Integumentary System

5

FIGURE: Immediate medical attention is essential in an attempt to save a person who has experienced an extensive and severe burn. Of major concern is the rapid loss of body fluids.

Clinical Case Study

A 27-year-old male was involved in a gasoline explosion and sustained burns to his face, neck, chest, and arms. Upon arrival at the emergency room, he complained of intense pain on his face and neck, both of which exhibited extensive blistering and erythema (redness). These findings were all curiously absent on the burned chest and arms, which had a pale, waxy appearance.

Examination revealed the skin on the patient's chest and arms to be leathery and lacking sensation. The emergency room physician commented to an observing medical student that third-degree burns were present on the skin of these regions and that excision of the burn eschar (traumatized tissue) with subsequent skin grafting would be required.

Why would the areas that sustained second-degree burns be red, blistered, and painful, while the third-degree burns were pale and insensate (without sensation, including pain)? Why would the chest and arms require skin grafting, but probably not the face and neck?

Hints: Think in terms of functions of the skin and survival of the germinal cells in functioning skin. Carefully examine figures 5.1 and 5.20.

THE SKIN AS AN ORGAN

The skin (integument) is the largest organ of the body, and together with its accessory organs (hair, glands, and nails), it constitutes the integumentary system. In certain areas of the body, it has adaptive modifications that accommodate protective or metabolic functions. In its role as a dynamic interface between the continually changing external environment and the body's internal environment, the skin helps maintain homeostasis.

Objective 1 Explain why the skin is considered an organ and a component of the integumentary system.

Objective 2 Describe some common clinical conditions of the skin that result from nutritional deficiencies or body dysfunctions.

We are more aware of and concerned with our integumentary system than perhaps any other system of our body. One of the first things we do in the morning is to look in a mirror and see what we have to do to make our skin and hair presentable. Periodically, we examine our skin for wrinkles and our scalp for gray hairs as signs of aging. We recognize other people to a large extent by features of their skin.

The appearance of our skin frequently determines the initial impression we make on others. Unfortunately, it may also determine whether or not we succeed in gaining social acceptance. For example, social rejection as a teenager, imagined or real, can be directly associated with skin problems such as acne. A person's self-image and consequent social behavior may be closely associated with his or her physical appearance.

Even clothing styles are somewhat determined by how much skin we, or the designers, want to expose. But our skin is much more than a showpiece. It helps regulate certain body functions and protect certain body structures.

The skin, or *integument (in-teg'yoo-ment)*, and its accessory structures (hair, glands, and nails) constitute the integumentary system. Included in this system are the millions of sensory receptors of the skin and its extensive vascular network. The skin is a dynamic interface between the body and the external environment. It protects the body from the environment even as it allows for communication with the environment.

The skin is an organ, because it consists of several kinds of tissues that are structurally arranged to function together. It is the largest organ of the body, covering over 7,600 sq cm (3,000 sq in.) in the average adult, and accounts for approximately 7% of a person's body weight. The skin is of variable thickness, averaging 1.5 mm. It is thickest on the parts of the body exposed to wear and abrasion, such as the soles of the feet and palms of the hand. In these areas, it is about 6 mm thick. It is thinnest on the eyelids, external genitalia, and tympanic membrane (eardrum), where it is approximately 0.5 mm thick. Even its appearance and texture varies from the rough, callous skin covering the elbows and knuckles to the soft, sensitive areas of the eyelids, nipples, and genitalia.

The general appearance of the skin is clinically important because it provides clues to certain body dysfunctions. Pale skin may indicate shock, whereas red, flushed, overwarm skin may indicate fever and infection. A rash may indicate allergies or local infections. Abnormal textures of the skin may be the result of glandular or nutritional problems (table 5.1). Even chewed fingernails may be a clue to emotional problems.

Knowledge Check

1. Explain why the skin is considered an organ and why the skin, together with the integumentary derivatives, is considered a system.
2. Which vitamins and minerals are important for healthy skin? (See table 5.1.)
3. Describe the appearance of the skin that may accompany each of the following conditions: allergy; shock; infection; dry, stiff hair; hyperpigmentation; and general dermatitis.

LAYERS OF THE SKIN

The skin consists of two principal layers. The outer epidermis is stratified into four or five structural layers, and the thick and deeper dermis consists of two layers. The hypodermis (subcutaneous tissue) connects the skin to underlying organs.

Objective 3 Describe the histological characteristics of each layer of the skin.

Objective 4 Summarize the transitional events that occur within each of the epidermal layers.

Epidermis

The **epidermis** (*ep"ĭ-der'mis*) is the superficial protective layer of the skin. Derived from ectoderm, the epidermis is composed of stratified squamous epithelium that varies in thickness from 0.007 to 0.12 mm. All but the deepest layers are composed of dead cells. Either four or five layers may be present, depending on where the epidermis is located (figs. 5.1 and 5.2). The epidermis of the palms and soles has five layers because these areas are exposed to the most friction. In all other areas of the body, the epidermis has only four layers. The names and characteristics of the epidermal layers are as follows.

1. **Stratum basale** (basal layer). The stratum basale (*stra'tum bă-sal'e*) consists of a single layer of cells in contact with the dermis. Four types of cells compose the stratum

integument: L. *integumentum*, a covering

stratum: L. *stratum*, something spread out

basale: Gk. *basis*, base

TABLE 5.1 Conditions of the Skin and Associated Structures Indicating Nutritional Deficiencies or Body Dysfunctions

Condition	Deficiency	Comments
General dermatitis	Zinc	Redness and itching
Scrotal or vulval dermatitis	Riboflavin	Inflammation in genital region
Hyperpigmentation	Vitamin B_{12}, folic acid, or starvation	Dark pigmentation on backs of hands and feet
Dry, stiff, brittle hair	Protein, calories, and other nutrients	Usually occurs in young children or infants
Follicular hyperkeratosis	Vitamin A, unsaturated fatty acids	Rough skin caused by keratotic plugs from hair follicles
Pellagrous dermatitis	Niacin and tryptophan	Lesions on areas exposed to sun
Thickened skin at pressure points	Niacin	Noted at belt area at the hips
Spoon nails	Iron	Thin nails that are concave or spoon-shaped
Dry skin	Water or thyroid hormone	Dehydration, hypothyroidism, rough skin
Oily skin (acne)		Hyperactivity of sebaceous glands

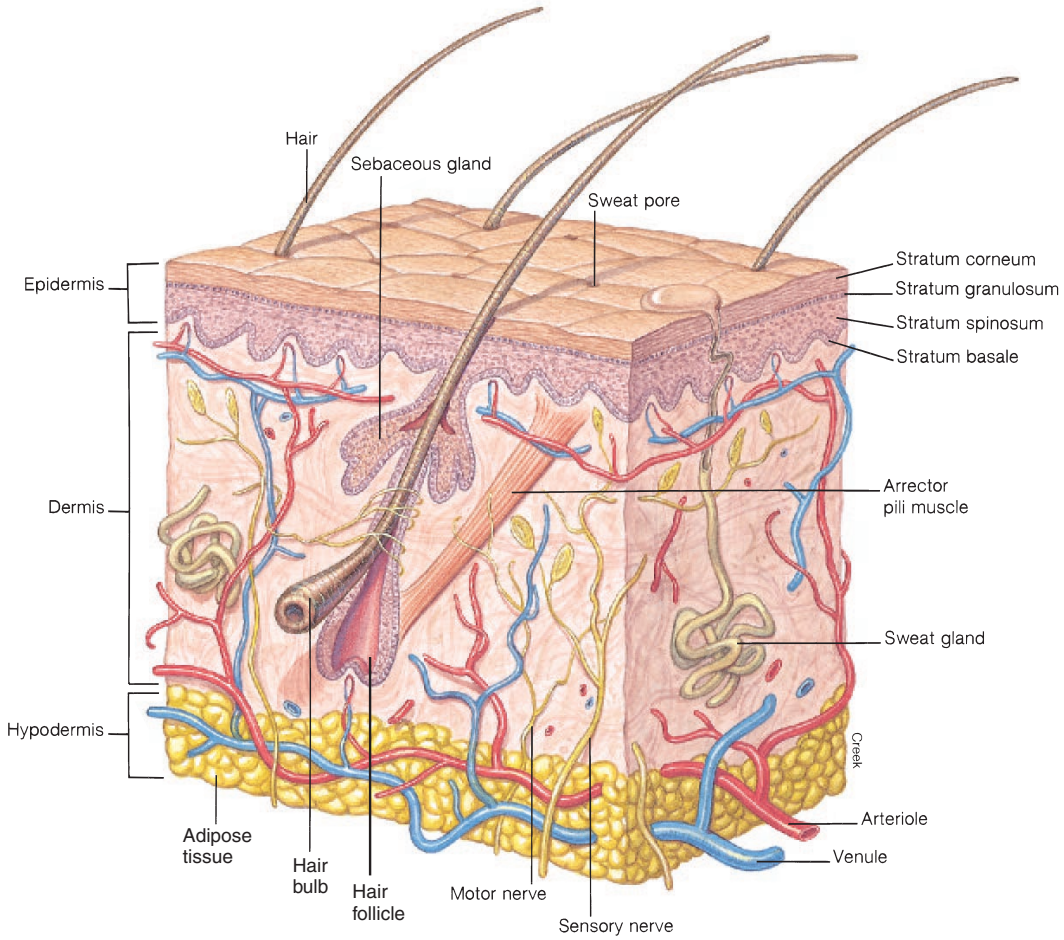


FIGURE 5.1 A diagram of the skin.

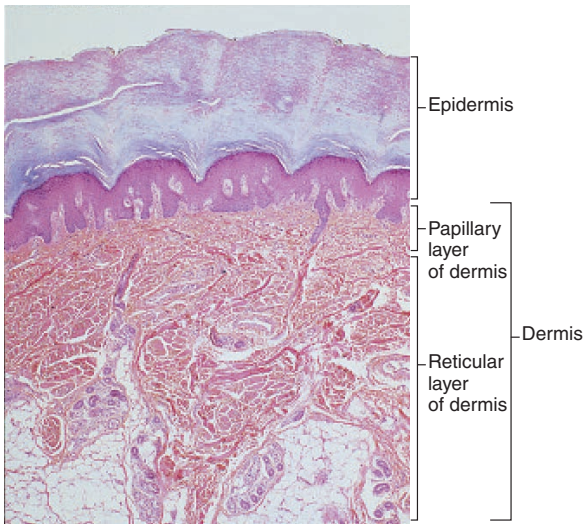


FIGURE 5.2 A light micrograph of the epidermis (25×).

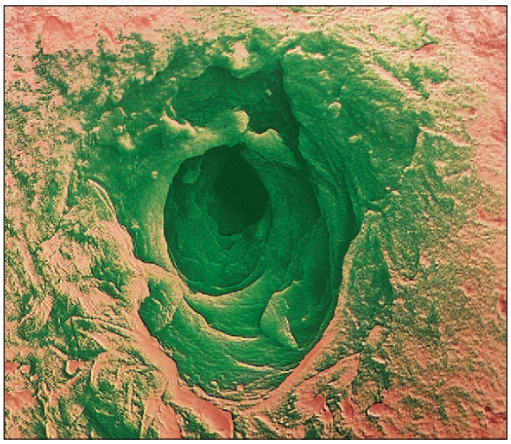


FIGURE 5.3 A scanning electron micrograph of the surface of the skin showing the opening of a sweat gland.

basale: *keratinocytes (ker''ă-tin'o-sīts)*, *melanocytes (mel'ă-no-sīts)*, *tactile cells (Merkel cells)*, and *nonpigmented granular dendrocytes (Langerhans cells)*. With the exception of tactile cells, these cells are constantly dividing mitotically and moving outward to renew the epidermis. It usually takes between 6 to 8 weeks for the cells to move from the stratum basale to the surface of the skin.

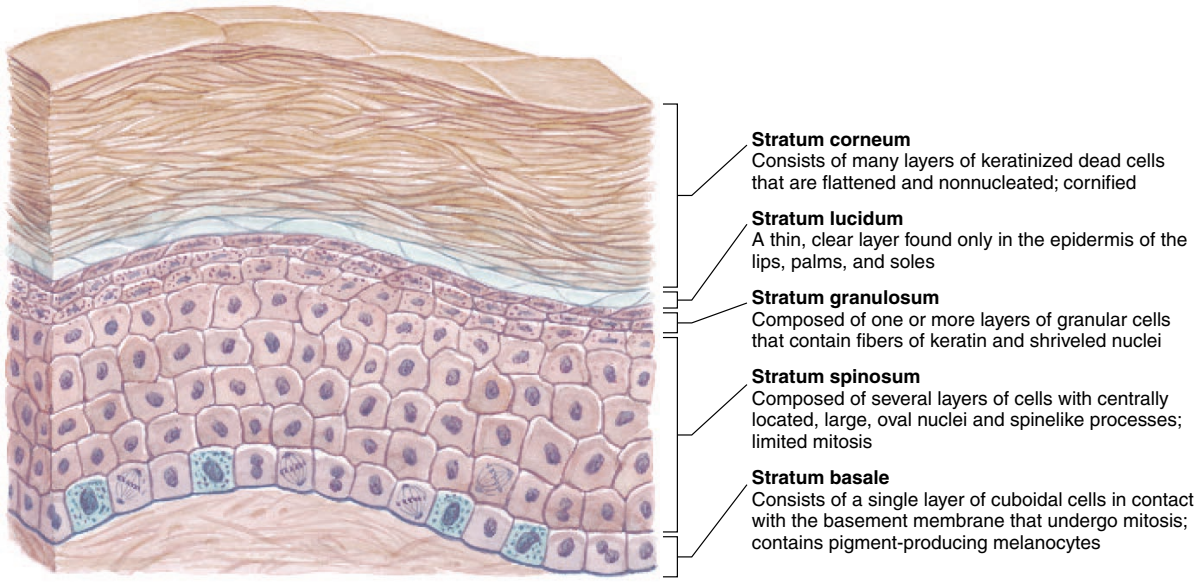
Keratinocytes are specialized cells that produce the protein **keratin** (*ker'ă-tin*), which toughens and waterproofs the skin. As keratinocytes are pushed away from the vascular nutrient and oxygen supply of the dermis, their nuclei degenerate, their cellular content becomes dominated by keratin, and the process of *keratinization* is completed. By the time keratinocytes reach the surface of the skin, they resemble flat dead scales. They are completely filled with keratin enclosed in loose cell membranes. **Melanocytes** are specialized epithelial cells that synthesize the pigment **melanin** (*mel'ă-nin*) which provides a protective barrier to the ultraviolet radiation in sunlight. **Tactile cells** are sparse compared to keratinocytes and melanocytes. These sensory receptor cells aid in tactile (touch) reception. **Nonpigmented granular dendrocytes** are scattered throughout the stratum basale. They are protective *macrophagic cells* that ingest bacteria and other foreign debris.

