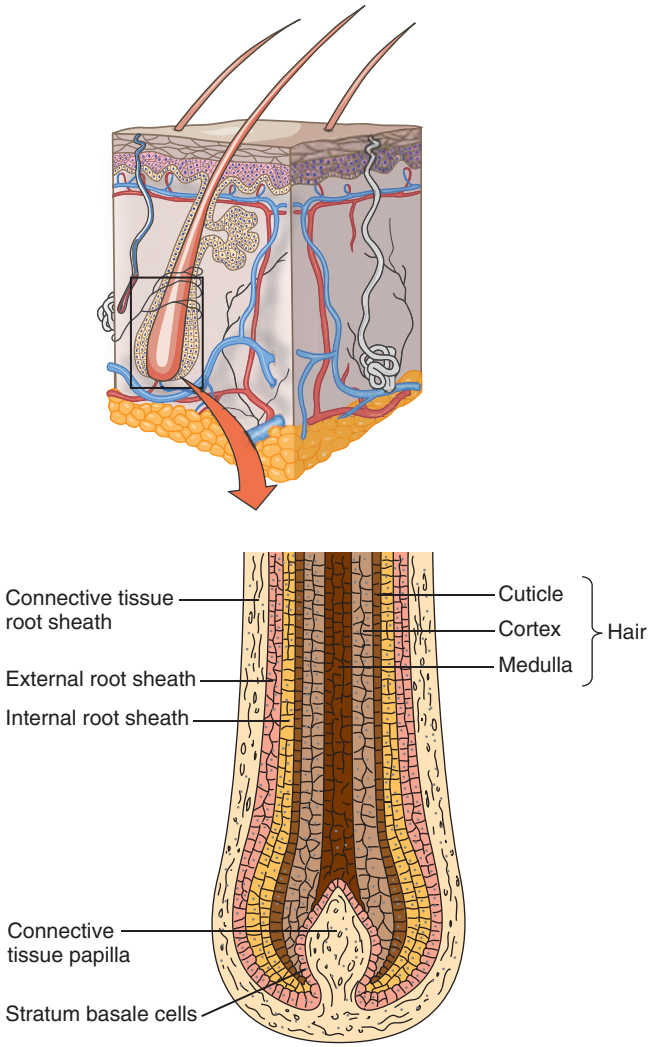


FIGURE 6-6 A hair follicle.

Each hair follicle is folded from the epidermal surface into the dermis. They may extend into the hypodermis of the scalp. Each follicle originates at about 4 mm below the skin surface, expanding to form a **hair bulb**. A *root hair plexus* or *hair follicle receptor* consists of a cluster of sensory nerve endings, wrapping around each hair bulb. When the hair is bent, these endings are stimulated, meaning that hairs act as touch receptors, with extreme sensitivity. Nipple-like dermal tissue makes up a *hair papilla*, which protrudes into each hair bulb. It contains a knot of capillaries that give nutrients to the growing hair. A *fibrous peripheral connective tissue sheath* makes up the wall of a hair follicle. This derives from the dermis. The other components of the hair follicle wall are the thickened basal *glassy membrane* and the inner *epithelial root sheath*. This sheath becomes thinner as it approaches the hair bulb, with only one layer of epithelial cells covering the papilla.

The **hair matrix** is the actively dividing part of the hair bulb that produces the hair. It originates in the *hair bulge*, just a small portion of 1 mm above the hair bulb. Chemical signals that reach the hair bulge cause certain cells to move to the papilla, divide, and produce new hair cells. The older part of each hair is then pushed upward, with the fused cells getting more keratin and dying.

Each hair has three concentric layers known as the *medulla, cortex,* and *cuticle*. The central core of a hair is the medulla. It is made up of air spaces and large cells. The medulla is the only hair portion that contains soft keratin. It does not exist in fine hairs. Surrounding the medulla is the bulky *cortex*, made up of a few layers of flat cells. A single layer of cells forms the outermost *cuticle* of a hair. In the cuticle, cells are overlapped like shingles, which helps keep each hair shaft from matting with others. Most hard keratin is in the cuticle, which provides strength to the hair shaft and keeps the inner layers compacted tightly together. The cuticle experiences the most abrasion and usually wears away at the tip. This causes what is commonly known as *split ends*, in which fibrils of keratin from the cortex and medulla become split. The rough surfaces of a hair cuticle are smoothed by hair conditioning products, which give a shiny appearance to a person's head of hair.

Hair color is reflected by genetics and variations in the pigment produced by melanocytes at the hair papilla. Darker hair has more eumelanin (which is brownish-black), whereas lighter hair has more pheomelanin (which is reddish-yellow). The different forms of melanin give hair a wide variety of shades, ranging from dark brown to yellow brown, to red. Albinos have white hair because their hair shafts completely lack melanin. Hormonal and environmental factors also influence the hair's condition. As pigment production decreases with age, hair color lightens. White hair results from a lack of pigment along with the presence of air bubbles in the medulla of the hair shaft. As the proportion of white hairs increases, the overall hair color is described as gray.

Hairs are basically classified as either *vellus* or *terminal*. Adult women and newborn children have body hair known as *vellus hair*, which is fine and pale in color. *Terminal hair* is coarser and longer, found on the scalp and eyebrows, and often darker than vellus hair. Terminal hairs appear in the axillary and pubic regions of males and females during puberty. On males at puberty, they also appear on the face, chest, and usually, the arms and legs. These hairs are stimulated to grow by androgens (primarily testosterone). Large amounts of male hormones cause thick terminal hair growth. Nutrition and hormones influence hair density and growth. Chronic physical inflammation or irritation may cause increased local hair growth. Hair growth that is not cosmetically attractive may be slowed or stopped by electrolysis or laser treatments.

