epidermal layer and not to overall or total skin thickness, which includes epidermis and dermis. Total skin thickness varies from 0.5 mm in areas such as the eyelids to more than 5 mm over the back, with most of the difference accounted for by variation in the depth of the dermis.

In thick skin, each of the five strata, or layers, of the epidermis described below are present, and each stratum is generally several cell layers thick. The outermost stratum—the stratum corneum—is especially noticeable in thick skin and generally is composed of many cell layers. Furthermore, in thick skin the underlying dermal papillae are raised in curving parallel ridges to form fingerprints or footprints that are visible on the overlying epidermis. Hair is not found in thick skin.

In thin skin, the number of cell layers in each epidermal stratum is less than in thick skin and one or more strata may be absent entirely. Raised parallel ridges are not present in the dermis of thin skin. Instead, the dermal papillae project upward individually and therefore no "fingerprints" are formed on the more superficial epidermis above.

EPIDERMIS

Cell Types

The epidermis is composed of several types of epithelial cells. **Keratinocytes** become filled with a tough, fibrous protein called ***keratin.*** These cells, arranged in distinct *strata,* or layers, are by far the most important cells in the epidermis. They make up more than 90% of the epidermal cells and form the principal structural element of the outer skin.

Melanocytes contribute color to the skin and serve to decrease the amount of ultraviolet light that can penetrate into the deeper layers of the skin. Although they may compose more than 5% of the epidermal cells, melanocytes may be completely absent from the skin in certain nonlethal conditions. Another cell type, *Langerhans cells,* are thought to play a limited role in immunological reactions that affect the skin and may serve as a defense mechanism for the body. These cells originate in the bone marrow but migrate to the deep cell layers of the epidermis early in life. They function together with highly specialized leukocytes (white blood cells), called *helper T cells,* to trigger immune reactions in certain pathological conditions.

Box 6-1 HEALTH MATTERS

Subcutaneous Injection

Although the subcutaneous layer is not part of the skin itself, it carries the major blood vessels and nerves to the skin above. The rich blood supply and loose spongy texture of this area make it an ideal site for the rapid and relatively pain-free absorption of injected material. Liquid medicines, such as insulin, and pelleted implant materials often are administered by *subcutaneous injection* into this spongy and porous layer beneath the skin.

Cell Layers

The cells of the epidermis are found in up to five distinct layers, or ***strata.*** Each stratum (meaning "layer") is named for its structural or functional characteristics.

1. **Stratum corneum** (horny layer). The stratum corneum is the most superficial layer of the epidermis. It is composed of very thin squamous (flat) cells, which at the skin surface are dead and are continually being shed and replaced. The cytoplasm in these cells has been replaced by a water-repellent protein called *keratin.* In addition, the cell membranes become thick and chemically resistant. Specialized junctions (desmosomes) that hold adjacent keratinocytes together strengthen this layer even more and permit it to withstand considerable wear and tear. The process by which cells in this layer are formed from cells in deeper layers of the epidermis and are then filled with keratin and moved to the surface is called **keratinization.** The stratum corneum is sometimes called the **barrier area** of the skin because it functions as a barrier to water loss, although it may absorb surrounding water, and to many environmental threats ranging from microorganisms and harmful chemicals to physical trauma. Once this barrier layer is damaged, the effectiveness of the skin as a protective covering is greatly reduced, and most contaminants can easily pass through the lower layers of the cellular epidermis. Certain diseases of the skin cause the stratum corneum layer of the epidermis to thicken far beyond normal limits—a condition called **hyperkeratosis.** The result is a thick, dry, scaly skin that is inelastic and subject to painful fissures.
2. **Stratum lucidum** (clear layer). The keratinocytes in the stratum lucidum are closely packed and clear. Typically, the nuclei are absent, and the cell outlines are indistinct. These cells are filled with a soft gel-like substance called **eleidin,** which eventually will be transformed to keratin. Eleidin is rich in protein-bound lipids and serves to block

Box 6-2

Wrinkled Fingers and Toes

A long, hot bath can be good for the soul, but it almost always causes wrinkling of the skin over the fingers and toes. When immersed in water for any length of time, dead cells in the stratum corneum act like miniature sponges that absorb water and expand. Because the deeper layers do not pick up water, they provide a foundation of cells that retain their size. When the swollen water-filled cells of the stratum corneum expand over the normal-sized cells they are attached to below, the skin surface puckers, wrinkles, and bulges. The wrinkling is especially noticeable in the fingers and toes because the diameter of the digits presents less area for the skin to stretch out over. When the skin surface is dried, the outer stratum corneum cells dehydrate, the skin shrinks, and the wrinkles disappear.

water penetration or loss. This layer is absent in thin skin but is apparent in sections of thick skin from the soles of the feet or palms of the hands.

3. **Stratum granulosum** (granular layer). The process of keratinization begins in the stratum granulosum of the epidermis. Cells are arranged in a sheet two to four layers deep and are filled with intensely staining granules called **keratohyalin,** which is required for keratin formation. Cells in the stratum granulosum have started to degenerate. As a result, high levels of lysosomal enzymes are present in the cytoplasm, and the nuclei are missing or degenerate. Like the stratum lucidum, this layer of the epidermis also may be missing in some regions of thin skin.
4. **Stratum spinosum** (spiny layer). The stratum spinosum layer of the epidermis is formed from 8 to 10 layers of irregularly shaped cells with very prominent intercellular bridges or desmosomes. When viewed under a microscope, the desmosomes joining adjacent cells give the layer a spiny or prickly appearance (Latin *spinosus,* "spinelike"). Cells in this epidermal layer are rich in ribonucleic acid (RNA) and are therefore well equipped to initiate protein synthesis required for production of keratin.
5. **Stratum basale** (base layer). The stratum basale is a single layer of columnar cells. Only the cells in this deepest stratum of the epithelium undergo mitosis. As a result of this regenerative activity, cells transfer or migrate from the basal layer through the other layers until they are shed from the skin surface.