2. **Stratum spinosum** (spiny layer). The stratum spinosum (*spi-no'sum*) contains several layers of cells. The spiny appearance of this layer is due to the spinelike extensions that arise from the keratinocytes when the tissue is fixed for microscopic examination. Because there is limited mitosis in the stratum spinosum, this layer and the stratum basale are collectively referred to as the **stratum germinativum** (*jer-mĭ''nă-ti'vum*).
3. **Stratum granulosum** (granular layer). The stratum granulosum (*gran''yoo-lo'sum*) consists of only three or four flattened layers of cells. These cells contain granules that are filled with *keratohyalin*, a chemical precursor to keratin.
4. **Stratum lucidum** (clear layer). The nuclei, organelles, and cell membranes are no longer visible in the cells of the stratum lucidum (*loo'sĭ-dum*), and so histologically this layer appears clear. It exists only in the lips and in the thickened skin of the soles and palms.
5. **Stratum corneum** (hornlike layer). The stratum corneum (*kor'ne-um*) is composed of 25 to 30 layers of flattened, scalelike cells. Thousands of these dead cells shed from the skin surface each day, only to be replaced by new ones from deeper layers. This surface layer is cornified; it is the layer that actually protects the skin (fig. 5.3). *Cornification*, brought on by keratinization, is the drying and flattening of the stratum corneum and is an important protective adaptation of the skin. Friction at the surface of

keratinocyte: Gk. *keras*, homlike; *kytos*, cell
melanocyte: Gk. *melas*, black; *kytos*, cell
Merkel cells: from F. S. Merkel, German anatomist, 1845–1919
Langerhans cells: from Paul Langerhans, German anatomist, 1847–1888
macrophagic: L. *makros*, large; *phagein*, to eat

spinosum: L. *spina*, thorn
germinativum: L. *germinare*, spout or growth
granulosum: L. *granum*, grain
lucidum: L. *lucidus*, light
corneum: L. *corneus*, hornlike

TABLE 5.2 Layers of the Epidermis



the skin stimulates additional mitotic activity in the stratum basale and stratum spinosum, which may result in the formation of a *callus* for additional protection.

The specific characteristics of each epidermal layer are described in table 5.2.

Tattooing colors the skin permanently because dyes are injected below the mitotic basal layer of the epidermis into the underlying dermis. In nonsterile conditions, infectious organisms may be introduced along with the dye. Small tattoos can be removed by skin grafting; for large tattoos, mechanical abrasion of the skin is preferred.

Coloration of the Skin

Normal skin color is the expression of a combination of three pigments: *melanin*, *carotene*, and *hemoglobin*. **Melanin** is a brown-black pigment produced in the melanocytes of the stratum basale (fig. 5.4). All individuals of similar size have approximately the same number of melanocytes, but the amount of melanin produced and the distribution of the melanin determine racial variations in skin color, such as black, brown, yellow, and white. Melanin protects the basal layer against the damaging effect of the ultraviolet (UV) rays of the sun. A gradual exposure to the sunlight promotes the increased production of melanin within the melanocytes, and hence tanning of the skin. The skin of a person with *albinism* (*al′bĭ-niz-em*) has the normal number of melanocytes in the epidermis but lacks the enzyme *tyrosinase* that converts the amino acid *tyrosine* to melanin. Albinism is a hereditary condition.

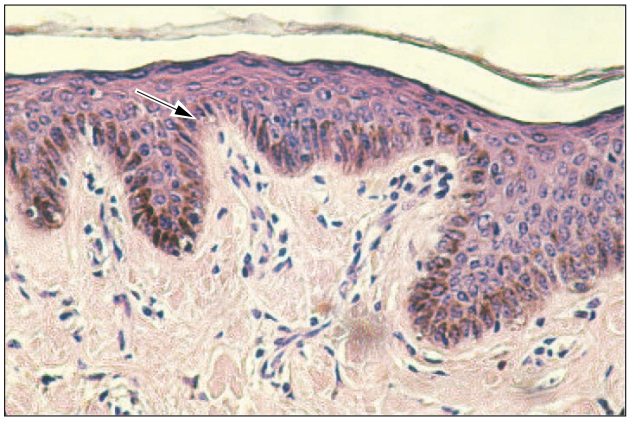


FIGURE 5.4 Melanocytes throughout the stratum basale (see arrow) produce melanin.

Other genetic expressions of melanocytes are more common than albinism. *Freckles*, for example, are caused by aggregated patches of melanin. A lack of melanocytes in localized

areas of the skin causes distinct white spots in the condition called *vitiligo (vit-ĭ-li'go)*. After the age of 50, brown plaquelike growths, called *seborrheic (seb''ŏ-re'ik) hyperkeratoses*, may appear on the skin, particularly on exposed portions. Commonly called "liver spots," these pigmented patches are benign growths of pigment-producing melanocytes. Usually no treatment is required, unless for cosmetic purposes.

Excessive exposure to sunlight can cause skin cancer (see Clinical Considerations and fig. 5.18). In sunlight, the skin absorbs two wavelengths of ultraviolet rays known as *UVA* and *UVB*. The DNA within the basal skin cells may be damaged as the sun's more dangerous UVB rays penetrate the skin. Although it was once believed that UVA rays were harmless, findings now indicate that excessive exposure to these rays may inhibit the DNA repair process that follows exposure to UVB. Therefore, individuals who are exposed solely to UVA rays in tanning salons are still in danger of basal cell carcinoma, because they will later be exposed to UVB rays of sunlight when they go outdoors.

Carotene (*kar'ŏ-tēn*) is a yellowish pigment found in certain plant products, such as carrots, that tends to accumulate in cells of the stratum corneum and fatty parts of the dermis. It was once thought to account for the yellow-tan skin of people of Asian descent, but this coloration is now known to be caused by variations in melanin.

Hemoglobin (*he''mo-glo'bin*) is not a pigment of the skin; rather, it is the oxygen-binding pigment found in red blood cells. Oxygenated blood flowing through the dermis gives the skin its pinkish tones.

Certain physical conditions or diseases cause symptomatic discoloration of the skin. *Cyanosis (si-ă-no'sis)* is a bluish discoloration of the skin that appears in people with certain cardiovascular or respiratory diseases. People also become cyanotic during an interruption of breathing. In *jaundice,* the skin appears yellowish because of an excess of bile pigment in the bloodstream. Jaundice is usually symptomatic of liver dysfunction and sometimes of liver immaturity, as in a jaundiced newborn. *Erythema (er''ĭ-the'mă)* is a redness of the skin generally due to vascular trauma, such as from a sunburn.

Surface Patterns

The exposed surface of the skin has recognizable patterns that are either present at birth or develop later. **Fingerprints** (*friction ridges*) are congenital patterns that are present on the finger and toe pads, as well as on the palms and soles. The designs formed by these lines have basic similarities but are not identical in any two individuals (fig. 5.5). They are formed by the pull of elastic fibers within the dermis and are well established prenatally. The ridges of fingerprints function to prevent slippage when grasping objects. Because they are precise and easy to reproduce, fingerprints are customarily used for identifying individuals.

vitiligo: L. *vitiatio*, blemish
carotene: L. *carota*, carrot (referring to orange coloration)
hemoglobin: Gk. *haima*, blood; *globus*, globe
cyanosis: Gk. *kyanosis*, dark blue color
jaundice: L. *galbus*, yellow
erythema: Gk. *erythros*, red; *haima*, blood

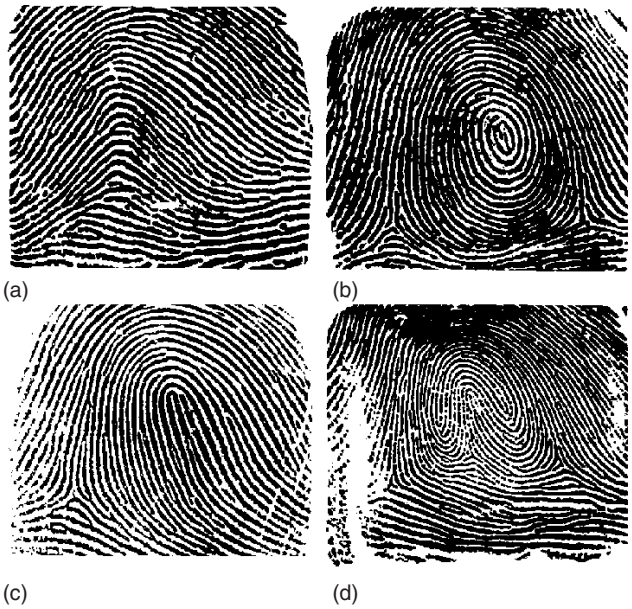


FIGURE 5.5 The four basic fingerprint patterns (*a*) arch, (*b*) whorl, (*c*) loop, and (*d*) combination.

Acquired lines include the deep **flexion creases** on the palms and the shallow **flexion lines** that can be seen on the knuckles and on the surface of other joints. Furrows on the forehead and face are acquired from continual contraction of facial muscles, such as from smiling or squinting in bright light or against the wind. Facial lines become more strongly delineated as a person ages.

The science known as *dermatoglyphics* is concerned with the classification and identification of fingerprints. Every individual's prints are unique, including those of identical twins. Fingerprints, however, are not exclusive to humans. All other primates have fingerprints, and even dogs have a characteristic "nose print" that is used for identification in the military canine corps and in certain dog kennels.

Dermis

The **dermis** is deeper and thicker than the epidermis (see fig. 5.1). Elastic and collagenous fibers within the dermis are arranged in definite patterns, producing *lines of tension* in the skin and providing skin tone (fig. 5.6). There are many more elastic fibers in the dermis of a young person than in an elderly one, and a decreasing number of elastic fibers is apparently associated with aging. The extensive network of blood vessels in the dermis provides nourishment to the living portion of the epidermis.

The dermis also contains many sweat glands, oil-secreting glands, nerve endings, and hair follicles.

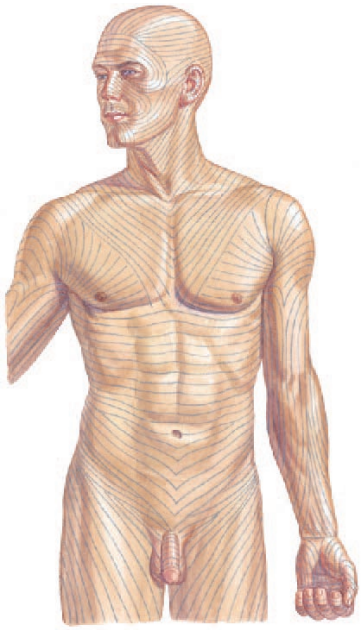


FIGURE 5.6 Lines of tension are caused by the pull of elastic and collagenous fibers within the dermis of the skin. Surgical incisions made parallel to the lines of tension heal more rapidly and create less scar tissue than those made across the lines of tension.

Layers of the Dermis

The dermis is composed of two layers. The upper layer, called the **stratum papillarosum** (papillary layer), is in contact with the epidermis and accounts for about one-fifth of the entire dermis (see fig. 5.2). Numerous projections, called *papillae (pă-pil'e)*, extend from the upper portion of the dermis into the epidermis. Papillae form the base for the friction ridges on the fingers and toes.

The deeper and thicker layer of the dermis is called the **stratum reticularosum** (reticular layer). Fibers within this layer are more dense and regularly arranged to form a tough, flexible meshwork. It is quite distensible, as is evident in pregnant women or obese individuals, but it can be stretched too far, causing "tearing" of the dermis. The repair of a strained dermal area leaves a white streak called a stretch mark, or **linea albicans** (*lin'e-ă al'bĭ-kanz*). Lineae albicantes are frequently found on the buttocks, thighs, abdomen, and breasts (fig. 5.7).