Hair grows at an average rate of 2.5 mm per week, but this varies with sex, age, and body regions. Growth cycles occur in each hair follicle, including an active phase that ranges from weeks to years and a regressive phase, when hair matrix cells die. The hair follicle base and hair bulb then shrink, causing the hair papilla to be moved upward to touch the part of the follicle that does not regress. Then, a 1- to 3-month resting phase occurs. After this, the cycling area of the follicle is regenerated. Activated bulge cells migrate to the papilla. The matrix is then able to form a new hair. Many proteins control a hair's life span, and scalp hair follicles are active for up to 10 years before being inactivated for several months. Approximately 90 scalp hairs are lost per day. The eyebrows never reach the length of the scalp hair because each eyebrow follicle is active for only 3 to 4 months.

Each hair follicle of the body has a limited number of growth cycles, with growing being fastest between the teenage years and the forties. Hair thinning occurs after this time because shedding happens more quickly than hair replacement. Both sexes, beginning in middle age, experience a certain degree of hair thinning and/or *alopecia* (baldness), but it is more commonly seen in men. By age 35, approximately 40% of men have visible hair loss, and by age 60 the percentage is about 85%. Scalp hair loss usually begins at the anterior hairline, progressing posteriorly. The hair becomes thinner as vellus hairs being to replace the coarser terminal hairs. However, *true baldness* (most commonly, *male pattern baldness*) is not the same situation. It is sex-influenced and genetically determined, linked to a gene that activates during adulthood and changes how the hair follicles respond to dihydrotestosterone, (DHT), which is a metabolite of testosterone.

FOCUS ON PATHOLOGY

Albinism is a genetic disorder in which there is a lack of melanin. Most cases are autosomal recessive. Albinism affects the hair, skin, and eyes. The hair is usually white or very pale yellow, the skin extremely pale, and the eyes may range in color from blue to reddish, violet, hazel, or brown. As a result of albinism, eye conditions may include nystagmus, strabismus, or decreased vision. Patients must avoid skin damage from the sun by wearing sunscreen, hats, and protective clothing. For eye movement disorders, surgery may be helpful.

Albinism. (© FangXiaNuo/iStockphoto.com)

FOCUS ON PATHOLOGY

In women, excessive hair growth (*hirsuitism*) may result from an adrenal gland or ovarian tumor secreting abnormally large amounts of androgens. This condition is defined as excessive growth of thick or dark hair in women in locations that are typical of male hair growth patterns, including the face, chest, shoulders, lower abdomen, back, and inner thighs. Oppositely, hair thinning may be linked to surgery, very high fever, severe emotional trauma, excessive vitamin A, and medications (anabolic steroids, certain antidepressants or blood thinners, and most chemotherapy drugs). Other reversible causes of hair thinning include lactation and protein-deficient diets.

TEST YOUR UNDERSTANDING

1. Describe the mechanism that causes hairs to "stand on end."
2. Explain the tissue that comprises the hair papilla.
3. Describe the hair follicles, the root hair plexus, and the hair matrix.

Glands in the Skin

The skin contains two types of exocrine glands: sebaceous glands and sweat glands. The sebaceous (oil) glands are simple and branched alveolar glands covering the body, except on the palms and soles. The sweat (sudoriferous) glands are found all over the body except for the lips, nipples and certain parts of the external genitalia.

Sebaceous Glands

Sebaceous glands (oil glands) are made up of specialized epidermal cells and are primarily located near hair follicles. These glands are largest on the face, neck, and upper chest. They are actually holocrine glands, secreting **sebum**, which is an oily mixture of fatty material and debris from cells. The central alveoli cells accumulate lipids until they burst, and the combined lipids and cell fragments make up sebum. The sebum is secreted through small hair follicle ducts, helping to keep both hair and skin pliable and waterproof. The sebum is a mixture of cholesterol, triacylglycerides, proteins, and electrolytes. Sebum inhibits bacterial growth, protecting the keratin of the hair shafts. Sebum is forced out of hair follicles, to the skin surface, via arrector pili contractions. This lubricates the hair and skin, keeping the hair supple and slowing the loss of water from the skin during times of low environmental humidity. Sebum has a strong bactericidal action. Its secretion is stimulated by androgens primarily. Hence, sebaceous glands are less active until a human reaches puberty and androgen production rises.

Sebaceous follicles are large sebaceous glands that surround hair follicles. Their ducts discharge sebum directly onto the epidermis (**FIGURE 6-7**). They are found on the face, chest, nipples, back, and external genitalia. During the final phases of fetal development, their secretions, as well as epidermal cells that have been shed, coat the skin surface to form a protective layer. When the sebaceous glands become overactive, usually occurring on the scalp, an inflammation may develop around them. This is known as *seborrheic dermatitis*.

Sweat Glands

Sweat glands consist of a small tube originating as a coil in the deep dermis or superficial subcutaneous layers. The coiled portion is lined with sweat-secreting epithelial cells. Sweat is carried out of the skin by tubes called pores that

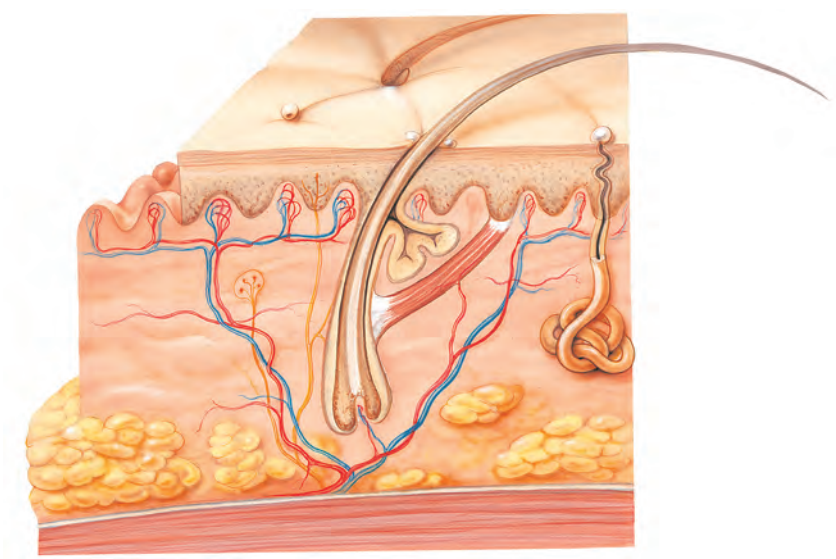


FIGURE 6-7 The structure of sebaceous glands and follicles.