The term ***stratum germinativum*** (growth layer) sometimes is used to describe the stratum spinosum and the stratum basale together.

Quick Check

1. Identify the two main or primary layers of skin. What tissue type dominates each layer?
2. The terms *thin* and *thick* skin refer to which primary layer of skin? How do thin and thick skin differ?
3. Identify the two main cell types found in the epidermis.
4. List the five layers or strata of the epidermis.

EPIDERMAL GROWTH AND REPAIR

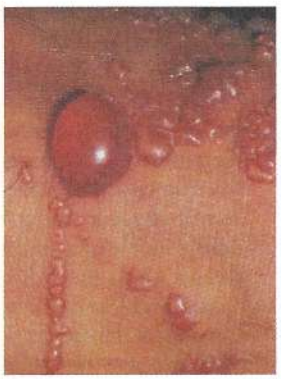
The most important function of the integument—protection—largely depends on the special structural features of the epidermis and its ability to create and repair itself following injury or disease. *Turnover* and *regeneration* time are terms used to describe the time period required for a population of cells to mature and reproduce. Obviously, as the surface cells of the stratum corneum are lost, replacement of keratinocytes by mitotic activity must occur. New cells must be formed at the same rate that old keratinized cells flake off from the stratum corneum to maintain a constant thickness of the epidermis. Cells push upward from the stratum basale into each successive layer, die, become keratinized, and eventually desquamate (fall away), as did their predecessors. This fact illustrates a physiological principle: while life continues, the body's work is never done. Even at rest it is producing millions on millions of new cells to replace old ones.

Current research suggests that the regeneration time required for completion of mitosis, differentiation, and movement of new keratinocytes from the stratum basale to the surface of the epidermis is about 35 days. The process can be accelerated by abrasion of the skin surface, which tends to peel off a few of the cell layers of the stratum corneum. The result is an intense stimulation of mitotic activity in the stratum basale and a shortened turnover period. If abrasion continues over a prolonged period of time, the increase in mitotic activity and shortened turnover time will result in an abnormally thick stratum corneum and the development of **calluses** at the point of friction or irritation. Although callus

Box 6-3 HEALTH MATTERS

Blisters

Blisters (see figures) may result from injury to cells in the epidermis or from separation of the dermal-epidermal junction. Regardless of cause, they represent a basic reaction of skin to injury. Any irritant such as poison ivy that damages the physical or chemical bonds that hold adjacent skin cells or layers together initiates blister formation. The specialized junctions (desmosomes) that hold adjacent cells in the epidermis together are essential for integrity of the skin. If these intercellular bridges, sometimes described as "spot-welds" between adjacent cells, are weakened or destroyed, the skin literally falls apart and away from the body. Damage to the dermal-epidermal junction produces similar results. Blister formation follows burns, friction injuries, exposure to primary irritants, or accumulation of toxic breakdown products following cell injury or death in the layers of the skin. Typically, chemical agents that break disulfide linkages or hydrogen bonds cause blisters. Because both types of these chemical bonds are the functional connecting links in intercellular bridges (or desmosomes), their involvement in blister formation serves as a good example of the relationship between structure and function at the chemical level of organization.



formation is a normal and protective response of the skin to friction, several skin diseases also are characterized by an abnormally high mitotic activity in the epidermis. In such conditions the thickness of the corneum is dramatically increased. As a result, scales accumulate, and development of skin lesions often occurs.

Normally about 10% to 12% of all cells in the stratum basale enter mitosis each day. Cells migrating to the surface proceed upward in vertical columns from discrete groups of 8 to 10 of these basal cells undergoing mitosis. Each group of active basal cells, together with its vertical columns of migrating keratinocytes, is called an *epidermal proliferating unit*, or EPU. Keratinization proceeds as the cells migrate toward the stratum corneum. As mitosis continues and new basal cells enter the column and migrate upward, fully cornified "dead" cells are sloughed off at the skin surface. Numerous skin diseases are characterized by an abnormally high rate of keratinization.

DERMAL-EPIDERMAL JUNCTION

Electron microscopy and histochemical studies have demonstrated the existence of a specialized area between the epidermis and dermis, called the *dermal-epidermal junction*. It is composed chiefly of an easily identified basement membrane. In addition, the junction also includes specialized fibrous elements and a unique polysaccharide gel that, together with the basement membrane, cement the superficial epidermis to the dermis below. The junction "glues" the two layers together and provides a mechanical support for the epidermis, which is attached to its upper surface. In addition, it serves as a partial barrier to the passage of some cells and large molecules. Certain dyes, for example, if injected into the dermis cannot passively diffuse upward into the epidermis unless the junctional barrier is damaged by heat, enzymes, or other chemicals that change its permeability characteristics. Although the junction is remarkably effective in preventing separation of the two skin

Box 6-4 HEALTH MATTERS

Skin Cancer

Each year in the United States more than 800,000 new cases of skin cancer are diagnosed. These *neoplasms,* or abnormal growths, result from cell changes in the epidermis and are the most common form of cancer in humans. They account for nearly 25% of all cancer in men and 14% of reported cases in women. Two forms of the disease, called ***basal cell carcinoma*** and ***squamous cell carcinoma***, account for more than 95% of all reported cases of skin cancer. Both types are very responsive to treatment and seldom *metastasize* (me-TAS-tah-size) or spread to other body areas. However, if left untreated these cancers can cause significant damage to adjacent tissues, resulting in disfigurement and loss of function. A third type of skin cancer called ***malignant melanoma*** has a tendency to spread to other body areas and is a much more serious form of the disease than either the basal cell or squamous cell varieties. About 35,000 new cases of malignant melanoma are reported each year, and of that number more than 7,000 die of the disease.