It is the strong, resilient reticular layer of domestic mammals that is used in making leather and suede. In the tanning process, the hide of an animal is treated with various chemicals that cause the epidermis with its hair and the papillary layer of the dermis to separate from the underlying reticular layer. The reticular layer is then softened and treated with protective chemicals before being cut and assembled into consumer goods.

papilla: L. *papula*, swelling or pimple

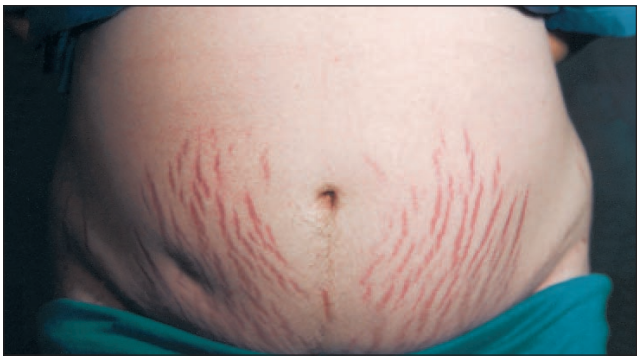


FIGURE 5.7 Stretch marks (lineae albicantes) on the abdomen of a pregnant woman. Stretch marks generally fade with time but may leave permanent markings.

Innervation of the Skin

The dermis of the skin has extensive innervation (nerve supply). Specialized integumentary *effectors* consist of smooth muscles or glands within the dermis that respond to motor impulses transmitted from the central nervous system to the skin by autonomic nerve fibers.

Several types of **sensory receptors** respond to various tactile (touch), pressure, temperature, tickle, or pain stimuli. Some are free nerve endings, some form a network around hair follicles, and some extend into the papillae of the dermis. Certain areas of the body, such as the palms, soles, lips, and external genitalia, have a greater concentration of sensory receptors and are therefore more sensitive to touch. Chapter 15 includes a detailed discussion of the structure and function of the various sensory receptors.

Vascular Supply of the Skin

Blood vessels within the dermis supply nutrients to the mitotically active stratum basale of the epidermis and to the cellular structures of the dermis, such as glands and hair follicles. Dermal blood vessels play an important role in regulating body temperature and blood pressure. Autonomic vasoconstriction or vasodilation responses can either shunt the blood away from the superficial dermal arterioles or permit it to flow freely throughout dermal vessels. Fever or shock can be detected by the color and temperature of the skin. Blushing is the result of involuntary vasodilation of dermal blood vessels.

It is important to maintain good blood circulation in people who are bedridden to prevent bedsores, or *decubitus (de-kyoo'bī-tus) ulcers*. When a person lies in one position for an extended period, the dermal blood flow is restricted where the body presses against the bed. As a consequence, cells die and open wounds may develop (fig. 5.8). Changing the position of the patient frequently and periodically massaging the skin to stimulate blood flow are good preventive measures against decubitus ulcers.

decubitus: L. *decumbere*, lie down

ulcer: L. *ulcus*, sore

FIGURE 5.8 A bedsore (decubitus ulcer) on the medial surface of the ankle. Bedsores are most common on skin overlying a bony projection, such as at the hip, ankle, heel, shoulder, or elbow.

Hypodermis

The **hypodermis,** or *subcutaneous tissue*, is not actually a part of the skin, but it binds the dermis to underlying organs. The hypodermis is composed primarily of loose connective tissue and adipose cells interlaced with blood vessels (see fig. 5.1). Collagenous and elastic fibers reinforce the hypodermis—particularly on the palms and soles, where the skin is firmly attached to underlying structures. The amount of adipose tissue in the hypodermis varies with the region of the body and the sex, age, and nutritional state of the individual. Females generally have about an 8% thicker hypodermis than males. This layer functions to store lipids, insulate and cushion the body, and regulate temperature.

The hypodermis is the site for subcutaneous injections. Using a hypodermic needle, medicine can be administered to patients who are unconscious or uncooperative, and when oral medications are not practical. Subcutaneous devices to administer slow-release, low-dosage medications are now available. For example, insulin may be administered in this way to treat some forms of diabetes. Even a subcutaneous birth-control device (Norplant) is currently being marketed (see fig. 21.26).

Knowledge Check

4. List the layers of the epidermis and dermis and explain how they differ in structure and function.
5. Describe the sequence of cellular replacement within the epidermis and the processes of keratinization and cornification.
6. How do both the dermis and hypodermis function in thermoregulation?
7. What two basic types of innervation are found within the dermis?

hypodermis: Gk. *hypo*, under; *derma*, skin

FUNCTIONS OF THE SKIN

The skin not only protects the body from pathogens and external injury, it is a highly dynamic organ that plays a key role in maintaining body homeostasis.

Objective 5 Discuss the role of the skin in the protection of the body from disease and external injury, the regulation of body fluids and temperature, absorption, synthesis, sensory reception, and communication.

Physical Protection

The skin is a barrier to microorganisms, water, and excessive sunlight (UV light). Oily secretions onto the surface of the skin form an acidic protective film (pH 4.0–6.8) that waterproofs the body and retards the growth of most pathogens. The protein keratin in the epidermis also waterproofs the skin, and the cornified outer layer (stratum corneum) resists scraping and keeps out microorganisms. As mentioned previously, exposure to UV light stimulates the melanocytes in the stratum basale to synthesize melanin, which absorbs and disperses sunlight. In addition, surface friction causes the epidermis to thicken by increasing the rate of mitosis in the cells of the stratum basale and stratum spinosum, resulting in the formation of a protective *callus*.

Regardless of skin pigmentation, everyone is susceptible to skin cancer if his or her exposure to sunlight is sufficiently intense. There are an estimated 800,000 new cases of skin cancer yearly in the United States, and approximately 9,300 of these are diagnosed as the potentially life-threatening *melanoma (mel-ă-no'mă)* (cancer of melanocytes). Melanomas (see fig. 5.19) are usually termed malignant, because they may spread rapidly. Sunscreens are advised for people who must be in direct sunlight for long periods of time.

Hydroregulation

The thickened, keratinized, and cornified epidermis of the skin is adapted for continuous exposure to the air. In addition, the outer layers are dead and scalelike, and a protein-polysaccharide basement membrane adheres the stratum basale to the dermis. Human skin is virtually waterproof, protecting the body from desiccation (dehydration) on dry land, and even from water absorption when immersed in water.

Thermoregulation

The skin plays a crucial role in the regulation of body temperature. Body heat comes from cellular metabolism, particularly in muscle cells as they maintain tone or a degree of tension. A nor-

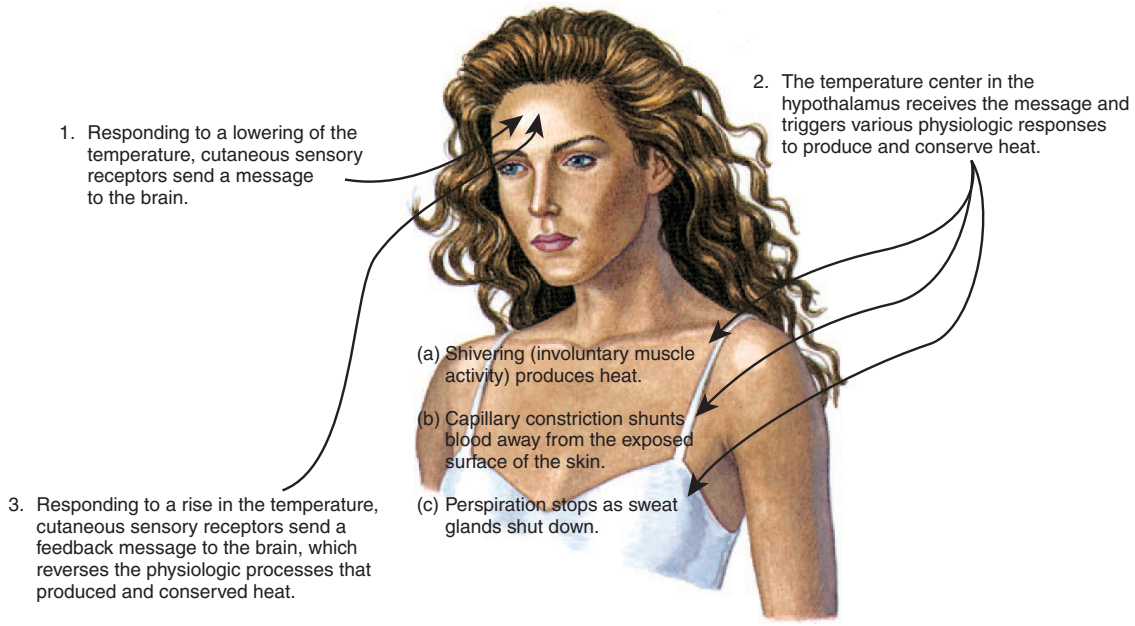


FIGURE 5.9 Temperature regulation involves cutaneous sensory receptors that relay messages of decreased body temperature to the brain. This triggers a response that can quickly generate up to 5 times the normal rate of body heat production.

mal body temperature of 37° C (98.6° F) is maintained in three ways, all involving the skin (fig. 5.9):

1. through radiant heat loss from dilated blood vessels,
2. through evaporation of perspiration, and
3. through retention of heat from constricted blood vessels (fig. 5.10).

The volume of perspiration produced is largely a function of how much the body is overheated. This volume increases approximately 100 to 150 ml/day for each 1° C elevation in body temperature. For each hour of hard physical work out-of-doors in the summertime, a person may produce 1 to 10 L of perspiration.

A serious danger of continued exposure to heat and excessive water and salt loss is *heat exhaustion,* characterized by nausea, weakness, dizziness, headache, and a decreased blood pressure. *Heat stroke* is similar to heat exhaustion, except that in heat stroke sweating is prevented (for reasons that are not clear) and body temperature rises. Convulsions, brain damage, and death may follow.

Excessive heat loss triggers a shivering response in muscles, which increases cellular metabolism. Not only do skeletal muscles contract, but tiny smooth muscles called **arrectores pilorum** (*ă″rek-to′rēz pil-o′rum*—singular, *arrector pili*), which are attached to hair follicles, are also contracted involuntarily and cause goose bumps.

When the body's heat-producing mechanisms cannot keep pace with heat loss, *hypothermia* results. A lengthy exposure to temperatures below 20° C (68° F) and dampness may lead to this condition. This is why it is so important that a hiker, for example, dress appropriately for the weather conditions, especially on cool, rainy spring or fall days. The initial symptoms of hypothermia are numbness, paleness, delirium, and uncontrolled shivering. If the core temperature falls below 32° C (90° F), the heart loses its ability to pump blood and will go into fibrillation (erratic contractions). If the victim is not warmed, extreme drowsiness, coma, and death follow.

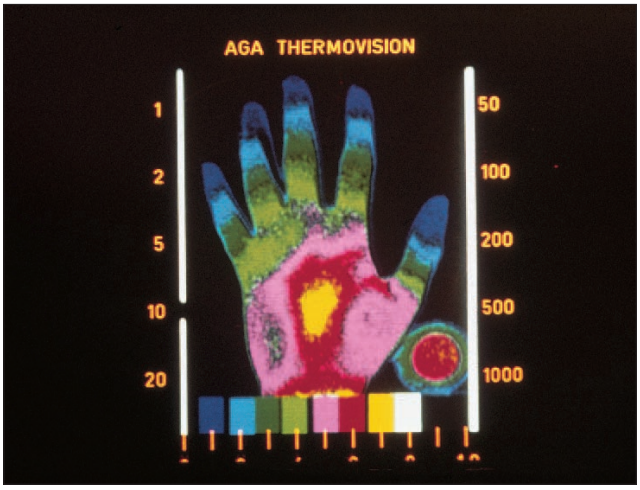


FIGURE 5.10 A thermogram of the hand showing differential heat radiation. Hair and body fat are good insulators. Red and yellow indicate the warmest parts of the body. Blue, green, and white indicate the coolest.

(a) (b)

FIGURE 5.11 (*a*) Rickets in a child from a Nepalese village, whose inhabitants live in windowless huts. During the rainy season, which may last 5 to 6 months, the children are kept indoors. (*b*) A radiograph of a 10-month-old child with rickets. Rickets develops from an improper diet and also from lack of the sunlight needed to synthesize vitamin D.

Cutaneous Absorption

Because of the effective protective barriers of the integument already described, cutaneous absorption (absorption through the skin) is limited. Some gases, such as oxygen and carbon dioxide, may pass through the skin and enter the blood. Small amounts of UV light, necessary for synthesis of vitamin D, are absorbed readily. Of clinical consideration is the fact that certain chemicals such as lipid-soluble toxins and pesticides can easily enter the body through the skin.

Synthesis

The integumentary system synthesizes melanin and keratin, which remain in the skin synthesis of vitamin D, which is used elsewhere in the body and begins in the skin with activation of a precursor molecule by UV light. The molecule is modified in the liver and kidneys to produce *calcitriol (kal-sĭ-tre′ol)*, the most active form of vitamin D. Only small amounts of UV light are necessary for vitamin D synthesis, but these amounts are very important to a growing child. Active vitamin D enters the blood and helps regulate the metabolism of calcium and phosphorus, which are important in the development of strong and healthy bones. *Rickets* is a disease caused by vitamin D deficiency (fig. 5.11).

Sensory Reception

Highly specialized sensory receptors (see chapter 15) that respond to the precise stimuli of heat, cold, pressure, touch, vibration, and pain are located throughout the dermis. Called **cutaneous receptors,** these sensory nerve cells are especially abundant in the skin of the face and palms, the fingers, the soles of the feet, and the genitalia. They are less abundant along the back and on the back of the neck and are sparse in the skin over joints, especially the elbow. Generally speaking, the thinner the skin, the greater the sensitivity.