open at the skin surface. Sweat is made up of 99% water as well as salts, which are primarily sodium chloride, ascorbic acid, or vitamin C; antibodies; and waste products, including urea, ammonia, and uric acid. Sweat also contains *dermicidin*, which is a peptide that kills microbes. Overall, sweat is a hypotonic filtrate of blood, passing through secretory cells via exocytosis. Its composition is based on diet, heredity, and, partially, certain drugs that are ingested. Sweat has a normal acidic pH of between 4 and 6. Sweating is regulated by the autonomic nervous system to prevent overheating. It begins on the forehead, spreading inferiorly to the rest of the body. When sweating is brought about by nervousness or fright (cold sweating), it starts on the palms, axillae, and soles before spreading throughout the body.

The skin contains two types of **sweat glands (sudoriferous glands)**: merocrine sweat glands and apocrine sweat glands. Merocrine (eccrine) glands are the predominant type of sweat glands, responding to body temperature, and are present at birth. They excrete water and electrolytes and also provide protection from hazards in the environment. Adult skin contains 2 to 5 million merocrine sweat glands. They are found on the forehead, neck, and back, although the palms and soles have the highest numbers. They are simple tubular glands with a coiled appearance. In the dermis is found the secretory portion, whereas the duct opens in a funnel-shaped *pore* at the surface of the skin. These pores are not the same as the "complexion pores," which are the outlets of hair follicles.

Apocrine glands are sweat glands that become active at puberty and number about 2,000. They are found mostly in the armpits and groin, with the sweat excreted at these places developing a scent as they come into contact with skin bacteria (**FIGURE 6-8**). This is the basis of body odor. Modified sweat glands include the **ceruminous glands** of the external ear (which produce earwax) and the mammary glands (which produce milk). *Cerumen* or earwax is believed to block entry of foreign materials or insects into the ear.

It should be noted that apocrine glands are still actually merocrine glands that produce their product in the same way as eccrine sweat glands. However, they are larger in size, are located in the dermis or hypodermis, and empty into hair follicles. Their secretions are similar to eccrine glands but also include proteins and fatty substances. The color of these secretions may be white or yellow. The function of apocrine glands is controlled by androgens, activated by sympathetic nerve fibers during stress and pain. In women they enlarge and recede along with the menstrual cycle. The secretory cells of apocrine glands are surrounded by *myoepithelial cells* that squeeze them to discharge accumulated sweat into the hair follicles.

TEST YOUR UNDERSTANDING

1. Describe how hairs grow out of the skin.
2. Distinguish between eccrine and apocrine glands.

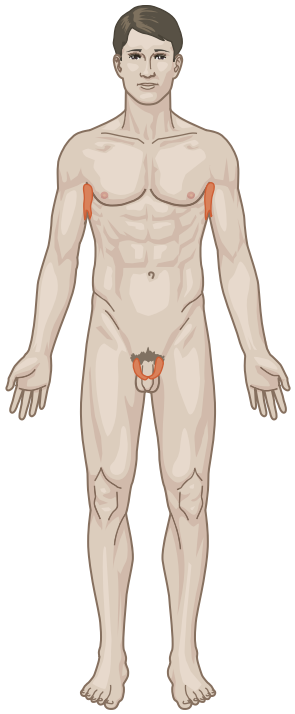


FIGURE 6-8 The locations of the apocrine sweat glands are shown in red. They include the axilla, areola, pubis, and circumanal region (not shown).

FOCUS ON PATHOLOGY

A sebaceous gland duct that is blocked by accumulated sebum is referred to as a *whitehead*, and when this material oxidizes and dries, it darkens, forming a *blackhead*. Active inflammation of the sebaceous glands accompanied by skin pustules or cysts is known as *acne*. These lesions are commonly referred to as *pimples*. Acne is usually caused by a staphylococci infection and can become severe enough to cause permanent scarring. *Seborrhea* is caused by overactive sebaceous glands. In infants, this is referred to as *cradle cap*.

Functions of the Integumentary System

The skin is constantly exposed to abrasion, microorganisms, chemicals, and extremes of temperature and has three primary barriers that protect the body: chemical, physical, and biological barriers. Chemical barriers include melanin and secretions from the skin. The low pH of skin secretions is described as the **acid mantle**, which slows the multiplication of microorganisms. Many bacteria are killed directly by

contact with bactericidal substances from the sebum and the **dermicidin** from the sweat. **Defensins** are natural substances secreted by skin cells that create holes in bacteria, helping to kill them. Protective peptides or *cathelicidins* are released by injured skin and are effective against many bacteria, but mostly against group A streptococci.

Physical barriers are created by skin continuity and hardened, keratinized cells. In the stratum corneum there are many layers of flat, dead cells surrounded by glycolipids along with the acid mantle and skin secretions to stop bacterial invasion. Water and water-soluble substances are largely kept from diffusing between cells by the glycolipids. Even so, a continual loss of small amounts of water occurs through the epidermis. In limited amounts, the following substances are able to penetrate the skin: lipid-soluble substances, oleoresins, organic solvents, heavy metal salts, certain drugs, and drug agents known as *penetration enhancers*. Lipid-soluble substances include carbon dioxide, oxygen, the fat-soluble vitamins (A, D, E, and K), and steroids such as estrogens.

Examples of *oleoresins* (plant resins) include poison oak and poison ivy. Organic solvents, which dissolve cell lipids, include acetone, dry-cleaning fluids, and paint thinner. Examples of heavy metal salts include lead and mercury. Drugs that can penetrate the skin include nicotine, nitroglycerine, and medications used to stop seasickness. Also, for at least 24 hours after being ingested, drinks containing alcohol enhance skin permeability to a large degree.