1. **Basal cell carcinoma.** This is the most common type of skin cancer. The malignancy begins in cells at the base of the epidermis (stratum basale) and most often appears on the nose and face (Figure *A*). Although lesions may occur at any age, incidence increases after age 40 years. Basal cell tumors rarely metastasize but may cause widespread destruction of normal tissue if left untreated.
2. **Squamous cell carcinoma.** Like basal cell carcinoma, this skin cancer is slow-growing and arises in the epidermis. It occurs most frequently in middle-aged and elderly individuals and typically is found on sun-exposed areas such as the scalp and forehead, backs of the hands, and top of the ears (Figure *B*). Some forms of squamous cell carcinoma may metastasize but, as a group, they are far less likely to spread to other body areas than are the malignant lesions described later.
3. **Malignant melanoma.** Malignant melanoma is the most deadly of all skin cancers. During the past 20 years, it has shown a steady increase in incidence at a rate of nearly 4% a year. The highest incidence is in older individuals (median age at diagnosis is 53 years) with light skin, eyes, and hair, and who have poor ability to tan and previous severe sunburns.

   This type of cancer sometimes develops from a pigmented *nevus* (mole) to become a dark, spreading lesion (Figure *C*). Benign moles should be checked regularly for warning signs of melanoma because early detection and removal are essential in treating this rapidly spreading cancer. The "ABCD" rule of self-examination of moles is summarized here:

   Asymmetry: Benign moles are *symmetrical;* their halves are mirror images of each other. Melanoma lesions are asymmetrical, or lopsided.

   Border: Benign moles are outlined by a distinct border, but malignant melanoma lesions are often irregular or indistinct.

   Color: Benign moles may be any shade of brown but are relatively evenly colored. Melanoma lesions tend to be unevenly colored, exhibiting a mixture of shades or colors.

   Diameter: By the time a melanoma lesion exhibits characteristics A, B, and C, it is also probably larger than 6 mm (¼ inch).

Although genetic predisposition also plays a role, many pathophysiologists believe that exposure to the sun's ultraviolet (UV) radiation is the most important factor in causing

layers even when they are subjected to relatively high shear forces, this barrier is thought to have only a limited role in preventing passage of harmful chemicals or disease-causing organisms through the skin from the external environment. Any generalized detachment of a large area of epidermis from the dermis is an extremely serious condition that may result in overwhelming infection and death.

DERMIS

The dermis, or *corium,* is sometimes called the "true skin." It is composed of a thin **papillary** and a thicker **reticular** layer. The dermis is much thicker than the epidermis and may exceed 4 mm on the soles and palms. It is thinnest on the eyelids and penis, where it seldom exceeds 0.5 mm. As a rule of thumb, the dermis on the ventral surface of the body and over the appendages is generally thinner than on the dorsal surface. The mechanical strength of the skin is in the dermis. In addition to serving a protective function against mechanical injury and compression, this layer of the skin provides a reservoir storage area for water and important electrolytes. A specialized network of nerves and nerve endings in the dermis called *somatic sensory receptors* also process sensory information such as pain, pressure, touch, and temperature. These specialized receptors are discussed in detail in Chapter 15. At various levels of the dermis, there are muscle fibers, hair follicles, sweat and sebaceous glands, and many blood vessels. It is the rich vascular supply of the dermis that plays a critical role in regulation of body temperature—a function described later in the chapter.

Papillary Layer

Note in Figure 6-1 that the thin superficial layer of the dermis forms bumps, called ***dermal papillae,*** which project into the epidermis. The papillary layer takes its name from the papillae arranged in rows on its surface. Between the sculptured surface of the papillary layer and the stratum

Box 6-4 HEALTH MATTERS

Skin Cancer–cont'd

the common skin cancers. UV radiation damages the DNA in skin cells, causing the mistakes in mitosis that produce cancer.

One of the rarer skin cancers, **Kaposi** (ka-PO-see) **sarcoma** now appears in many cases of AIDS and other immune deficiencies. Kaposi sarcoma, first appearing as purple papules (Figure *D*), quickly spreads to the lymph nodes and internal organs. Some researchers believe that a virus or other agent, perhaps transmitted along with the HIV, is a possible cause of this cancer.

A

B

C

D

basale lies the important dermal-epidermal junction. The papillary layer and its papillae are composed essentially of loose connective tissue elements and a fine network of thin collagenous and elastic fibers. The thin epidermal layer of the skin conforms tightly to the ridges of dermal papillae. As a result, the epidermis also has characteristic ridges on its surface. Epidermal ridges are especially well defined on the tips of the fingers and toes. In each of us they form a unique pattern—an anatomical fact made famous by the art of fingerprinting. These ridges perform a function that is very important to human survival: they allow us to grip surfaces well enough to walk upright on slippery surfaces and to grasp and use tools.

Reticular Layer

The thick reticular layer of the dermis consists of a much more dense *reticulum,* or network of fibers, than is seen in the papillary layer above it. It is this dense layer of tough and interlacing white collagenous fibers that, when commercially processed from animal skin, results in leather. Although most of the fibers in this layer are of the collagenous type, which gives toughness to the skin, elastic fibers are also present. These make the skin stretchable and elastic (able to rebound).