Communication

Humans are highly social animals, and the integument plays an important role in communication. Various emotions, such as anger or embarrassment, may be reflected in changes of skin color. The contraction of specific facial muscles produces facial expressions that convey an array of emotions, including love, surprise, happiness, sadness, and despair. Secretions from certain integumentary glands have odors that frequently elicit subconscious responses from others who detect them.

Knowledge Check

8. List five modifications of the integument that are structurally or functionally protective.
9. Explain how the integument functions to regulate body fluids and temperature.
10. What substances are synthesized in the integument?

EPIDERMAL DERIVATIVES

Hair, nails, and integumentary glands form from the epidermal layer, and are therefore of ectodermal derivation. Hair and nails are structural features of the integument and have a limited functional role. By contrast, integumentary glands are extremely important in body defense and maintenance of homeostasis.

Objective 6 Describe the structure of hair and list the three principal types.

Objective 7 Discuss the structure and function of nails.

Objective 8 Compare and contrast the structure and function of the three principal kinds of integumentary glands.

Hair

The presence of **hair** on the body is one of the distinguishing features of mammals, but its distribution, function, density, and texture varies across mammalian species. Humans are relatively hairless, with only the scalp, face, pubis, and axillae being densely haired. Men and women have about the same density of hair on their bodies, but hair is generally more obvious on men (fig. 5.12) as a result of male hormones. Certain structures and regions of the body are hairless, such as the palms, soles, lips, nipples, penis, and parts of the female genitalia.

Hirsutism (her'soo-tiz''em) is a condition of excessive body and facial hair, especially in women. It may be a genetic expression, as in certain ethnic groups, or occur as the result of a metabolic disorder, usually endocrine. Hirsutism occurs in some women as they experience hormonal changes during menopause. Various treatments for hirsutism include hormonal injections and electrolysis to permanently destroy selected hair follicles.

The primary function of hair is protection, even though its effectiveness is limited. Hair on the scalp and eyebrows protect against sunlight. The eyelashes and the hair in the nostrils protect against airborne particles. Hair on the scalp may also protect against mechanical injury. Some secondary functions of hair are to distinguish individuals and to serve as a sexual attractant.

Each hair consists of a diagonally positioned **shaft, root,** and **bulb** (fig. 5.13). The shaft is the visible, but dead, portion of the hair projecting above the surface of the skin. The bulb is the enlarged base of the root within the **hair follicle.** Each hair develops from stratum basale cells within the bulb of the hair, where nutrients are received from dermal blood vessels. As the cells divide, they are pushed away from the nutrient supply toward the surface, and cellular death and keratinization occur. In a healthy person, hair grows at the rate of approximately 1 mm every 3 days. As the hair becomes longer, however, it enters a resting period, during which there is minimal growth.

hirsutism: L. *hirsutus*, shaggy

(a)

(b)

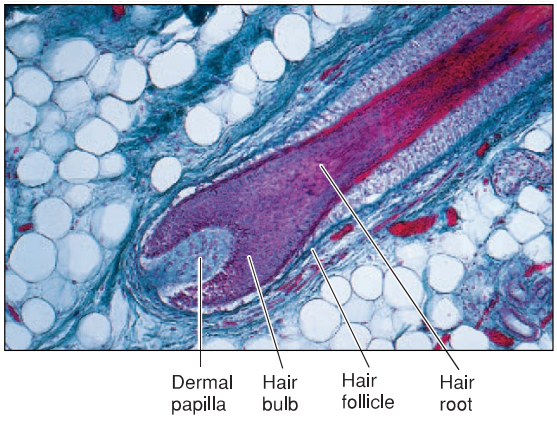
FIGURE 5.12 A comparison of the expression of body hair in males and females.

The life span of a hair varies from 3 to 4 months for an eyelash to 3 to 4 years for a scalp hair. Each hair lost is replaced by a new hair that grows from the base of the follicle and pushes the old hair out. Between 10 and 100 hairs are lost daily. Baldness results when hair is lost and not replaced. This condition may be disease-related, but it is generally inherited and most frequently occurs in males because of genetic influences combined with the action of the male sex hormone *testosterone (tes-tos'tĕ-rōn)*. No treatment is effective in reversing genetic baldness; however, flaps or plugs of skin containing healthy follicles from hairy parts of the body can be grafted onto hairless regions.

Three layers can be observed in hair that is cut in cross section. The inner **medulla** (*mĕ-dul'ă*) is composed of loosely arranged cells separated by numerous air cells. The thick **cortex**

medulla: L. *medulla*, marrow

cortex: L. *cortex*, bark



(a)

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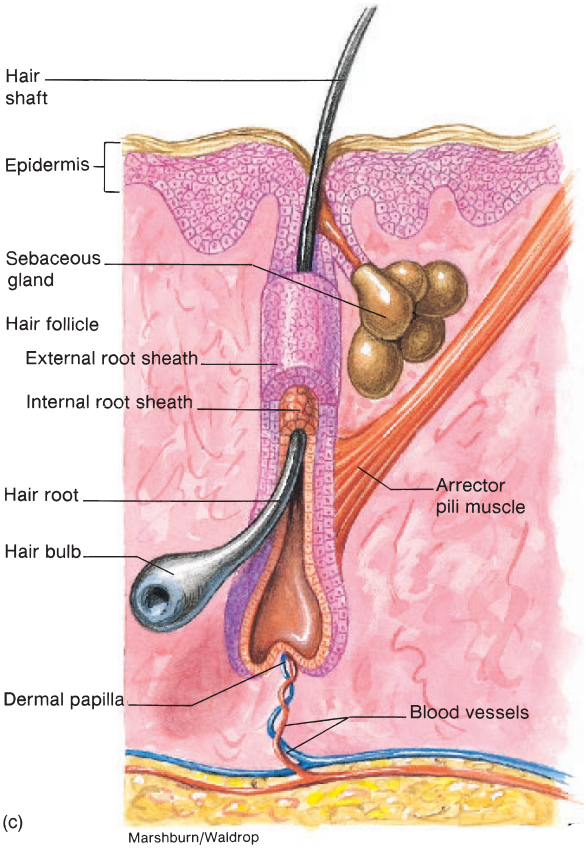


(c)

Marshburn/Waldrop

FIGURE 5.13 The structure of hair and the hair follicle. (*a*) A photomicrograph (63×) of the bulb and root of a hair within a hair follicle. (*b*) A scanning electron micrograph (280×) of a hair as it extends from a follicle. (*c*) A diagram of hair, a hair follicle, and sebaceous gland, and an arrector pili muscle.

surrounding the medulla consists of hardened, tightly packed cells. A **cuticle** covers the cortex and forms the toughened outer layer of the hair. Cells of the cuticle have serrated edges that give a hair a scaly appearance when observed under a dissecting scope.

People exposed to heavy metals, such as lead, mercury, arsenic, or cadmium, will have concentrations of these metals in their hair that are 10 times as great as those found in their blood or urine. Because of this, hair samples can be extremely important in certain diagnostic tests.

Even evidence of certain metabolic diseases or nutritional deficiencies may be detected in hair samples. For example, the hair of children with cystic fibrosis will be deficient in calcium and display excessive sodium. There is a deficiency of zinc in the hair of malnourished individuals.

Hair color is determined by the type and amount of pigment produced in the stratum basale at the base of the hair follicle. Varying amounts of melanin produce hair ranging in color from blond to brunette to black. The more abundant the melanin, the darker the hair. A pigment with an iron base (*trichosiderin*) produces red hair. Gray or white hair is the result of a lack of pigment production and air spaces within the layers of the shaft of the hair. The texture of hair is determined by the cross-sectional shape: straight hair is round in cross section, wavy hair is oval, and kinky hair is flat.

Sebaceous glands and arrectores pilorum muscles (described previously) are attached to the hair follicle (fig. 5.13*c*). The arrectores pilorum muscles are involuntary, responding to thermal or psychological stimuli. When they contract, the hair is pulled into a more vertical position, causing goose bumps.

Humans have three distinct kinds of hair:

1. **Lanugo.** Lanugo (*lă-noo′go*) is a fine, silky fetal hair that appears during the last trimester of development. It is usually seen only on premature infants.
2. **Vellus.** Vellus is a short, fine hair that replaces lanugo. It is especially abundant in children and women just barely extending from the hair follicules.
3. **Terminal hair.** Terminal hair is coarse, pigmented (except in most elderly people), and sometimes curly. Examples are

cuticle: L. *cuticula*, small skin

lanugo: L. *lana*, wool

vellus: L. *vellus*, fleece

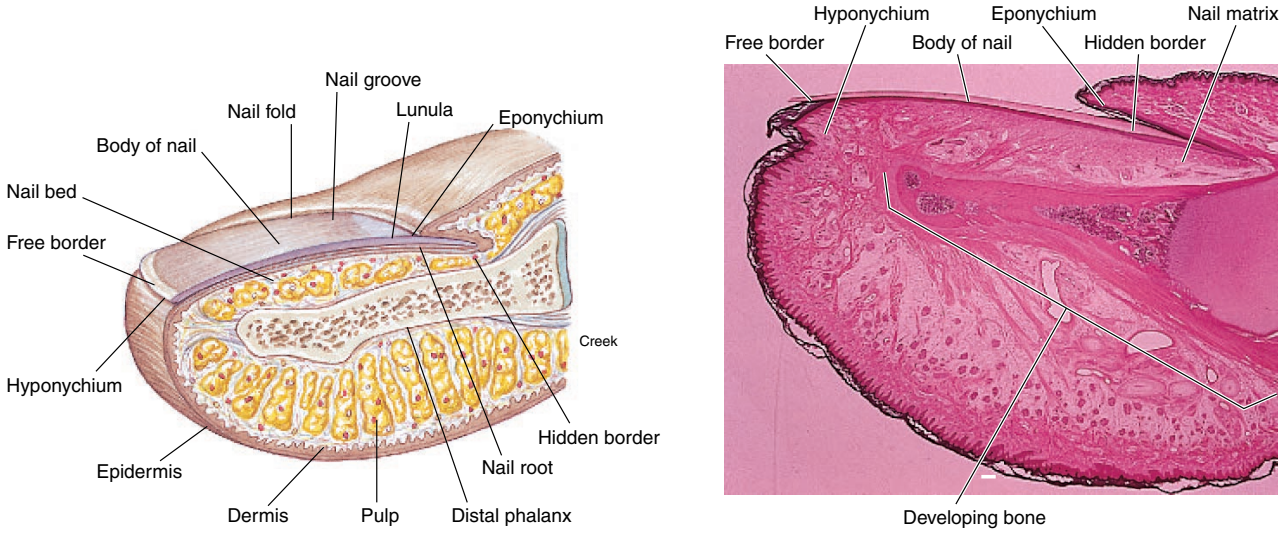


FIGURE 5.14 The fingertip and the associated structures of the nail. (*a*) A diagram of a dissected nail, and (*b*) a photomicrograph of a nail from a fetus (3.5×).

scalp hair, axillary hair, pubic hair, eyebrows, eyelashes, and hair on the extremities. **Angora hair** is terminal hair that grows continuously. It is found on the scalp and on the faces of mature males. **Definitive hair** is terminal hair that grows to a certain length and then stops. It is the most common type of hair. Eyelashes, eyebrows, pubic, and axillary hair are examples.

Anthropologists have referred to humans as the naked apes because of our relative hairlessness. The clothing that we wear over the exposed surface areas of our bodies functions to insulate and protect us, just as hair or fur does in other mammals. However, the nakedness of our skin does lead to some problems. *Skin cancer* occurs frequently in humans, particularly in regions of the skin exposed to the sun. *Acne,* another problem unique to humans, is partly related to the fact that hair is not present to dissipate the oily secretion from the sebaceous glands.

Nails

The **nails** on the ends of the fingers and toes are formed from the compressed outer layer (stratum corneum) of the epidermis. The hardness of the nail is due to the dense keratin fibrils running parallel between the cells. Both fingernails and toenails protect the digits, and fingernails also aid in grasping and picking up small objects.

Each nail consists of a **body, free border,** and **hidden border** (fig. 5.14). The platelike body of the nail rests on a **nail bed,** which is actually the stratum spinosum of the epidermis. The body and nail bed appear pinkish because of the underlying vascular tissue. The sides of the nail body are protected by a **nail fold,** and the furrow between the sides and body is the **nail groove.** The free border of the nail extends over a thickened region of the stratum corneum called the **hyponychium** (*hi''pŏ-nik'e-um*) (quick). The root of the nail is attached at the base.

An **eponychium** (cuticle) covers the hidden border of the nail. The eponychium frequently splits, causing a hangnail. The growth area of the nail is the **nail matrix.** A small part of the nail matrix, the **lunula** (*loo'nyoo-lă*), can be seen as a half-moon-shaped area near the eponychium of the nail.

The nail grows by the transformation of the superficial cells of the nail matrix into nail cells. These harder, transparent cells are then pushed forward over the strata basale and spinosum of the nail bed. Fingernails grow at the rate of approximately 1 mm each week. The growth rate of toenails is somewhat slower.

The condition of nails may be indicative of a person's general health and well-being. Nails should appear pinkish, showing the rich vascular capillaries beneath the translucent nail. A yellowish hue may indicate certain glandular dysfunctions or nutritional deficiencies. Split nails may also be caused by nutritional deficiencies. A prominent bluish tint may indicate improper oxygenation of the blood. Spoon nails (concave body) may be the result of iron-deficiency anemia, and clubbing at the base of the nail may be caused by lung cancer. Dirty or ragged nails may indicate poor personal hygiene, and chewed nails may suggest emotional problems.