The body also has biologic barriers that act for its protection: the dendritic cells in the epidermis, the macrophages in the dermis, and the body's DNA. Dendritic cells are active immune system components that patrol the epidermis for *antigens* (foreign substances). The dendritic cells play the same role in the epidermis as the lymphocytes in the blood. The second line of biological barriers consists of the dermal macrophages, which function in much the same way as the dendritic cells. They dispose of bacteria and viruses that get past the epidermis. DNA is a fairly potent biologic sunscreen, and its electrons absorb UV radiation. This is transferred to the nuclei of DNA atoms, causing them to heat and vibrate quickly. The heat dissipates to nearby water molecules in an instant. Therefore, DNA converts possibly harmful UV radiation into heat, which has no negative effects in this example.

As mentioned previously, the skin is important in regulating body temperature. The deeper body parts are normally set at 98.6°F (which is equivalent to 37 degrees Celsius [°C]). Body heat is produced by cellular metabolism, with most body heat being produced by the skeletal and cardiac muscle cells as well as certain glandular cells (such as liver cells). As temperature rises, the body is stimulated to release body heat by relaxing dermal blood vessel walls. The eccrine sweat glands release sweat to the skin surface, which evaporates to cool the skin. The reverse process occurs when the body temperature drops. This holds heat in, and if the temperature continues to drop, the body signals certain muscles to contract. Shivering is the result, which helps to generate more body heat.

The sweat glands secrete about 17 ounces (500 mL) of sweat per day when the body is at rest and when the environmental temperature is below 88 to 90°F (31–32°C). This normal, unnoticed sweating is described as *insensible perspiration*. The sweat glands greatly increase their activity when body temperature rises and the nervous system causes the dermal blood vessels to dilate. If the weather is hot, sweat becomes noticeable (*sensible perspiration*), accounting for up to 3 gallons (12 liters) of body water loss in a single day. As the sweat evaporates, the body is cooled and overheating is prevented. On cold days, dermal blood vessels constrict to cause the blood to temporarily bypass the skin. The skin temperature assumes the temperature of the external environment. Passive heat loss slows down, and the body conserves heat.

Sensory receptors are located in the dermis and are actually parts of the nervous system. They initiate nerve impulses that can reach our conscious awareness and are classified as *exteroceptors* because they respond to stimuli from outside the body. Nerve fibers in the skin control blood flow, adjust gland secretion rates, and monitor sensory receptors in the dermis and deeper layers of the epidermis. The epidermis also contains the extension of sensory neurons that provide sensations of pain and temperature. The dermis contains similar receptors and other, more specialized receptors (for example, sensations of touch and pressure). In the dermal papillae, *Meissner's (tactile) corpuscles* and *tactile discs* sense light surface touching. In the deeper dermis or hypodermis, *Pacinian* or *lamellar corpuscles* sense harder contacts that involve deep pressure. Even hair follicle receptors play a part in the sense of touch. Painful stimuli are sensed by free nerve endings located throughout the skin.

The skin also has many metabolic functions. It reacts to sunlight by converting modified cholesterol molecules to vitamin D precursors. These are carried by the blood to other areas of the body for conversion to vitamin D, which aids in calcium metabolism. Without vitamin D, calcium could not be absorbed from the gastrointestinal tract. Therefore, sunlight is essential so the bones can absorb calcium via the presence of vitamin D. The epidermis carries out chemical conversions that assist the liver. Keratinocyte enzymes play important roles related to cancer and inflammation. These enzymes can either convert harmless chemicals to carcinogens or disarm chemicals that are carcinogenic. They activate certain steroids, such as when they transform cortisone into hydrocortisone, which has strong anti-inflammatory properties. Other important proteins manufactured by skin cells include *collagenase*, which fights against wrinkling by stimulating the natural use and reuse of collagen.

The skin also acts as a blood reservoir and plays a role in excretion. Nearly 5% of the body's entire blood volume can be contained by the extensive vascular supply of the dermis. The nervous system constricts dermal blood vessels to supply more blood to other body organs that need this supply. More blood is moved into the general circulation by this constriction, and working muscles or other organs use it. Nitrogen-containing wastes are also eliminated through the sweat, although most of this elimination goes through the urine. These nitrogen-containing wastes include ammonia, urea, and uric acid. When sweating is profuse, water and sodium chloride (salt) are lost in large quantities.

TEST YOUR UNDERSTANDING

1. What are the three types of skin protection?
2. Explain metabolic skin functions.
3. Describe the chemical agents that protect the skin.
4. Why is sunlight essential for bone health?

Response of the Integument to Injuries and Wounds

The integument responds to injuries and wounds with inflammation, which causes redness, increased warmth, and painful swelling. The blood vessels of the wounded area dilate and allow fluids to leak into the damaged tissues. This provides more nutrients and oxygen to the tissues, aiding in healing. Shallow breaks in the skin cause epithelial cells to divide more rapidly, with the new cells filling the break.

A cut that extends into the dermis or subcutaneous layers breaks blood vessels. The escaping blood then forms a clot in the wound, eventually forming a *scab* as it dries. The scab protects the underlying tissues. Cells called *fibroblasts* move to the injury to form new collagenous fibers that bind the edges of the wound together. Large skin breaks may require suturing or other methods of closing them more completely, which actually helps to speed up the action of the fibroblasts in healing.

Wound healing proceeds as blood vessels extend into the area below the scab, with phagocytic cells removing dead cells and debris. As tissue is replaced, the scab eventually falls off. Extensive wounds may cause the newly formed tissue to appear on the skin surface as a *scar*. Large open wounds may develop small round masses called *granulations*, which consist of new blood vessel branches and clusters of fibroblasts. Once the fibroblasts eventually move away, the resultant scar is mostly composed of collagenous fibers.