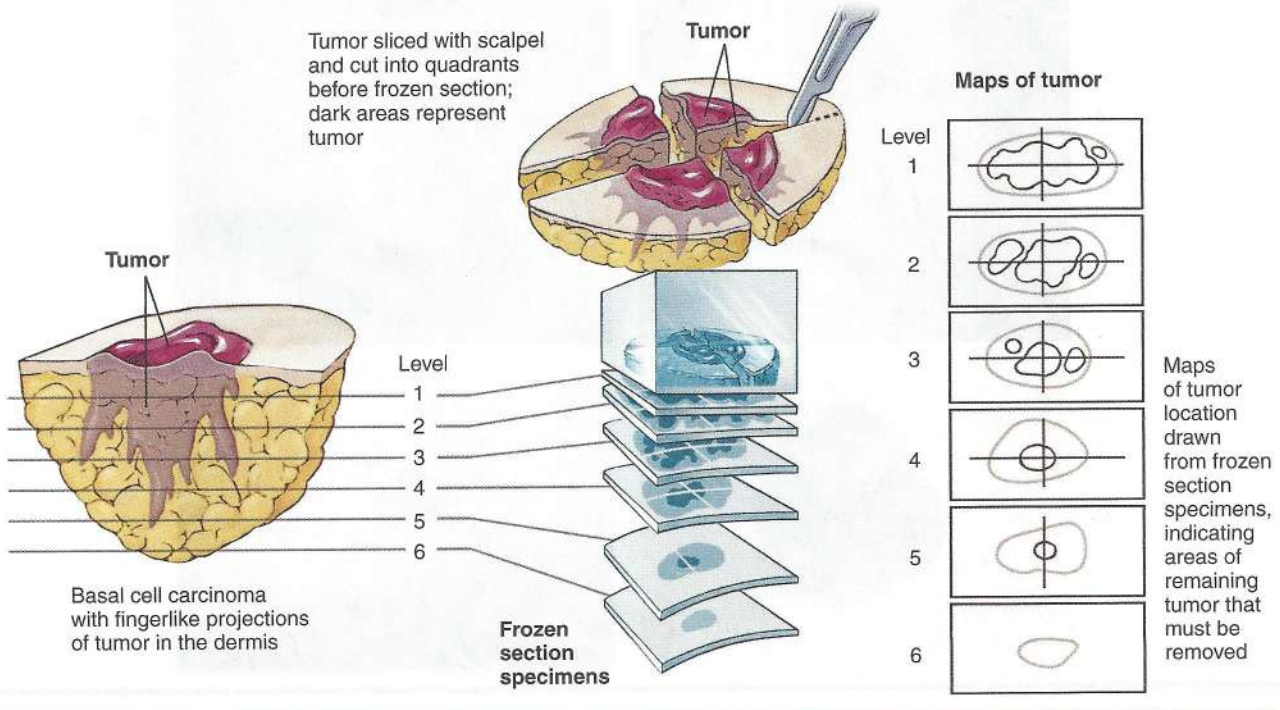
The dermis serves as a point of attachment for numerous skeletal (voluntary) and smooth (involuntary) muscle fibers. Several skeletal muscles are located in the skin of the face and scalp. These muscles permit a variety of facial expressions and are also responsible for voluntary movement of the scalp. The distribution of smooth muscle fibers in the dermis is much more extensive than the skeletal variety. Each hair follicle has a small bundle of involuntary muscles attached to it. These are the **arrector pili muscles.** Contraction of these muscles makes the hair "stand on end"—as in extreme fright, for example, or from cold. As the hair is pulled into an upright position, it

Box 6-5 DIAGNOSTIC STUDY

Mohs' Surgery

More than 60 years ago, Dr. Frederick Mohs, working at the University of Wisconsin, described a microscopically guided method for removing certain skin cancers such as basal cell carcinomas, which have fingerlike projections extending into deeper areas of the skin. These cancerous projections from the tumor must be identified and totally excised or the disease will recur. In some areas of the body, excision using standard surgical techniques may result in incomplete removal of the cancer and considerable loss of normal tissue.

In Mohs' surgery, the tumor and a minimal amount of surrounding tissue is removed in a number of thin layers. Each cut section is divided into quadrants, frozen, stained, and microscopically examined to create a series of "maps" showing areas of remaining tumor that must be excised. Sections continue to be removed until a cancer-free plane is reached. The technique is time-consuming and technically difficult, but it preserves maximum amounts of normal tissue and ensures complete removal of the tumor and its fingerlike projections. Cure rates of 95% to 99% are typical following this surgery.



raises the skin around it into what we commonly call "goose pimples." In the dermis of the skin of the scrotum and in the pigmented skin called the areolae surrounding the nipples, smooth muscle cells form a loose network. Contraction of these smooth muscle cells wrinkles the skin and cause elevation of the testes or erection of the nipples.

Millions of specialized somatic sensory receptors are located in the dermis of all skin areas (Figure 6-3; see Figure 6-1). They permit the skin to serve as a sense organ transmitting sensations of pain, pressure, touch, and temperature to the brain.

DERMAL GROWTH AND REPAIR

Unlike the epidermis, the dermis does not continually shed and regenerate. It does maintain itself, but rapid regeneration of connective tissue in the dermis occurs only during unusual circumstances, as in the healing of wounds (see Figure 5-30, p. 146). In the healing of a wound such as a surgical incision, fibroblasts in the dermis quickly reproduce and begin forming an unusually dense mass of new connective tissue fibers. If this dense mass is not replaced by normal tissue, it remains as a *scar.* The dense bundles of white collagenous fibers that characterize the reticular layer of the dermis tend to orient themselves in patterns that differ in appearance from one body area to another. The result is formation of patterns called ***Langer's cleavage lines*** (Figure 6-4). If surgical incisions are made parallel to the cleavage, or Langer's lines, the resulting wound will have less tendency to gape open and will tend to heal with a thin and less noticeable scar.