Glands

Although they originate in the epidermal layer, all of the glands of the skin are located in the dermis, where they are physically supported and receive nutrients. Glands of the skin are referred

hyponychium: Gk. *hypo,* under; *onyx,* nail

lunula: L. *lunula,* small moon

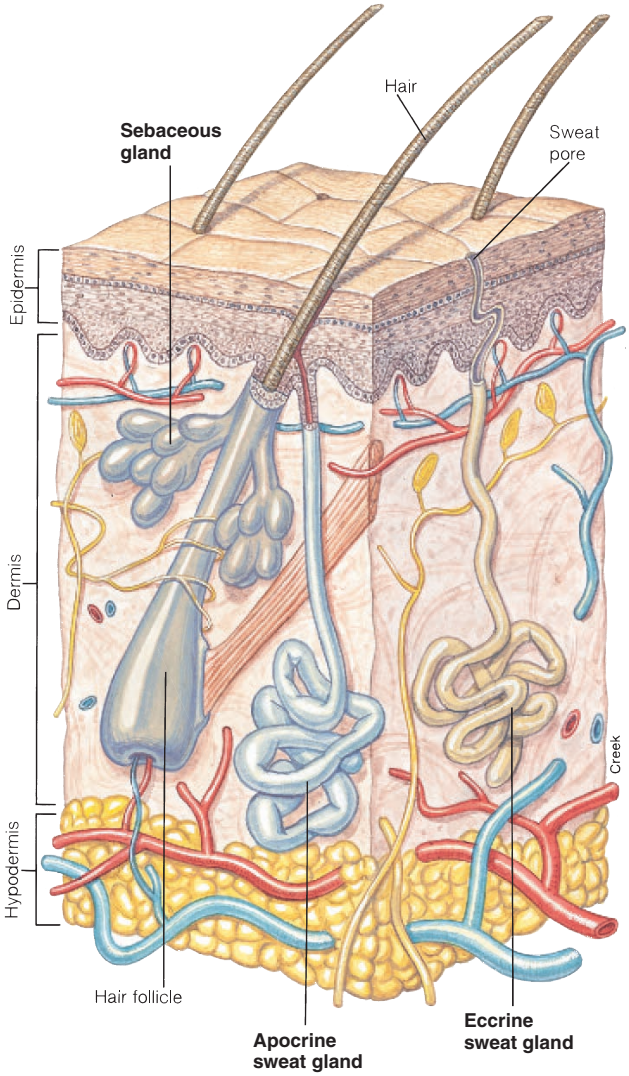


FIGURE 5.15 Types of skin glands.

to as *exocrine*, because they are externally secreting glands that either release their secretions directly or through ducts. The glands of the skin are of three basic types: *sebaceous (sĕ-ba'shus)*, *sudoriferous (soo''dor-if'er-us)*, and *ceruminous (sĕ-roo'mĭ-nus)*.

Sebaceous Glands

Commonly called oil glands, sebaceous glands are associated with hair follicles, because they develop from the follicular epithelium of the hair. They are holocrine glands (see chapter 4) that secrete **sebum** (*se'bum*) onto the shaft of the hair (fig. 5.13). Sebum, which consists mainly of lipids, is dispersed along the shaft of the hair to the surface of the skin, where it lubricates and waterproofs the stratum corneum and also prevents the hair from becoming brittle. If the ducts of sebaceous glands become blocked for some reason, the glands may become infected, resulting in acne. Sex hormones regulate the production and secretion of sebum, and hyperactivity of sebaceous glands can result in serious acne problems, particularly during teenage years.

FIGURE 5.16 A photomicrograph of an eccrine sweat gland (27×). The coiled structure of the ductule portion of the gland (see arrows) accounts for its discontinuous appearance.

Sudoriferous Glands

Commonly called sweat glands, **sudoriferous glands** excrete perspiration, or sweat, onto the surface of the skin. Perspiration is composed of water, salts, urea, and uric acid. It serves not only for evaporative cooling, but also for the excretion of certain wastes. Sweat glands are most numerous on the palms, soles, axillary and pubic regions, and on the forehead. They are coiled and tubular (fig. 5.15) and are of two types: *eccrine (ek'rin)* and *apocrine (ap'ŏ-krin) sweat glands*.

1. **Eccrine sweat glands** are widely distributed over the body, especially on the forehead, back, palms, and soles. These glands are formed before birth and function in evaporative cooling (figs. 5.15 and 5.16).
2. **Apocrine sweat glands** are much larger than the eccrine glands. They are found in the axillary and pubic regions, where they secrete into hair follicles. Apocrine glands are not functional until puberty, and their odoriferous secretion is thought to act as a sexual attractant.

sebum: L. *sebum*, tallow or grease

sudoriferous: L. *sudorifer*, sweat; *ferre*, to bear

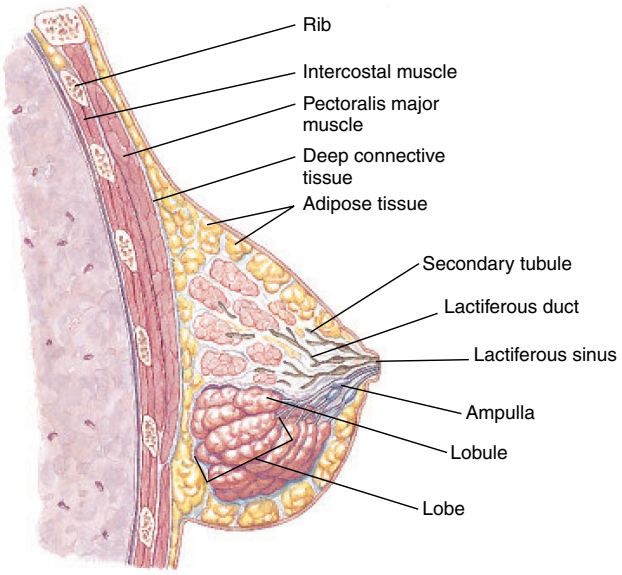


FIGURE 5.17 A sagittal section of a mammary gland within the human breast.

Mammary glands, found within the breasts, are specialized sudoriferous glands that secrete milk during lactation (fig. 5.17) The breasts of the female reach their greatest development during the childbearing years, under the stimulus of pituitary and ovarian hormones.

Good routine hygiene is very important for health and social reasons. Washing away the dried residue of perspiration and sebum eliminates dirt. Excessive bathing, however, can wash off the natural sebum and dry the skin, causing it to itch or crack. The commercial lotions used for dry skin are, for the most part, refined and perfumed lanolin, which is sebum from sheep.

Ceruminous Glands

These specialized glands are found only in the external auditory canal (ear canal) where they secrete **cerumen** (*sĕ-roo′men*), or earwax. Cerumen is a water and insect repellent, and also keeps the tympanic membrane (eardrum) pliable. Excessive amounts of cerumen may interfere with hearing.

Knowledge Check

11. Draw and label a hair. Indicate which portion is alive and discuss what causes the cells in a hair to die.
12. Describe the structure and function of nails.
13. List the three types of integumentary glands and describe the structure and function of each.
14. Are skin glands mesodermal or ectodermal in derivation? Are they epidermal or dermal in functional position?

cerumen: L. *cera*, wax

CLINICAL CONSIDERATIONS

The skin is a buffer against the external environment and is therefore subject to a variety of disease-causing microorganisms and physical assaults. A few of the many diseases and disorders of the integumentary system are briefly discussed here.

Inflammatory Conditions (Dermatitis)

Inflammatory skin disorders are caused by immunologic hypersensitivity, infectious agents, poor circulation, or exposure to environmental assaults such as wind, sunlight, or chemicals. Some people are allergic to certain foreign proteins and, because of this inherited predisposition, experience such hypersensitive reactions as asthma, hay fever, hives, drug and food allergies, and eczema. **Lesions,** as applied to inflammatory conditions, are defined as more or less circumscribed pathologic changes in the tissue. Some of the more common inflammatory skin disorders and their usual sites are illustrated in fig. 5.18

There are also a number of *infectious diseases* of the skin, which is not surprising considering the highly social and communal animals we are. Most of these diseases can now be prevented, but too frequently people fail to take appropriate precautionary measures. Infectious diseases of the skin include childhood viral infections (measles and chicken pox); bacteria, such as staphylococcus (impetigo); sexually transmitted diseases; leprosy; fungi (ringworm, athlete's foot, candida); and mites (scabies).

Neoplasms

Both benign and malignant neoplastic conditions or diseases are common in the skin. *Pigmented moles* (nevi), for example, are a type of benign neoplastic growth of melanocytes. *Dermal cysts* and *benign viral infections* are also common. *Warts* are virally caused abnormal growths of tissue that occur frequently on the hands and feet. These warts are usually treated effectively with liquid nitrogen or acid. A different type of wart, called a *venereal wart*, occurs in the anogenital region of affected sexual partners. Risk factors for cervical cancer may be linked to venereal warts, so they are treated aggressively with chemicals, cryosurgery, cautery, or laser therapy.

neoplasm: Gk. *neo*, new; *plasma*, something formed
benign: L. *benignus*, good-natured
malignant: L. *malignus*, acting from malice

Developmental Exposition

The Integumentary System

EXPLANATION

Both the ectodermal and mesodermal germ layers (see chapter 4) function in the formation of the structures of the integumentary system. The epidermis and the hair, glands, and nails of the skin develop from the ectodermal germ layer (exhibits I, II, and III). The dermis develops from a thickened layer of undifferentiated mesoderm called *mesenchyme (mez′en-kīm)*.

By 6 weeks, the ectodermal layer has differentiated into an outer flattened *periderm* and an inner cuboidal *germinal (basal) layer* in contact with the mesenchyme. The periderm eventually

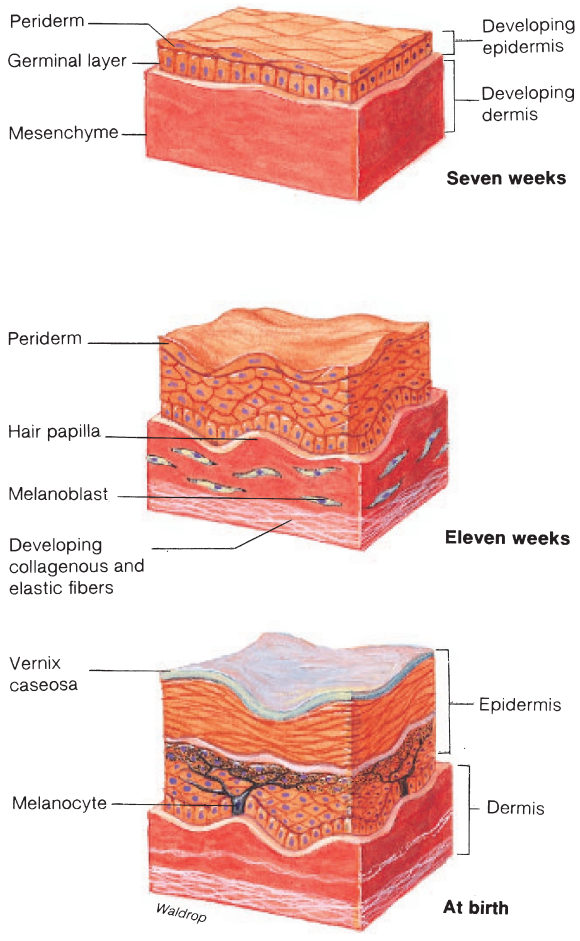


EXHIBIT I The development of the skin.

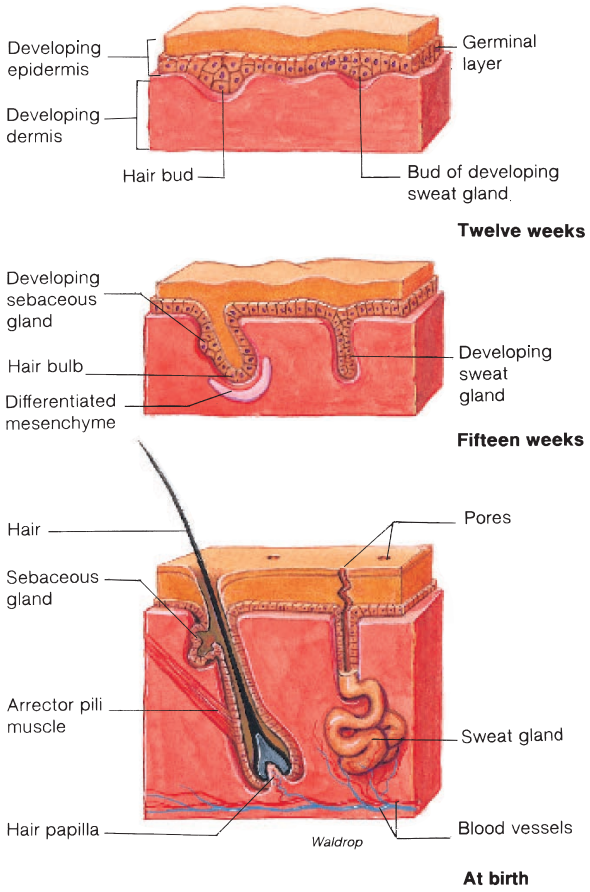


EXHIBIT II The development of hair and glands.