If a wound is large or occurs in an area where the skin is thin, epithelial cells cannot cover the surface until dermal repairs are already under way. Circulation to the area is enhanced so that blood clotting, fibroblasts, and an extensive capillary network can combine to combat the injury. (Together, these components are known as *granulation tissue*.) Repairs do not restore the dermis to its original condition, and collagen fibers dominate with relatively few new blood vessels. *Scar tissue* is relatively inflexible and noncellular. Thickened, raised scar tissue is referred to as a *keloid*, featuring a shiny and smooth surface. Keloids are harmless but unsightly.

Effects of Aging on the Integumentary System

Damaged skin affects almost every body system. It leads to bone softening, impaired or accelerated metabolism, failure of the cardiovascular system, changes in immune function, and many other outcomes. Intact skin can greatly improve quality of life in later years. It protects the muscles, improving body temperature regulation and blood flow. Nervous system organs such as touch receptors are protected by intact skin. It also protects endocrine organs, prevents fluid loss, regulates normal secretions, protects lymphatic organs to prevent edema, protects respiratory organs for adequate oxygen supply, protects digestive organs for nutrient absorption, protects urinary organs for proper excretion, and protects reproductive organ health.

The skin initially develops from either the embryonic ectoderm (epidermis) or the mesoderm (dermis and hypodermis). The skin is mostly formed by the end of the fourth month of gestation. The fetus is covered with delicate colorless hairs (the *lanugo coat*) during months 5 and 6 of gestation, but this coat disappears by the seventh month, replaced by vellus hairs. At birth, the newborn's skin is covered with *vernix caseosa*, a white substance that appears "cheese-like." It is produced by the sebaceous glands to protect the skin while the infant is still inside the mother's amnion. Small white spots appear on the forehead and nose (these are called *milia*), which are accumulations in the sebaceous glands. They usually disappear by the third week after birth. The skin thickens during infancy and childhood, with more subcutaneous fat being deposited. During adolescence, skin and hair both become oilier due to activation of the sebaceous glands. Acne may develop during this time, which usually subsides by early adulthood. The skin reaches its best appearance in a person's twenties and thirties. Later, when it shows the effects of abrasion, chemicals, sun, and wind, common conditions include scaling or *dermatitis* (skin inflammation). *Atopic dermatitis* or *eczema* is a genetic condition that is also exacerbated by environmental factors.

In older age, epidermal cells are replaced less quickly. The skin becomes thinner and is more susceptible to bruises and other injuries. It is less lubricated and often becomes dry and itchy. Clumping of elastic fibers occurs. There are less collagen fibers, and they also become stiffer. Older people are unable to tolerate colder temperatures as well because their subcutaneous fat layer diminishes. Fat distribution becomes more similar between men and women because they have lower levels of sex hormones than earlier in life. Wrinkling occurs due to decreased skin elasticity and less subcutaneous tissue. Incidence of skin cancer is higher because of decreased amounts of melanocytes and dendritic cells. Because they have less melanin than other people, fair-skinned and redheaded people usually show age-related changes more quickly. Hair thinning results by age 50, because active hair follicles are two-thirds less prevalent. The hair loses its luster, and the genes activate that trigger male pattern baldness and hair graying.

To slow skin aging, you should shield your skin from the aging UVA rays and the burning UVB rays of the sun. When protection from the sun is lifelong, aged skin will remain unwrinkled and unmarked, although it still thins and loses a certain amount of elasticity. Protective clothing and sunscreens or sunblocks of 15 (or higher) sun protection factors (SPFs) are encouraged. Although a nice tan may be appealing early in life, sunlight eventually causes the skin to sag, wrinkle, and become marked with pigmented "liver spots." UVA rays activate *matrix metalloproteinase* enzymes, degrading dermal components such as collagen. However, the skin aging process may be delayed by cleanliness, good nutrition, plenty of fluid

consumption, and the drug *tretinoin* (Retin-A®). This agent is related to vitamin A and inhibits the matrix metalloproteinases. It is found in many skin creams designed to slow photo-aging.

In most people, signs of aging generally appear by their late forties. Signs of aging in the integumentary system include thinning, graying hair; dry hair and skin; thinning skin; sagging skin; bleeding within the skin; easier bruising; slower healing from injuries; and recurring infections. Body heat regulation varies because of atrophy of blood vessels, sweat glands, and subcutaneous fat. The skin may also show signs of yellowing, mottling, age spots, and wrinkling. The most serious condition affecting the skin during the aging process is skin cancer (discussed below). With age, germinative cell activity declines, Langerhans cells decrease, vitamin D_3 production decreases, melanocytes decline, glandular activity declines, dermal blood supply reduces, and many hormones reduce in level.

FOCUS ON PATHOLOGY

Eczema, or *atopic dermatitis,* is most common in patients with allergies or asthma and usually begins in infancy on the face, scalp, or knees. The condition spreads to other locations on the body with aging and causes severe itching, papules, and plaques. Eczema is an immune-mediated inflammation of the skin that is linked to both genetic and environmental factors. Diagnosis is by history and examination. Treatment involves moisturizers, topical corticosteroids, and avoidance of allergic and irritant triggers.

Eczema. (Courtesy of Dr. Richard Antaya, Dermatology Department, Yale University School of Medicine.)

TEST YOUR UNDERSTANDING

1. What is the vernix caseosa that covers the skin of a newborn baby?
2. Why are elderly people less able to tolerate cold temperatures?
3. Why do skin wrinkles develop because of the aging process?

FIGURE 6-9 Basal cell carcinoma. (Courtesy of National Cancer Institute.)