If the elastic fibers in the dermis are stretched too much—for example, by a rapid increase in the size of the abdomen during pregnancy or as a result of great obesity—these fibers will weaken and tear. The initial result is formation of pinkish or slightly bluish depressed furrows with jagged edges. These tiny linear markings *(stretch marks)* are really tiny tears. When

Box 6-5 DIAGNOSTIC STUDY

Mohs' Surgery—cont'd

A

B

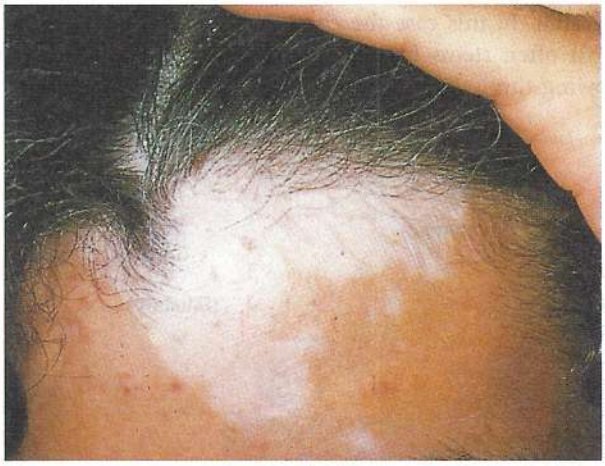
C

Mohs' surgery. A, Basal cell carcinoma that appears to be rather small. B, Mohs' surgery shows actual area of tumor growth. C, Six weeks after Mohs' surgery, the defect is healing in the absence of tumor tissue.

Box 6-6 HEALTH MATTERS

Vitiligo

An acquired condition called **vitiligo** results in loss of pigment in certain areas of the skin. The patches of depigmented white skin that characterize this condition contain melanocytes, but for unknown reasons they no longer produce pigment.



Box 6-7 HEALTH MATTERS

Cancer Vaccine

People who suffer a recurrence of malignant melanoma after their initial treatment often have a poor prognosis for long-term survival. In these individuals a few malignant cells remain after the initial surgery and then spread to other body areas. Unless detected and destroyed by the immune system, they develop into deadly new tumors that are very difficult to treat.

We now know that only about 5% of melanoma patients can effectively mount the type of immune response required to find and kill migrating melanoma cells should they escape initial treatment. Fortunately, clinical testing of two new vaccines to boost the effectiveness of the immune system in destroying melanoma cells are now underway and show great promise. One of the experimental and as yet unnamed vaccines is made from the *gm2* antigen found on the surface of the melanoma cell. This vaccine is intended to prevent recurrence of the disease after initial treatment. The other vaccine, called *Melacine,* is made from whole cell preparations of laboratory-grown cancer cells. It is being tested for both prevention of recurrence of the disease and as a less toxic alternative to chemotherapy for the treatment of advanced melanoma.

strict, for example, skin blood volume decreases, and the skin may turn pale. Or if skin blood vessels dilate, as they do during blushing, the skin appears to be pinker.

In general, the sparser the pigments in the epidermis, the more transparent the skin is and therefore the more vivid the change in skin color will be with a change in skin blood volume. Conversely, the richer the pigmentation, the more opaque the skin, resulting in less skin color changes with a change in skin blood volume.

In some abnormal conditions, skin color changes because of an excess amount of unoxygenated hemoglobin in the skin capillary blood. If skin contains relatively little melanin, it will appear bluish, that is, *cyanotic,* when its blood has a high proportion of unoxygenated hemoglobin. In general, the darker the skin pigmentation, the greater the amount of unoxygenated hemoglobin that must be present before **cyanosis** ("condition of blueness") becomes visible.

FUNCTIONS OF THE SKIN

Skin functions are crucial to maintenance of homeostasis and thus to survival itself. They are also diverse. They include such different processes as protection, sensation, growth, synthesis of important chemicals and hormones (such as vitamin D), excretion, temperature regulation, and immunity. Because of its structural flexibility, the skin permits body growth and movement to occur without injury. We also know that certain substances can be absorbed through the skin. These include the fat-soluble vitamins (A, D, E, and K), estrogens and other sex hormones, corticoid hormones, and certain drugs, including nicotine and nitroglycerine.

The skin also produces melanin—the pigment that serves as an extremely effective screen to potentially harmful ultraviolet light—and keratin—one of nature's most flexible yet enduring protective proteins. Refer to Table 6-1 as you read about the seven functions of the skin described in the paragraphs that follow.

PROTECTION

The keratinized stratified squamous epithelial cells that cover the epidermis makes the skin a formidable barrier. It protects underlying tissues against invasion by hordes of microorganisms, bars entry of most harmful chemicals, and minimizes mechanical injury of underlying structures that might otherwise be harmed by even the relatively minor types of trauma experienced on a regular basis.

In addition to protection from microbiological entry, chemical hazards, and mechanical trauma, the skin also protects us from dehydration caused by loss of internal body fluids and from unwanted entry of fluids from the external environment. The ability of the pigment melanin to protect us from the harmful effects of overexposure to ultraviolet light is yet another protective function of the skin.