Skin cancer is the most common malignancy in the United States. As shown in figure 5.19, there are three frequently encountered types. **Basal cell carcinoma,** the most common skin cancer, accounts for about 70% of total cases. It usually occurs where exposure to sunlight is the greatest—on the face and arms. This type of cancer arises from cells in the stratum basale. It appears first on the surface of the skin as a small, shiny bump. As the bump enlarges, it often develops a central crater that erodes, crusts, and bleeds. Fortunately, there is little danger that it will spread (metastasize) to other body areas. These carcinomas are usually treated by excision (surgical removal).

sloughs off, forming the *vernix caseosa (ka''se-o'să)*, a cheeselike protective coat that covers the skin of the fetus.

By 11 weeks, the mesenchymal cells below the germinal cells have differentiated into the distinct collagenous and elastic connective tissue fibers of the dermis. The tensile properties of these fibers cause a buckling of the epidermis and the formation of dermal papillae. During the early fetal period (about 10 weeks), specialized neural crest cells called *melanoblasts* migrate into the developing dermis and differentiate into *melanocytes*. The melanocytes soon migrate to the germinal layer of the epidermis, where they produce the pigment *melanin* that colors the epidermis.

Before hair can form, a *hair follicle* must be present. Each hair follicle begins to develop at about 12 weeks (exhibit II), as a mass of germinal cells called a *hair bud* proliferates into the underlying mesenchyme. As the hair bud becomes club-shaped, it is referred to as a *hair bulb*. The hair follicle, which physically supports and provides nourishment to the hair, is derived from specialized mesenchyme called the *hair papilla*, which is localized around the hair bulb, and from the epithelial cells of the hair bulb called the *hair matrix*. Continuous mitotic activity in the epithelial cells of the hair bulb results in the growth of the hair.

Sebaceous glands and sweat glands are the two principal types of integumentary glands. Both develop from the germinal layer of the epidermis (exhibit II). Sebaceous glands develop as proliferations from the sides of the developing hair follicle. Sweat glands become coiled as the secretory portion of the developing gland proliferates into the dermal mesenchyme. Mammary glands (exhibit III) are modified sweat glands that develop in the skin of the anterior thoracic region.

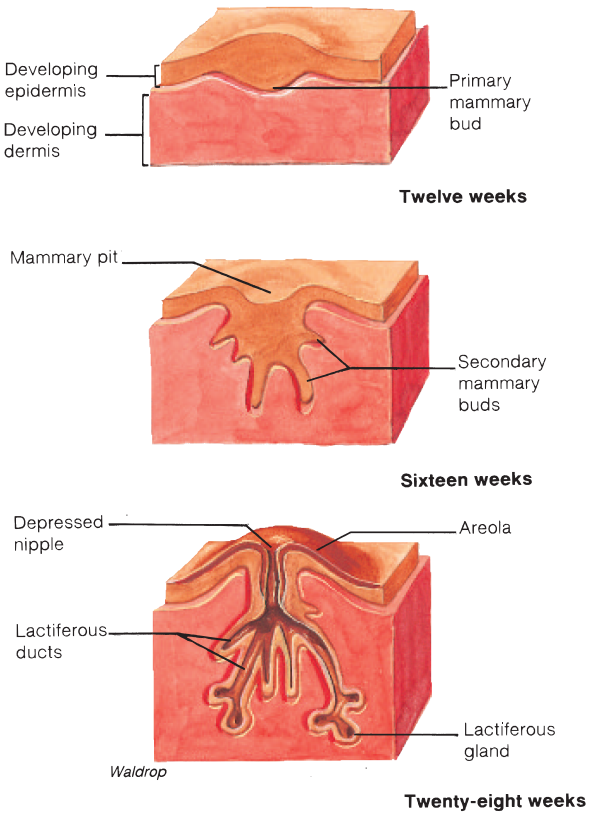


EXHIBIT III The development of mammary glands at (*a*) 12 weeks, (*b*) 16 weeks, and (*c*) about 28 weeks.

Squamous cell carcinoma arises from cells immediately superficial to the stratum basale. Normally, these cells undergo very little division, but in squamous cell carcinoma they continue to divide as they produce keratin. The result is usually a firm, red keratinized tumor, confined to the epidermis. If untreated, however, it may invade the dermis and metastasize. Treatment usually consists of excision and radiation therapy.

Malignant melanoma, the most life-threatening form of skin cancer, arises from the melanocytes located in the stratum basale. Often, it begins as a small molelike growth, which enlarges, changes color, becomes ulcerated, and bleeds easily. Metastasis occurs quickly, and unless treated early—usually by widespread excision and radiation therapy—this cancer is often fatal.

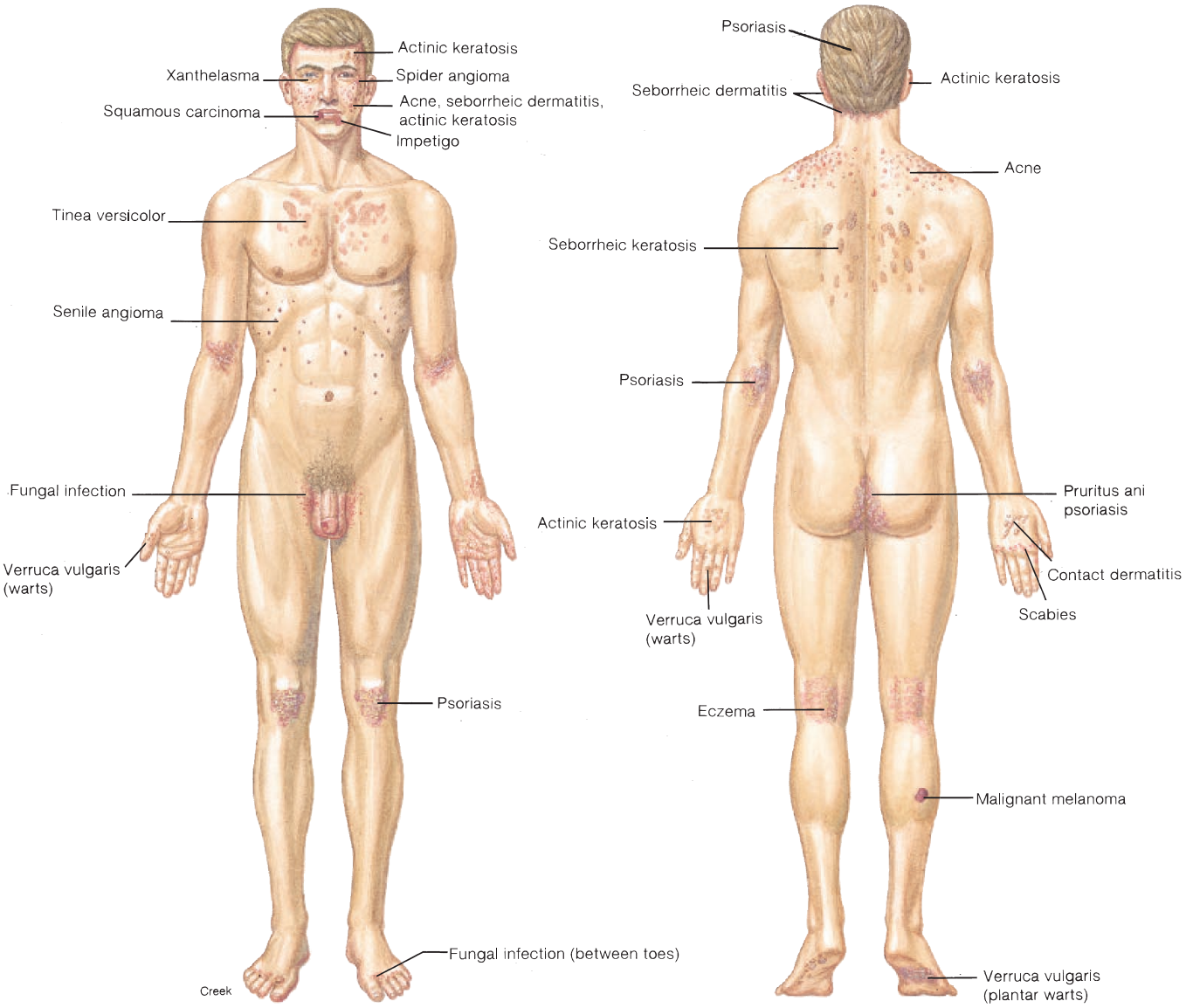
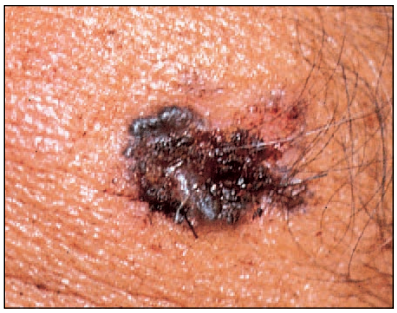


FIGURE 5.18 Common inflammatory skin disorders and their usual sites of occurrence.

Burns

A burn is an epithelial injury caused by contact with a thermal, radioactive, chemical, or electrical agent. Burns generally occur on the skin, but they can involve the linings of the respiratory and GI tracts. The extent and location of a burn is frequently less important than the degree to which it disrupts body homeostasis. Burns that have a **local effect** (local tissue destruction) are not as serious as those that have a **systemic effect.** Systemic effects directly or indirectly involve the entire body and are a threat to life. Possible systemic effects include body dehydration, shock, reduced circulation and urine production, and bacterial infections.

Burns are classified as first degree, second degree, or third degree, based on their severity (fig. 5.20). In **first-degree burns,** the epidermal layers of the skin are damaged and symptoms are restricted to local effects such as redness, pain, and edema (swelling). A shedding of the surface layers (desquamation) generally follows in a few days. A sunburn is an example. **Second-degree burns** involve both the epidermis and dermis. Blisters appear and recovery is usually complete, although slow. **Third-degree burns** destroy the entire thickness of the skin and frequently some of the underlying muscle. The skin appears waxy or charred and is insensitive to touch. As a result, ulcerating wounds develop, and the body attempts to heal itself by forming scar tissue. Skin grafts are frequently used to assist recovery.



(a) Basal cell carcinoma

(b) Squamous cell carcinoma

(c) Malignant melanoma

FIGURE 5.19 Three types of skin cancer.

(a)

(b)

(c)

FIGURE 5.20 The classification of burns, (*a*) First-degree burns involve the epidermis and are characterized by redness, pain, and edema—such as with a sunburn; (*b*) second-degree burns involve the epidermis and dermis and are characterized by intense pain, redness, and blistering; and (*c*) third-degree burns destroy the entire skin and frequently expose the underlying organs. The skin is charred and numb and does not protect against fluid loss.

As a way of estimating the extent of damaged skin suffered in burned patients, the *rule of nines* (fig. 5.21) is often applied. The surface area of the body is divided into regions, each of which accounts for about 9% (or a multiple of 9%) of the total skin surface. An estimation of the percentage of surface area damaged is important in treating with intravenous fluid, which replaces the fluids lost from tissue damage.

Frostbite

Frostbite is a local destruction of the skin resulting from freezing. Like burns, frostbite is classified by its degree of severity: first degree, second degree, and third degree. In **first-degree frostbite,** the skin will appear cyanotic (bluish) and swollen. Vesicle formation and hyperemia (engorgement with blood) are symptoms of **second-degree frostbite.** As the affected area is warmed, there will be further swelling, and the skin will redden and blister. In **third-degree frostbite,** there will be severe edema, some bleeding, and numbness followed by intense throbbing pain and necrosis of the affected tissue. Gangrene will follow untreated third-degree frostbite.

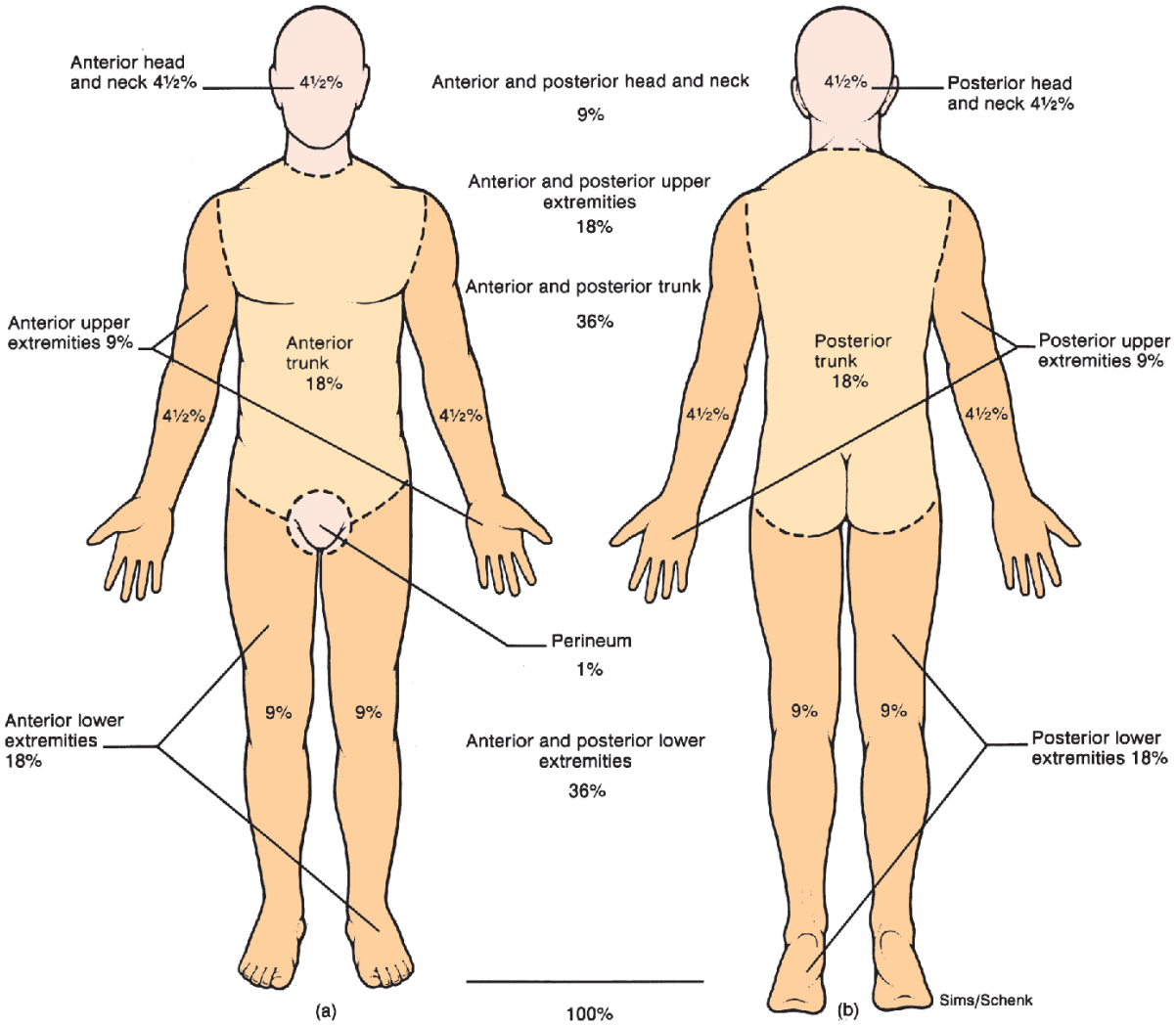


FIGURE 5.21 The extent of burns, as estimated by the rule of nines. (*a*) Anterior and (*b*) posterior.