Skin Cancer

Skin cancers originating from epithelial cells are called *cutaneous carcinomas* (squamous cell carcinomas or basal cell carcinomas), whereas those arising from melanocytes are *cutaneous melanomas* (melanocarcinomas or malignant melanomas). The UV rays of the sun can cause skin cancer, usually on the head and neck because they are the areas most exposed. Fair-skinned people and elderly people are the most likely candidates for skin cancer. The use of sunscreen or sunblock, minimum SPF-15, may protect against sunburn (including UVA and UVB rays) but not completely against skin cancer. Genetic factors and hormones may influence a person's chance for developing skin cancer. Although very common, skin cancer is one of the easiest forms of cancer to diagnose and treat. When detected and treated early, survival rates are high. The three types of skin cancer, named for the specific epidermal cells in which they originate, are as follows:

- *Basal cell carcinoma:* The most common yet least dangerous type, it begins in the stratum basale, invading the dermis. A small, shiny lesion appears as a "bump" on the skin, which enlarges to form a central depression with a beaded, pearl-like edge (**FIGURE 6-9**).
- *Squamous cell carcinoma:* It begins in the keratinocytes of the stratum spinosum; the lesion appears raised, reddened, and scaly, forming a concave ulcer with edges that are raised (**FIGURE 6-10**). Early detection

FIGURE 6-10 Squamous cell carcinoma. (Courtesy of National Cancer Institute.)

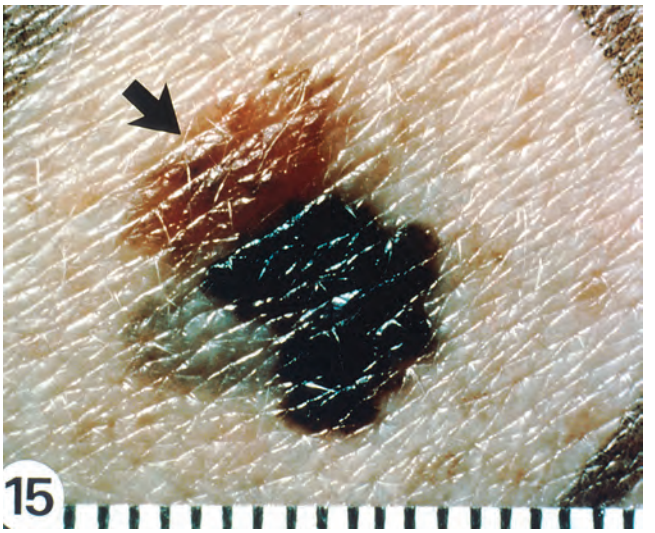


FIGURE 6-11 Malignant melanoma. (Courtesy of National Cancer Institute.)

and surgical removal raises the survival rate, but this cancer often metastasizes to the lymph nodes to become potentially fatal.

- *Malignant melanoma:* This much more serious form of skin cancer is increasing in incidence. It often starts in the melanocytes of a preexisting mole, metastasizing quickly. It is often fatal if not treated immediately. The lesion appears as a large, flat, dark-colored patch that spreads and has a "scalloped" border (**FIGURE 6-11**). According to the American Cancer Society, the *ABCD Rule* should be used for recognizing melanoma:

  Asymmetry: The two sides of a mole or pigmented spot do not match
  Border irregularity: The lesion's borders have indentations
  Color: There are several colors in the pigmented spot, such as black, brown, tan, and, occasionally, blue or red
  Diameter: The lesion is larger than a pencil eraser (approximately 6 mm in diameter)
  NOTE: Some cancer authorities also add an "E" to the ABCD Rule, which signifies "elevation" above the surface of the skin.

TEST YOUR UNDERSTANDING

1. What type of skin cancer is the most malignant?
2. What is the rule used for recognizing melanoma?

Burns

A **burn** is tissue damage caused by intense heat, chemicals, electricity, or radiation that kills cells and denatures cell proteins. The leading causes of accidental death are burns. They may occur because of fires, UV radiation, hot water, spills, radiation, strong acids or bases, or electrical shock. Burns may cause death as a result of fluid loss, infection, and the toxic effects of burned tissue (known as *eschar*). A severely burned patient often dies from dehydration and electrolyte imbalance, which lead to renal failure and circulatory shock. Immediate intravenous infusion of lost fluids is required to save the lives of these patients.

TABLE 6-1
Rule of Nines

Surface Area of the Body	Percentage of Each Body Region
Anterior head and neck	4½
Posterior head and neck	4½
Anterior upper limbs	9
Posterior upper limbs	9
Anterior trunk	18
Posterior trunk	18
Anterior lower limbs	18
Posterior lower limbs	18
Perineum	1

In a burned adult, fluid loss volume is estimated by using the **rule of nines**, which assesses the percentage of the overall body that has been burned. The body is divided into 11 areas that basically each account for 9% of the overall body area, with an additional area accounting for the genital area (1%). **TABLE 6-1** summarizes an estimation of body burns by using the rule of nines. To allow for tissue repair and replace lost proteins, the burn patient requires thousands of daily food calories that are in excess of normal caloric requirements. This is provided by supplementary nutrition via intravenous and gastric tubing. Once stabilized, the next concern is infection. Widespread bacterial infection (sepsis) is the primary cause of death in burn victims. Although burned skin remains sterile for 24 hours, the destroyed skin barrier can then be easily penetrated by many different pathogens, which multiply quickly in this nutrient-rich environment. The immune system, by this point, has also become deficient.

Burns are classified into three types:

- *First-degree burns:* Involve only the epidermis; signified by redness, pain, and slight edema. These burns heal quickly and usually do not leave scars. Most sunburns are first-degree burns (**FIGURE 6-12**).
- *Second-degree (partial-thickness) burns:* Involve the epidermis and dermis but leave some of the dermis intact; they may appear red, tan, or white with blisters. Second-degree burns are very painful, are slow healing, and may leave scars. Serious sunburns and many scaldings are second-degree burns (**FIGURE 6-13**).
- *Third-degree (full-thickness) burns:* The epidermis and dermis are completely destroyed, and deeper

FIGURE 6-12 First-degree burn. (© Amy Walters/ShutterStock, Inc.)

tissue may even be damaged; the skin can repair itself only from the edges of the wound. These burns often require skin grafts, and if left to heal on their own may result in abnormal connective tissue fibrosis and severe disfigurement (**FIGURE 6-14**).