Surface Film

The ability of the skin to act as a protective barrier against an array of potentially damaging assaults from the environment begins with the proper functioning of a thin film of

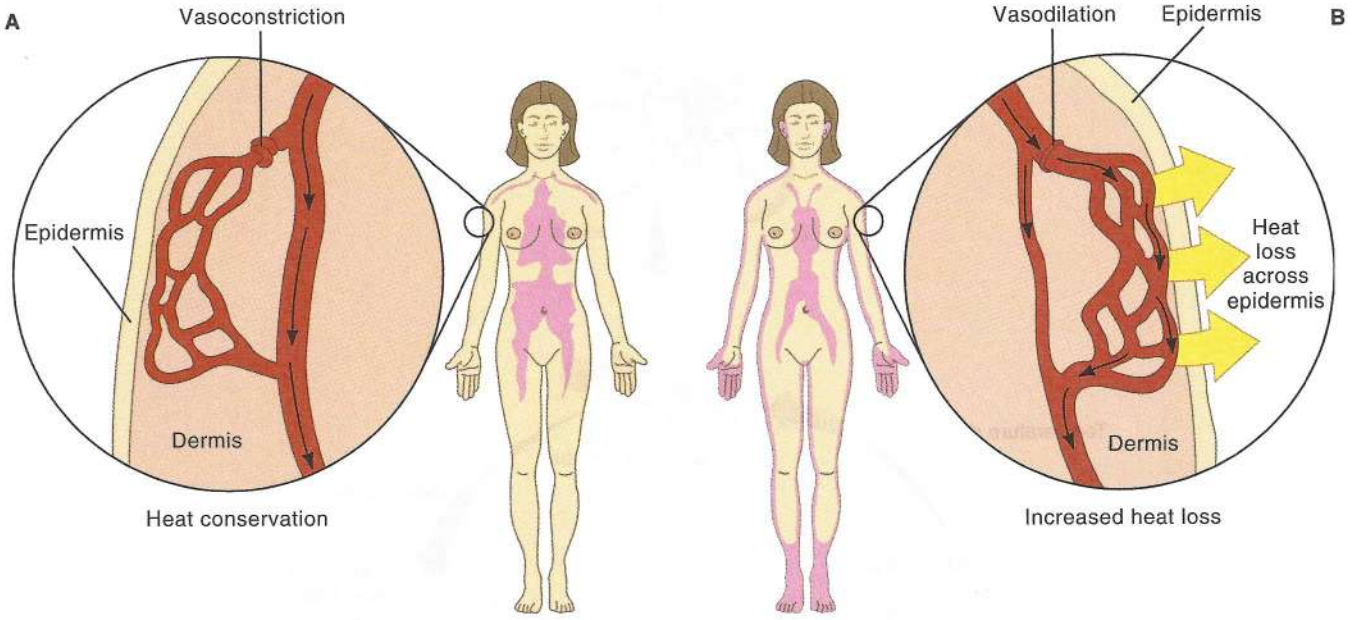


Figure 6-6 The skin as a thermoregulatory organ. When homeostasis requires that the body conserve heat, blood flow in the warm organs of the body's core increases, **A.** When heat must be lost to maintain the stability of the internal environment, flow of warm blood to the skin increases, **B.** Heat can be lost from the blood and skin by means of radiation, conduction, convection, and evaporation. The head is a major area of heat loss.

perature seems hotter in humid climates than in dry ones. At moderate temperatures, evaporation accounts for about half as much heat loss as does radiation.

Radiation

Radiation is the transfer of heat from the surface of one object to that of another without actual contact between the two. Heat radiates from the body surface to nearby objects that are cooler than the skin and radiates to the skin from those that are warmer than the skin. This is the principle of heating and cooling systems. In cool environmental temperatures, radiation accounts for a greater percentage of heat loss from the skin than conduction and evaporation combined. In hot environments, no heat is lost by radiation but may be gained by radiation from warmer surfaces to the skin.

Conduction

Conduction means the transfer of heat to any substance actually in contact with the body—to clothing or jewelry, for example, or even to cold foods or liquids ingested. This process accounts for a relatively small amount of heat loss.

Convection

Convection is the transfer of heat away from a surface by movement of heated air or fluid particles. Usually convection causes very little heat loss from the body's surface. However, under certain conditions, it can account for considerable heat loss, as you know if you have ever stepped from your shower into even slightly moving air from an open window.

Box 6-9 HEALTH MATTERS

Sunburn and Skin

Burns caused by exposure to harmful UV radiation in sunlight are commonly called *sunburns*. As with any burn, serious sunburns can cause tissue damage and lead to secondary infections and fluid loss. Cancer researchers have recently theorized that blistering (second-degree) sunburns during childhood may trigger the development of malignant melanoma later in life. Some epidemiological studies show that adults who had more than two blistering sunburns before the age of 20 years have a greater risk of developing melanoma than someone who experienced no such burns. If this theory is true, it could explain the dramatic increase in skin cancer rates in the United States in recent years. Those who grew up as sunbathing and "suntans" became popular in the 1950s and 1960s are now, as adults, exhibiting melanoma at a much higher rate than in previous generations.

HOMEOSTATIC REGULATION OF HEAT LOSS

The operation of the skin's blood vessels and sweat glands must be coordinated carefully and must take into account moment-by-moment fluctuations in body temperature. Like most homeostatic mechanisms, heat loss by the skin is controlled by a negative-feedback loop (Figure 6-7). Temperature receptors in a part of the brain, called the *hypothalamus*, detect changes in the body's internal temperature. If

branched tubular glands. Apocrine glands enlarge and begin to function at puberty, producing a more viscous and colored secretion than eccrine glands. In the female, apocrine gland secretions show cyclic changes linked to the menstrual cycle. Odor often associated with apocrine gland secretion is not caused by the secretion itself. Instead, it is caused by contamination and decomposition of the secretion by skin bacteria.