Skin Grafts

If extensive areas of the stratum basale of the epidermis are destroyed in second-degree or third-degree burns or frostbite, new skin cannot grow back. In order for this type of wound to heal, a skin graft must be performed.

A **skin graft** is a segment of skin that has been excised from a *donor site* and transplanted to the *recipient site*, or *graft bed*. As stated in chapter 4, an *autograft* is the most successful type of tissue transplant. It involves taking a thin sheet of healthy epidermis from a donor site of the burn or frostbite patient and moving it to the recipient site (fig. 5.22). A *heterotransplant* (*xenograph*—between two different species) can serve as a temporary treatment to prevent infection and fluid loss.

Synthetic skin fabricated from animal tissue bonded to a silicone film (fig. 5.23) may be used on a patient who is extensively burned. The process includes seeding the synthetic skin with basal skin cells obtained from healthy locations on the patient. This treatment eliminates some of the problems of skin grafting—for example, additional trauma, widespread scarring, and rejection, as in the case of skin obtained from a cadaver.

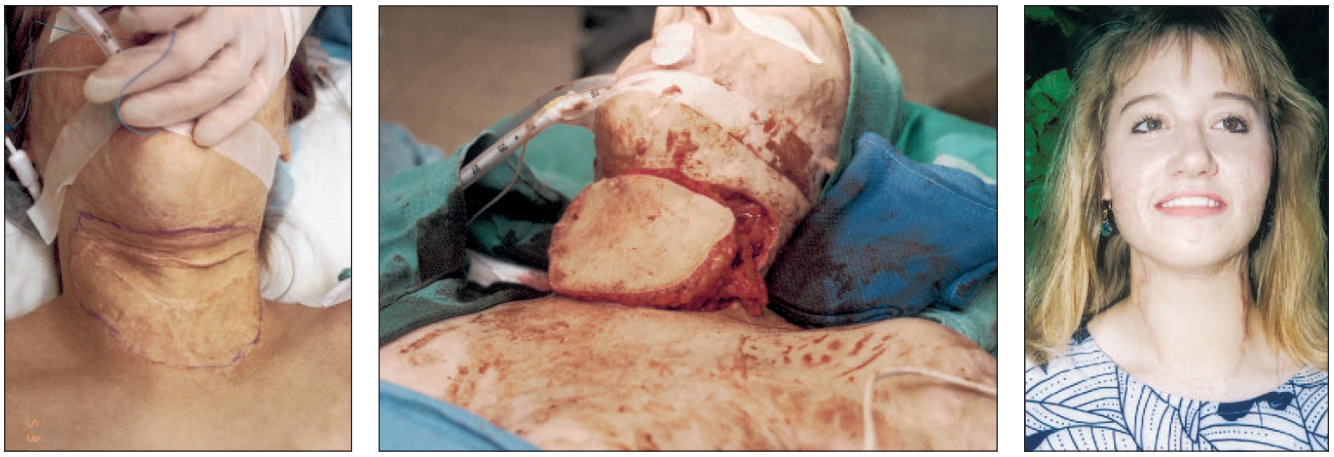


FIGURE 5.22 A skin graft to the neck. (*a*) Traumatized skin is prepared for excision; (*b*) healthy skin from another body location is transplanted to the graft site; and (*c*) 1 year following the successful transplant, healing is complete.

FIGURE 5.23 Synthetic skin used in grafting.

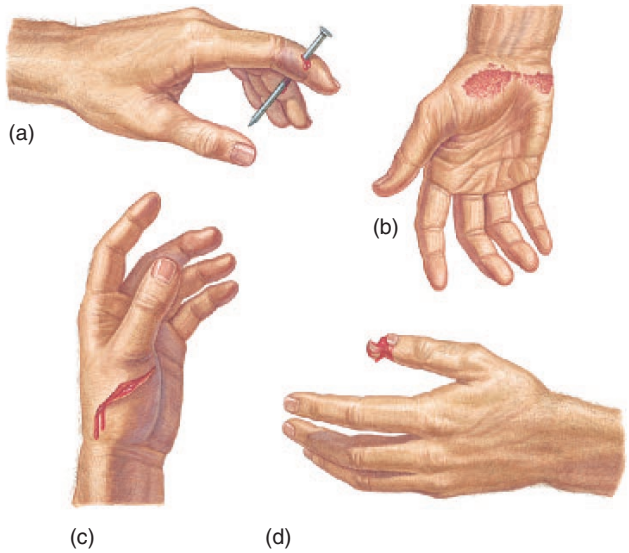


FIGURE 5.24 Various kinds of wounds: (*a*) puncture, (*b*) abrasion, (*c*) laceration, and (*d*) avulsion.

Wound Healing

The skin effectively protects against many abrasions, but if a wound does occur (fig. 5.24) a sequential chain of events promotes rapid healing. The process of wound healing depends on the extent and severity of the injury. Trauma to the epidermal layers stimulates increased mitotic activity in the stratum basale, whereas injuries that extend to the dermis or subcutaneous layer elicit activity throughout the body, not just within the wound area. General body responses include a temporary elevation of temperature and pulse rate.

In an open wound (fig. 5.25), blood vessels are broken and bleeding occurs. Through the action of **blood platelets** and protein molecules called **fibrinogen** (*fi-brin′ŏ-jen*), a clot forms and

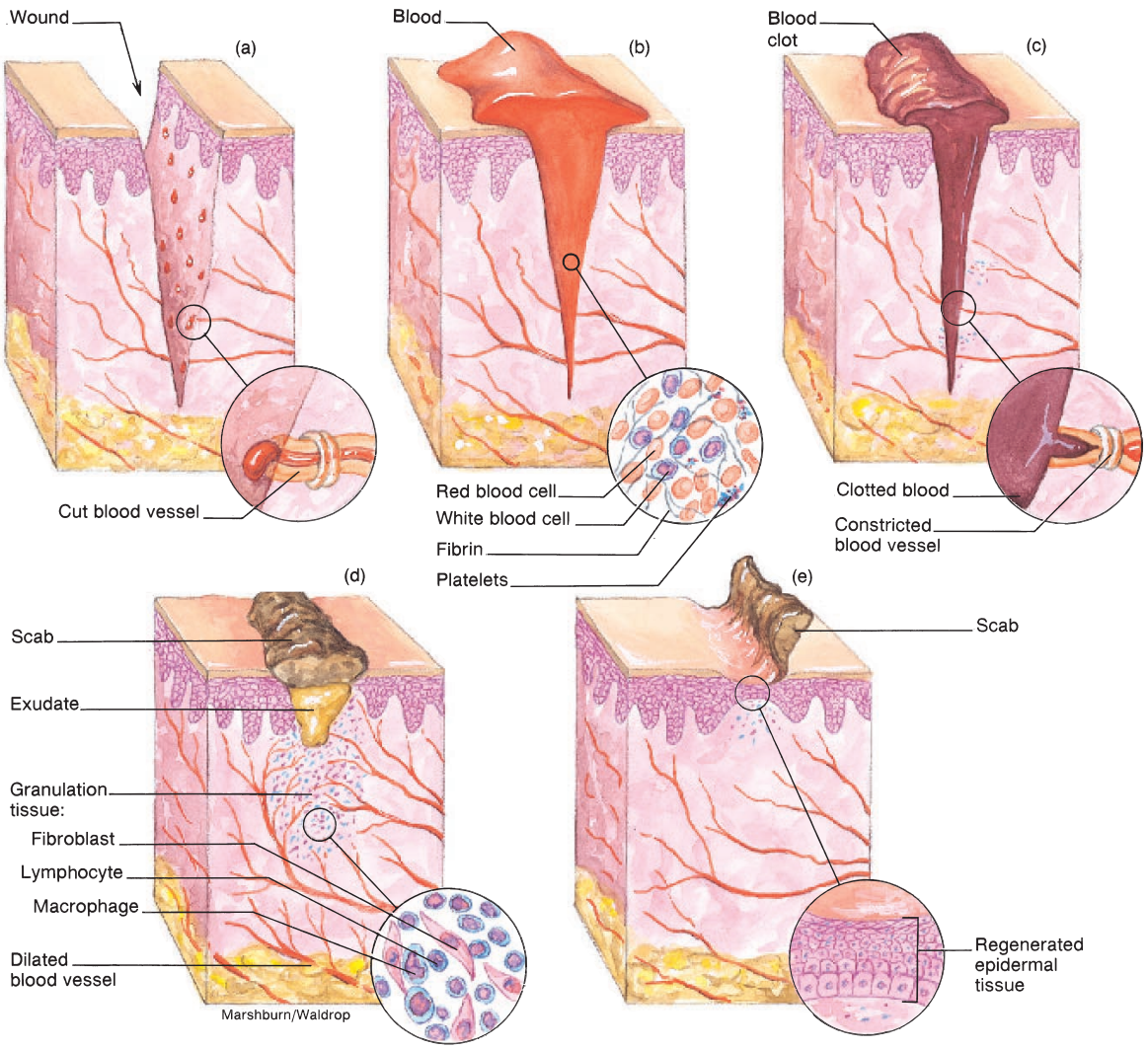


FIGURE 5.25 The process of wound healing. (*a*) A penetrating wound into the dermis ruptures blood vessels. (*b*) Blood cells, fibrinogen, and fibrin flow out of the wound. (*c*) Vessels constrict and a clot blocks the flow of blood. (*d*) A protective scab is formed from the clot, and granulation occurs within the site of the wound. (*e*) The scab sloughs off as the epidermal layers are regenerated.

soon blocks the flow of blood. The scab that forms from the clot covers and protects the damaged area. Mechanisms are activated to destroy bacteria, dispose of dead or injured cells, and isolate the injured area. These responses are collectively referred to as *inflammation* and are characterized by redness, heat, edema, and pain. Inflammation is a response that confines the injury and promotes healing.

The next step in healing is the differentiation of binding **fibroblasts** from connective tissue at the wound margins. Together with new branches from surrounding blood vessels, **granulation tissue** is formed. Phagocytic cells migrate into the wound and ingest dead cells and foreign debris. Eventually, the damaged area is repaired and the protective scab is sloughed off.

If the wound is severe enough, the granulation tissue may develop into **scar tissue** (fig. 5.26). The collagenous fibers of scar tissue, are more dense than those of normal tissue, and scar tissue has no stratified squamous or epidermal layer. Scar tissue also has fewer blood vessels than normal skin, and may lack hair, glands, and sensory receptors. The closer the edges of a wound, the less granulation tissue develops and the less obvious a scar. This is one reason for suturing a large break in the skin.

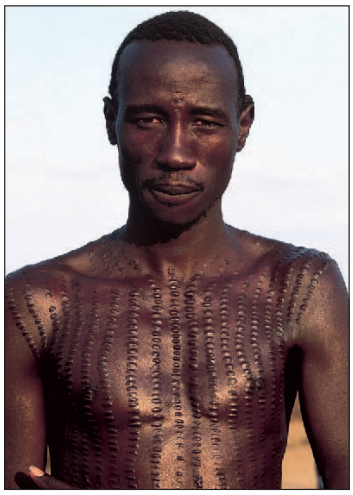


FIGURE 5.26 Scars for body adornment on the face of this Buduma man from the islands of Lake Chad are created by instruments that make crescent-shaped incisions into the skin in beadlike patterns. Special ointments are applied to the cuts to retard healing and promote scar formation.

FIGURE 5.27 Aging of the skin results in a loss of elasticity and the appearance of wrinkles.