Burns are considered critical if over 25% of the body has second-degree burns, if over 10% of the body has third-degree burns, or if there are third-degree burns on the face, hands, or feet. A facial burn may include burning of the respiratory passageways, causing swelling and suffocation. Burned joints of the body can result in debilitating scar tissue, preventing mobility.

FIGURE 6-13 Second-degree burn. (© Dr P. Marazzi/Science Source)

FIGURE 6-14 Third-degree burn. (© John Radcliffe Hospital/Science Source)

TEST YOUR UNDERSTANDING

1. Is sunburn *usually* an example of a first-degree, second-degree, or third-degree burn?
2. List the main causes of burns.

SUMMARY

The skin is also known as the *integument*, which means "covering." The integumentary system consists of the skin and its accessory structures (hair, nails, glands, muscles, and nerves). The skin is the largest organ of the body in surface area and weight. The major parts of the skin are the epidermis (which is not vascularized) and the dermis (which is highly vascularized). The subcutaneous layer (hypodermis) is deep below the dermis and not part of the skin.

Keratinocytes and melanocytes are the main cells in the epidermis. The keratinocytes produce keratin, which is the fibrous protein that aids the epidermis in protecting the body. The melanocytes produce melanin, which is the dark pigment that absorbs UV radiation from sunlight. The epidermal layers, from deep to superficial, are the stratum basale (also known as stratum germinativum), stratum spinosum, stratum granulosum, stratum lucidum,

SUMMARY (CONTINUED)

and stratum corneum. The stratum lucidum is located only on the soles and palms.

The dermis consists of papillary and reticular regions and lies between the epidermis and subcutaneous layer. The papillary region contains fine elastic fibers and dermal papillae. The reticular region is composed of connective tissue containing collagen, elastic fibers, fat tissue, hair follicles, nerves, sebaceous (oil) glands, and the ducts of sweat glands. The color of skin is due to melanin, carotene, and hemoglobin.

Skin functions include body temperature regulation, protection, sensation, excretion, absorption, and the synthesis of vitamin D. The skin participates in thermoregulation by liberating sweat at its surface. The skin provides physical, chemical, and biological barriers that help protect the body. Cutaneous sensations include touch, hot, cold, and pain.

Nails protect the ends of the fingers and toes and are modifications of the epidermis that contain hard keratin. Hairs (pili) project above the skin surfaces and are also dominated by hard keratin. Hairs are basically classified as either vellus or terminal, with terminal hairs being coarser, darker, and longer. Hair follicles have limited growth cycles and usually begin to slow their activity when a person is in his or her forties. The skin contains two types of exocrine glands: sebaceous (oil) and sudoriferous (sweat) glands.

The three primary skin barriers are the chemical, physical, and biological barriers. Chemical barriers include melanin and skin secretions. Skin continuity and hardened, keratinized cells create physical barriers. Biological barriers include the dendritic cells (epidermal), macrophages (dermal), and the body's DNA. The skin is also important for regulating body temperature, providing touch reception, maintaining many metabolic functions, storing blood, and excreting a variety of substances.

The skin responds to injuries and wounds with inflammation, which causes redness, increased warmth, and painful swelling. Wound healing involves the processes of clotting, scabbing, collagenous fiber formation, revascularization, phagocytosis, scarring, and granulation tissue formation. Signs of skin aging usually appear when a person is in his or her late forties and include thinned gray hair, dry hair and skin, thin and sagging skin, bleeding inside skin, easier bruising, slower healing, and recurring infections. Protecting the skin from excessive UV radiation should continue throughout life to limit the amount of skin damage, wrinkling, sagging, and unsightly marking that might occur.

The three types of skin cancers are basal cell carcinoma, squamous cell carcinoma, and malignant melanoma. Malignant melanoma is the least common but most dangerous form because of its tendency to metastasize quickly. Burns are caused by intense heat, chemicals, electricity, or radiation that kills cells and denatures cell proteins. They are the leading causes of accidental death, which actually occurs after the burn due to dehydration, electrolyte imbalance, renal failure, and circulatory shock. First-degree burns most frequently occur from sunburns, whereas second-degree burns are often from scalding or severe sunburns. Third-degree burns often require skin grafts and usually cause severe disfigurement.

KEY TERMS

Acid mantle
Basal lamina
Burn
Ceruminous glands
Cleavage lines
Cuticle
Defensins
Dendritic cells
Dermicidin
Dermis
Desmosomes
Epidermis
Flexure lines
Hair bulb
Hair follicles
Hair matrix
Hyponychium
Integumentary system
Keratinocytes
Melanin
Melanocytes
Melanosomes
Nail folds
Papillary layer
Rule of nines
Sebaceous follicles
Sebaceous glands
Sebum
Sensory receptors
Stratum basale
Stratum corneum
Stratum germinativum
Stratum granulosum
Stratum lucidum
Stratum spinosum
Subcutaneous layer
Sweat glands (sudoriferous glands)
Tactile cells
Tyrosinase

LEARNING GOALS

The following learning goals correspond to the objectives at the beginning of this chapter:

1. The epidermis is the outer skin layer, made up of stratified squamous epithelium. The dermis is the inner layer and is much thicker than the epidermis. The dermis consists of papillary and reticular regions and is connected to the epidermis by a basement membrane.
2. Differences in skin color are based on the amount of melanin produced and how it is distributed throughout the skin. Well-oxygenated blood makes light-skinned people appear pinker, whereas poorly oxygenated blood makes them appear bluer. The build-up of bilirubin makes the skin appear yellowish.
3. The skin protects the body and helps to maintain homeostasis. It also aids in the regulation of body temperature, slows water loss from deep tissues, synthesizes biochemicals, excretes certain wastes, and contains sensory receptors. It also helps to produce vitamin D and to stimulate the development of white blood cells known as T lymphocytes.
4. Nails consist of a nail plate above a skin surface called the nail bed. The part of the nail plate that grows most actively is covered by a whitish, half-moon–shaped lunula, where epithelial cells divide and become keratinized. The nail cells push forward over the nail bed, causing the nail to continually grow outward.
5. Skin glands include sebaceous glands and sweat (sudoriferous) glands. Sebaceous glands are primarily located near hair follicles and secrete sebum, an oily mixture of fatty material and cell debris. Sebum helps to keep both hair and skin pliable and waterproof. Sweat (sudoriferous) glands originate in the deep dermis or superficial subcutaneous layers, and secrete sweat. The two types of sweat glands are merocrine (eccrine) and apocrine glands. Sweat is carried out of the skin through the pores and is made up of water, salt, and waste products such as urea and uric acid. Modified sweat glands include the ceruminous glands of the ear (which produce earwax) and the mammary glands (which produce milk).
6. The sweat glands help to regulate body temperature by releasing sweat to the skin surface, which evaporates to cool the skin.
7. The three most common forms of skin cancer are as follows:
   - *Basal cell carcinoma:* The least dangerous type, it appears as a small, shiny lesion and "bump" on the skin, which enlarges to form a central depression with a beaded, pearl-like edge.
   - *Squamous cell carcinoma:* The lesion appears raised, reddened, and scaly, forming a concave ulcer with edges that are raised. Early detection and surgical removal raises the survival rate, but this cancer often metastasizes to the lymph nodes to become potentially fatal.
   - *Malignant melanoma:* The least common yet most dangerous type, it metastasizes quickly and is often fatal if not treated immediately. The lesion appears as a large, flat, dark-colored patch that spreads and has a "scalloped" border.
8. Sebaceous glands are located near hair follicles and secrete sebum to lubricate the skin and hair. Ceruminous glands are located in the ears and secrete earwax.
9. A hair is made up of a root and a shaft. Hairs develop from epidermal cells at the base of tube-like hair follicles that extend from the skin surface into the dermis. The hair roots are nourished with dermal blood. Each hair follicle is attached to an arrector pili muscle, which helps the hair shaft to stand on end. Hairs are pushed upward, becoming keratinized and then dying. Hair shafts are actually composed of dead epidermal cells. Hair is found in most areas of the body.
10. Signs of aging in the integumentary system include the following:
    - The hair becomes thin, gray, and dry.
    - The skin becomes thinner, saggy, and less resistant to bleeding within the skin and bruising. It also heals more slowly from injuries and may experience recurring infections. The skin may also become yellowed, mottled, wrinkled, and marked with age spots.
    - Body heat regulation changes due to atrophy of blood vessels, sweat glands, and subcutaneous fat.

CRITICAL THINKING QUESTIONS

A 10-year-old boy who lived in Florida his entire life was diagnosed with melanoma. The boy previously had a mole that was ignored.

1. Why is melanoma the deadliest type of skin cancer?
2. List the methods that may be used to reduce likelihood of developing melanoma.
3. How is melanoma differentiated from the other types of skin cancer discussed in this chapter?

REVIEW QUESTIONS

1. Which of the following layers of the epidermis is found only on the skin of the soles of the feet and palms of the hands?
    A. stratum germinativum
    B. stratum granulosum
    C. stratum spinosum
    D. stratum lucidum
2. The most abundant cells in the epidermis are
    A. melanocytes
    B. keratinocytes
    C. adipocytes
    D. leukocytes
3. Which of the following glands discharge an oily secretion into the hair follicles?
    A. merocrine sweat glands
    B. sebaceous glands
    C. apocrine sweat glands
    D. ceruminous glands
4. The nail body covers the
    A. nail bed
    B. nail root
    C. free edge
    D. lunula
5. The highest concentration of merocrine sweat glands can be found
    A. on the palms of the hands
    B. on the chest
    C. on the upper back
    D. in the axillae
6. Which of the following vitamins is formed in the skin when it is exposed to sunlight?
    A. vitamin A
    B. vitamin B
    C. vitamin C
    D. vitamin D
7. Which of the following is a true statement about merocrine sweat glands?
    A. They primarily function in lubricating hairs.
    B. They secrete a watery fluid directly onto the surface of the skin.
    C. They increase in number and activity with aging.
    D. They produce a toxin that destroys bacteria.
8. An albino individual lacks the ability to produce
    A. carotene
    B. melanin
    C. keratin
    D. vitamin D
9. The cutaneous membrane includes which of the following components?
    A. epidermis and hypodermis
    B. integument and dermis
    C. epidermis and dermis
    D. epidermis and superficial fascia
10. Which layer of the epidermis undergoes cell division?
    A. stratum germinativum
    B. stratum granulosum
    C. stratum spinosum
    D. stratum corneum
11. Nails begin growing at the nail
    A. cuticle
    B. root
    C. body
    D. bed
12. A mammary gland is one type of
    A. ceruminous gland
    B. merocrine sweat gland
    C. apocrine sweat gland
    D. eccrine sweat gland

REVIEW QUESTIONS (CONTINUED)

13. Which of the following layers of the skin provides initial protection against bacteria?
    A. subcutaneous layer
    B. dermis
    C. stratum corneum
    D. epidermis
14. The region of the dermis that is in direct contact with the epidermis is the
    A. papillary region
    B. stratum corneum
    C. hypodermis
    D. reticular region
15. Which of the following statements about the function of the skin is false?
    A. It helps regulate body temperature.
    B. It participates in the synthesis of vitamin D.
    C. It is waterproof.
    D. It detects stimuli related to temperature and pain.

ESSAY QUESTIONS

1. Distinguish between sensible and insensible perspiration.
2. Which layer of the epidermis is the thickest, and what is its role?
3. Describe the process of hair formation.
4. Explain melanin, carotene, and hemoglobin.
5. Which epidermal cells are referred to as prickle cells?
6. What is the cause of skin wrinkling?
7. Distinguish first-, second-, and third-degree burns.
8. What condition may cause horizontal Beau's lines across the nails?
9. Distinguish between vellus and terminal hair.
10. What is the role of the sebaceous glands in the skin?