Sebaceous Glands

Sebaceous glands secrete oil for the hair and skin. Wherever hairs grow from the skin, there are sebaceous glands, at least two for each hair. The oil, or **sebum,** keeps the hair supple and the skin soft and pliant. It is nature's own protective skin cream by preventing excessive water loss from the epidermis. Because sebum is rich in chemicals such as triglycerides, waxes, fatty acids, and cholesterol that have an antifungal effect, it also contributes to reducing fungal activity on the skin surface. This property of sebum increases the effectiveness of the skin's surface film and helps protect the skin from numerous types of fungal infections. Sebaceous glands are simple branched glands of varying size that are found in the dermis, except in the skin of the palms and soles. Although almost always associated with hair follicles, some specialized sebaceous glands do open directly on the skin surface in such areas as the glans penis, lips, and eyelids. Sebum secretion increases during adolescence, stimulated by increased blood levels of the sex hormones. Frequently sebum accumulates in and enlarges some of the ducts of the sebaceous glands, forming white pimples. With oxidation, this accumulated sebum darkens, forming a **blackhead.**

Ceruminous Glands

Ceruminous glands are a special variety or modification of apocrine sweat glands. Histologically, they appear as simple coiled tubular glands with excretory ducts that open onto the free surface of the skin in the external ear canal or with sebaceous glands into the necks of hair follicles in this area. The mixed secretions of sebaceous and ceruminous glands form a brown waxy substance called ***cerumen.*** Although it serves a useful purpose in protecting the skin of the ear canal from dehydration, excess cerumen can harden and cause blockage in the ear, resulting in loss of hearing.

Quick
1. What are the two types of sweat glands? How do they differ?
2. List two functions of sebum.
3. What substances make up the skin's surface film?

Box 6-10 HEALTH MATTERS

Acne

Common *acne,* or *acne vulgaris,* occurs most frequently in the adolescent years as a result of overactive secretion by the sebaceous glands, with blockage and inflammation of their ducts. The rate of sebum secretion increases more than fivefold between 10 and 19 years of age. As a result, sebaceous gland ducts may become plugged with sloughed skin cells and sebum contaminated with bacteria. The inflamed plug is called a *comedo* and is the most characteristic sign of acne. Pus-filled *pimples* or *pustules* result from secondary infections within or beneath the epidermis, often in a hair follicle or sweat pore.

CYCLE OF LIFE

Skin

Everyone is aware of dramatic changes in skin that each person experiences from birth and through the mature years. Infants and young children have relatively smooth and unwrinkled skin characterized by the elasticity and flexibility associated with extreme youth. Because the skin tissues are in an active phase of new growth, healing of skin injuries is often rapid and efficient. Young children have fewer sweat glands than adults, so their bodies rely more on increased blood flow to maintain a normal body temperature. This explains why preschoolers often become "red-faced" while playing outdoors on a warm day.

As adulthood begins, at puberty, hormones stimulate the development and activation of sebaceous glands and sweat glands. After the sebaceous glands become active, especially during the initial years, they often overproduce sebum and thus give the skin an unusually oily appearance. Sebaceous ducts may become clogged or infected and form acne pimples or other blemishes on the skin. Activation of apoc-

rine sweat glands during puberty causes increased sweat production—an ability needed to maintain an adult body properly—and also the possibility of increased "body odor." Body odor is caused by wastes produced by bacteria that feed on the organic compounds found in apocrine sweat and on the surface of the skin.

As one continues past early adulthood, the sebaceous and sweat glands become less active. Although this can provide a welcome relief to those who suffer from acne or other problems associated with overactivity of these glands, it can affect normal function of the body. For example, the reduction of sebum production can cause the skin and hair to become less resilient and therefore more likely to wrinkle or crack. Wrinkling also can be caused by an overall degeneration in the skin's ability to maintain itself as efficiently as it did during the early years of development. Loss of function in sweat glands as adulthood advances adversely affects the body's ability to cool itself during exercise or when the external temperature is high. Thus elderly individuals are more likely to suffer severe problems during hot weather than young adults.

THE BIG PICTURE

The Skin and the Whole Body

The skin is one of the major components of the body's structural framework. It is continuous with the connective tissues that hold the body together, including those of fascia, bones, tendons, and ligaments. The integumentary, skeletal, and muscular systems work together to protect and support the whole body.

As stated several times in this chapter, the skin is a barrier that separates the internal environment from the external environment. Put another way, the skin *defines* the internal environment of the body. The barrier formed by the skin is a formidable one indeed, possessing numerous mechanisms for protecting internal structures from the sometimes harsh external environment. Without these protective mechanisms, the internal environment could not maintain a relative constancy that is independent of the external environment.

First, the dermis and epidermis work together to form a tough, waterproof envelope that protects us from drying out and from the dangers of chemical or microbial contamination. The sebaceous secretions of the skin, along with other components of the skin's surface film, enhance the skin's ability to protect the internal environment. Protection against mechanical injuries is provided by hair, calluses, and the layers of the skin itself. Pigmentation in the skin and our ability to regulate its concentration, protect us from the harmful effects of solar radiation.

Although its primary functions are support and protection, the skin has other important roles in maintaining homeostasis. For example, the skin is also an important agent in the regulation of body temperature—serving as a sort of "radiator" that can be activated or deactivated as needed. It helps maintain a constant level of calcium in the body by producing vitamin D, which is necessary for normal absorption of calcium in the digestive tract. Ridges on the palms and fingers allow us to make and use tools for getting food, building shelters, and conducting other survival tasks. The skin's flexibility and elasticity permit the free movement required to perform such tasks. Sensory nerve receptors in the dermis allow the skin to be a "window on the world." Information about the external environment is relayed from skin receptors to nervous control (integration) centers, where it is used to coordinate the function of other organs.