Aging of the Skin

As the skin ages, it becomes thin and dry, and begins to lose its elasticity. Collagenous fibers in the dermis become thicker and stiffer, and the amount of adipose tissue in the hypodermis diminishes, making it thinner. Skinfold measurements indicate that the diminution of the hypodermis begins at about the age of 45. With a loss of elasticity and a reduction in the thickness of the hypodermis, wrinkling, or permanent infolding of the skin, becomes apparent (fig. 5.27).

During the aging of the skin, the number of active hair follicles, sweat glands, and sebaceous glands also declines. Consequently, there is a marked thinning of scalp hair and hair on the extremities, reduced sweating, and decreased sebum production. Because elderly people cannot perspire as freely as they once did, they are more likely to complain of heat and are at greater risk for heat exhaustion. They also become more sensitive to cold because of the loss of insulating adipose tissue and diminished circulation. A decrease in the production of sebum causes the skin to dry and crack frequently.

The integument of an elderly person is not as well protected from the sun because of thinning, and melanocytes that produce melanin gradually atrophy. The loss of melanocytes accounts for graying of the hair and pallor of the skin.

Clinical Case Study Answer

The blistering and erythema characteristic of second-degree burns is a manifestation of intact and functioning blood vessels, which exist in abundance within the spared dermis. In third-degree burns, the entire dermis and its vasculature are destroyed, thus explaining the absence of these findings. In addition, nerve endings and other nerve end organs that reside in the dermis are destroyed in third-degree burns, resulting in a desensitized area. By contrast, significant numbers of these structures are spared and functional in second-degree burns, thus preserving sensation—including pain. The third-degree burn areas will all require skin grafting in order to prevent infection, one of the skin's most vital functions. In second-degree burns, the spared dermis serves somewhat of a barrier to bacteria. Consequently, skin grafting is usually unnecessary, especially if sufficient numbers of skin adnexa (hair follicles, sweat glands, and so forth), which generally lie deep within the dermis, are spared. These structures serve as starting points for regeneration of surface epithelium and skin organs.

CLINICAL PRACTICUM 5.1

A 13-year-old male presents at your office with an itchy rash on his left arm. The boy explained that he and his father had just returned from a camping trip. The rash first appeared after he arrived home. Upon examination, you notice the arm is somewhat swollen and has areas of erythema and weeping blisters arranged in linear patterns.

QUESTIONS

1. What is the cause of the rash?
2. How does the rash develop?
3. What is the treatment for this condition?

Important Clinical Terminology

acne An inflammatory condition of sebaceous glands. Acne is effected by gonadal hormones, and is therefore common during puberty and adolescence. Pimples and blackheads on the face, chest, and back are expressions of this condition.

albinism (*al′bĭ-niz″em*) A congenital condition in which the pigment of the skin, hair, and eyes is deficient as a result of a metabolic block in the synthesis of melanin (fig. 5.28).

alopecia (*al″ŏ-pe′she-ă*) Loss of hair; baldness. Male pattern baldness is genetically determined and irreversible. Other types of hair loss may respond to treatment.

athlete's foot (tinea pedis) A fungus disease of the skin of the foot.

blister A collection of fluid between the epidermis and dermis resulting from excessive friction or a burn.

boil (furuncle) A localized bacterial infection originating in a hair follicle or skin gland.

carbuncle A bacterial infection similar to a boil, except that a carbuncle infects the subcutaneous tissues.

cold sore (fever blister) A lesion on the lip or oral mucous membrane caused by type I herpes simplex virus (HSV) and transmitted by oral or respiratory exposure.

comedo (*kom′e-do*) A plug of sebum and epithelial debris in the hair follicle and excretory duct of the sebaceous gland; also called a *blackhead* or *whitehead*.

corn A type of callus localized on the foot, usually over toe joints.

dandruff Common dandruff is the continual shedding of epidermal cells of the scalp; it can be removed by normal washing and brushing of the hair. Abnormal dandruff may be caused by certain skin diseases, such as seborrhea or psoriasis.

decubitus (*de-kyoo′bĭ-tus*) ulcer A bedsore—an exposed ulcer caused by a continual pressure that restricts dermal blood flow to a localized portion of the skin (see fig. 5.8).

dermabrasion A procedure for removing tattoos or acne scars by high-speed sanding or scrubbing.

dermatitis An inflammation of the skin.

dermatology A specialty of medicine concerned with the study of the skin—its anatomy, physiology, histopathology, and the relationship of cutaneous lesions to systemic disease.

FIGURE 5.28 The individual on the left has melanocytes within his skin, but as a result of a mutant gene he is affected with albinism—an inability to synthesize melanin.

eczema (*ek′ze-mă*) A noncontagious inflammatory condition of the skin producing itchy, red vesicular lesions that may be crusty or scaly.

erythema (*er″ĭ-the-mă*) Redness of the skin, generally is a result of vascular trauma.

furuncle A boil—a localized abscess resulting from an infected hair follicle.

gangrene Necrosis of tissue resulting from the obstruction of blood flow. It may be localized or extensive and may be infected secondarily with anaerobic microorganisms.

hives (urticaria) (*ur″tĭ-ka′re-ă*) A skin eruption of reddish wheals usually accompanied by extreme itching. It may be caused by drugs, food, insect bites, inhalants, emotional stress, or exposure to heat or cold.

impetigo (*im-pĕ-ti'go*) A contagious skin infection that results in lesions followed by scaly patches. It generally occurs on the face and is caused by staphylococci or streptococci.
keratosis Any abnormal growth and hardening of the stratum corneum of the skin.
melanoma (*mel-ă-no'mă*) A cancerous tumor originating from proliferating melanocytes within the epidermis of the skin.
nevus (*ne'vus*) A mole or birthmark—a congenital pigmentation of a limited area of the skin.
papilloma (*pap-ĭ-lo'mă*) A benign epithelial neoplasm, such as a wart or corn.
papule A small inflamed elevation of the skin, such as a pimple.
pruritus (*proo-ri'tus*) Itching. It may be symptomatic of systemic disorders but is generally due to dry skin.
psoriasis (*so-ri'ă-sis*) An inherited inflammatory skin disease, usually expressed as circular scaly patches of skin.
pustule A small, localized pus-filled elevation of the skin.
seborrhea (*seb-ŏ-re'ă*) A disease characterized by an excessive activity of the sebaceous glands and accompanied by oily skin and dandruff. It is known as "cradle cap" in infants.
wart A roughened projection of epidermal cells caused by a virus.

Chapter Summary

The Skin as an Organ (p. 106)

1. The skin is considered an organ because it consists of several kinds of tissues.
2. The appearance of the skin is clinically important because it provides clues to certain body conditions or dysfunctions.

Layers of the Skin (pp. 106–112)

1. The stratified squamous epithelium of the epidermis is composed of five structural and functional layers: the stratum basale, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum.
   (a) Normal skin color is the result of a combination of melanin and carotene in the epidermis and hemoglobin in the blood of the dermis and hypodermis.
   (b) Fingerprints on the surface of the epidermis are congenital patterns, unique to each individual; flexion creases and flexion lines are acquired.
2. The thick dermis of the skin is composed of fibrous connective tissue interlaced with elastic fibers. The two layers of the dermis are the papillary layer and the deeper reticular layer.
3. The hypodermis, composed of adipose and loose connective tissue, binds the dermis to underlying organs.

Functions of the Skin (pp. 112–114)

1. Structural features of the skin protect the body from disease and external injury.
   (a) Keratin and acidic oily secretions on the surface of the skin protect it from water and microorganisms.
   (b) Cornification of the skin protects against abrasion.
   (c) Melanin is a barrier to UV light.
2. The skin regulates body fluids and temperatures.
   (a) Fluid loss is minimal as a result of keratinization and cornification.
   (b) Temperature regulation is maintained by radiation, convection, and the antagonistic effects of sweating and shivering.
3. The skin permits the absorption of UV light, respiratory gases, steroids, fat-soluble vitamins, and certain toxins and pesticides.
4. The integument synthesizes melanin and keratin, which remain in the skin, and has a role in the synthesis of vitamin D, which is used elsewhere in the body.
5. Sensory reception in the skin is provided through cutaneous receptors throughout the dermis and hypodermis. Cutaneous receptors respond to precise sensory stimuli and are more sensitive in thin skin.
6. Certain emotions are reflected in changes in the skin.

Epidermal Derivatives (pp. 115–119)

1. Hair is characteristic of all mammals, but its distribution, function, density, and texture varies across mammalian species.
   (a) Each hair consists of a shaft, root, and bulb. The bulb is the enlarged base of the root within the hair follicle.
   (b) The three layers of a hair shaft are the medulla, cortex, and cuticle.
   (c) Lanugo, vellus, and terminal are the three principal kinds of human hair. In addition, angora and definitive are two kinds of terminal hair.
2. Hardened, keratinized nails are found on the distal dorsum of each digit, where they protect the digits; fingernails aid in grasping and picking up small objects.
   (a) Each nail consists of a body, free border, and hidden border.
   (b) The hyponychium, eponychium, and nail fold support the nail on the nail bed.
3. Integumentary glands are exocrine, because they either secrete or excrete substances through ducts.
   (a) Sebaceous glands secrete sebum onto the shaft of the hair.
   (b) The two types of sudoriferous (sweat) glands are eccrine and apocrine.
   (c) Mammary glands are specialized sudoriferous glands that secrete milk during lactation.
   (d) Ceruminous glands secrete cerumen (earwax).

Review Activities

Objective Questions

1. Hair, nails, integumentary glands, and the epidermis of the skin are derived from embryonic
   (a) ectoderm. (c) endoderm.
   (b) mesoderm. (d) mesenchyme.
2. Spoon-shaped nails may be the result of a dietary deficiency of
   (a) zinc. (c) niacin.
   (b) iron. (d) vitamin B_{12}.
3. The epidermal layer *not* present in the thin skin of the face is the stratum
   (a) granulosum. (c) spinosum.
   (b) lucidum. (d) corneum.

4. Which of the following does *not* contribute to skin color?
   (a) dermal papillae
   (b) melanin
   (c) carotene
   (d) hemoglobin
5. Which of the following is *not* true of the epidermis?
   (a) It is composed of stratified squamous epithelium.
   (b) As the epidermal cells die, they undergo keratinization and cornification.
   (c) Rapid mitotic activity (cell division) within the stratum corneum accounts for the thickness of this epidermal layer.
   (d) In most areas of the body, the epidermis lacks blood vessels and nerves.
6. Integumentary glands that empty their secretions into hair follicles are
   (a) sebaceous glands.
   (b) endocrine glands.
   (c) eccrine glands.
   (d) ceruminous glands.
7. Fetal hair that is present during the last trimester of development is referred to as
   (a) angora. (c) lanugo.
   (b) definitive. (d) replacement.
8. Which of these conditions is potentially life threatening?
   (a) acne (c) eczema
   (b) melanoma (d) seborrhea
9. The skin of a burn victim has been severely damaged through the epidermis and into the dermis. Integumentary regeneration will be slow with some scarring, but it will be complete. Which kind of burn is this?
   (a) first degree (c) third degree
   (b) second degree
10. The technical name for a blackhead or whitehead is
    (a) a carbuncle. (c) a nevus.
    (b) a melanoma. (d) a comedo.

Essay Questions

1. Discuss the development of the skin and associated hair, glands, and nails. What role do the ectoderm and mesoderm play in integumentary development?
2. List the functions of the skin. Which of these occur(s) passively as a result of the structure of the skin? Which occur(s) dynamically as a result of physiological processes?
3. What are types of tissues found in each of the three layers of skin?
4. Discuss the growth process and regeneration of the epidermis.
5. What are some physical and chemical features of the skin that make it an effective protective organ?
6. Of what practical value is it for the outer layers of the epidermis and hair to be composed of dead cells?
7. Define the following: *lines of tension*, *friction ridges*, and *flexion lines*. What causes each of these to develop?
8. Distinguish between a hair follicle and a hair. Aside from hair and hair follicles, what are the other epidermal derivatives?
9. Compare and contrast the structure and function of sebaceous, sudoriferous, mammary, and ceruminous glands.
10. Discuss what is meant by an inflammatory lesion. What are some frequent causes of skin lesions?
11. Explain the relationship of the dermis with the circulatory and nervous systems.
12. What characterizes the hypodermis? Explain the variations of this layer in males and females. How does this layer vary in thickness in different parts of the body? Of what value might this be?
13. Relate how hair color and texture are determined. What kinds of hair do humans have?
14. Describe the degrees of skin burns.
15. Explain the similarities and differences between the growth of hair and the growth of nails.
16. Review the steps in the healing process of an open wound.

Critical-Thinking Questions

1. Why is it important that the epidermis serve as a barrier against UV rays, yet not block them out completely?
2. Review the structure and function of the skin by explaining (a) the mechanisms involved in thermoregulation; (b) variations in skin color; (c) abnormal coloration of the skin (for example, cyanosis, jaundice, and pallor); and (d) the occurrence of acne.
3. Do you think that humans derive any important benefit from contraction of the arrectores pilorum muscles? Justify your answer.
4. The relative hairlessness of humans is unusual among mammals. Why should it be that we have any hair at all?
5. Compounds such as lead, zinc, and arsenic may accumulate in the hair and nails. Chemical toxins from pesticides and pollutants may accumulate in the adipose tissue (subcutaneous fat) of the hypodermis. Discuss some of the possible clinical situations where this knowledge would be of importance.
6. During the aging process, the skin becomes drier, wrinkled, and slower to heal. Knowing that these are normal structural changes, how would you advise a middle-aged person to safeguard his or her skin as a protective organ?

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