As you continue your study of the various organ systems of the body, keep in mind that none of them could operate properly without the structural and functional assistance of the integumentary system.

MECHANISMS OF DISEASE

Skin Disorders

Any disorder of the skin can be called a ***dermatosis,*** which means "skin condition." Many dermatoses involve inflammation of the skin, or **dermatitis.** Various disorders involving the skin have already been discussed in this chapter. A few more representative disorders are described here (see Box 6-4 on pp. 164-165).

Skin Infections

The skin is the first line of defense against microorganisms that might invade the body's internal environment. It is no wonder that the skin is a common site of infection. In adults, the antimicrobial characteristics of sebum in the skin's surface film often inhibit skin infections. In children, the lack of sebum in the surface film makes the skin less resistant to infection.

Many different viruses, bacteria, and fungi cause skin conditions. Here are a few examples of skin infections caused by different types of pathogenic (disease-causing) organisms:

1. **Impetigo.** This highly contagious bacterial condition results from *Staphylococcus* or *Streptococcus* infection and occurs most often in young children. Impetigo starts as a reddish discoloration, or *erythema,* but soon develops into vesicles (blisters) and yellowish crusts. Occasionally, the infection becomes systemic (bodywide) and thus is life threatening.

2. **Tinea.** Tinea is the general name for many different *mycoses* (fungal infections) of the skin. Ringworm, jock itch, and athlete's foot are all classified as tinea. Signs of tinea include erythema, scaling, and crusting. Occasionally, fissures, or cracks, in the epidermis develop at creases in the epidermis. Figure 6-15 shows a case of ringworm, a tinea infection that typically forms a round rash that heals in the center to form a ring. Antifungal agents usually stop the acute infection but are unable to completely destroy the fungus. Recurrence of tinea can be avoided by keeping the skin dry, because fungi require a moist environment to grow.
3. **Warts.** Caused by papillomaviruses, warts are nipplelike neoplasms of the skin. Although they are usually benign, some warts transform to become malignant. Transmission of warts generally occurs through direct contact with warts on the skin of an infected person. Warts can be removed by freezing, drying, laser therapy, or application of chemicals.
4. **Boils.** Also called *furuncles,* boils are local *Staphylococcus* infections of hair follicles characterized by large, inflamed, pus-filled lesions. A group of untreated boils may fuse into even larger lesions called *carbuncles.*

Vascular and Inflammatory Skin Disorders

Everyone who might ever be called on to provide care to a bedridden or otherwise immobilized individual should be aware of the causes and nature of pressure sores, or **decubitus ulcers** (Figure 6-16). *Decubitus* means "lying down," a name that hints at a common cause of pressure sores: lying in one position for long periods. Also called *bedsores,* these lesions appear after blood flow to a local area of skin slows because of pressure on skin covering bony prominences such as the ankles. Ulcers form and infections develop as lack of blood flow causes tissue damage. Frequent changes in body position and soft support cushions help prevent decubitus ulcers.

A common type of skin disorder that involves blood vessels is **urticaria,** or *hives.* This condition is characterized by raised red lesions, called *wheals,* caused by leakage of fluid from the skin's blood vessels. Urticaria is often associated with severe itching. Hypersensitivity or allergic reactions, physical irritants, and systemic diseases are common causes.

Scleroderma is an autoimmune disease that affects the blood vessels and connective tissues of the skin. The name *scleroderma* comes from the word parts *sclera-,* which means "hard," and *derma,* which means "skin." Hard skin is a good description of the lesions characteristic of scleroderma. Scleroderma begins as a mild inflammation that later develops into a patch of yellowish, hardened skin. Scleroderma most commonly remains a mild, localized condition. Very rarely, localized scleroderma progresses to a systemic form, affecting large areas of the skin and other organs. Persons with advanced systemic scleroderma seem to be wearing a mask because skin hardening prevents them from moving their mouths freely. Both forms of scleroderma occur more commonly in women than in men.

Psoriasis is a chronic inflammatory disorder of the skin thought to have a genetic basis. This common skin problem is characterized by cutaneous inflammation accompanied by scaly lesions that develop from an excessive rate of epithelial cell growth (Figure 6-17).

Eczema is the most common inflammatory disorder of the skin. This condition is characterized by inflammation often accompanied by papules (bumps), vesicles (blisters), and crusts. Eczema is not a distinct disease but rather a sign or symptom of an underlying condition. For example, an allergic reaction called *contact dermatitis* can progress to become eczematous. Poison ivy is a form of contact dermatitis—occurring on *contact* with chemicals produced by the poison ivy plant.

Abnormal Body Temperature

Maintenance of a body temperature within a narrow range is necessary for normal functioning of the body. Figure 6-18 shows that straying too far out of the normal range of body temperatures can have very serious physiological conse-

Figure 6-15 *Tinea* infection (ringworm).

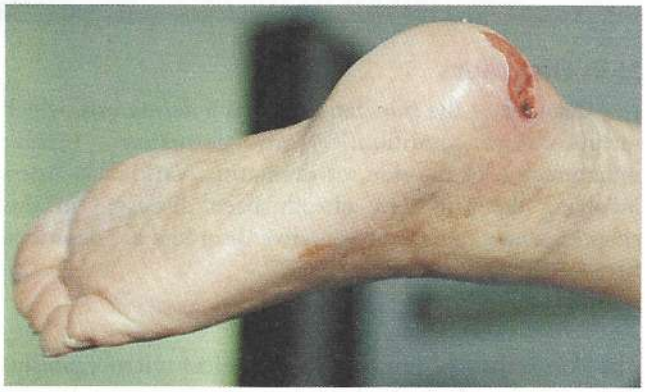


Figure 6-16 Decubitus ulcer.