19

Support and Movement

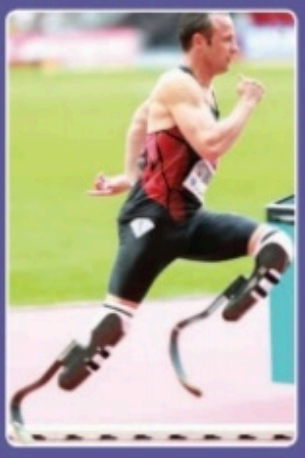
Going Further in Life Science

Blade Runner

How fast do you think this man with no feet can run? His name is Oscar Pistorius, and both of his legs were amputated when he was very young. With the help of prosthetic limbs, Pistorius was able to play several sports, but his real passion is running. And Pistorius is fast, faster than most men with two normal legs. He can run the 100-meter sprint in 10.91 seconds. As of 2011, the fastest man on earth could do it in 9.58 seconds. Pistorius's prosthetic limbs have earned him the nickname "Blade Runner."

Officials for the 2008 Summer Olympics decided that Pistorius's prosthetic limbs were so good that he had an unfair advantage. They decided not to allow him to compete. Pistorius appealed the decision and won permission to try out for the South African Olympic team. Though he just barely missed qualifying, the Blade Runner effectively demonstrated the potential of prosthetic limbs and of people with handicaps.

What factors do prosthetic designers have to consider? The real challenge is creating prosthetic limbs that imitate the human body. Because the human body is very complex, this is not an easy task. Your hand alone contains over 35 bones and many muscles. The skin acts as a flexible, protective covering for these bones and muscles. Your muscles can be gentle enough to stroke a kitten or strong enough to open a jar of jelly. You know how much force to use because you know the difference between a kitten and a jelly jar—you can react to different situations in your environment.



For scientists to make a prosthesis that works correctly, they have to know how all those bones and muscles work. They even need to know about the skin that covers the bones and muscles.

19A Introduction to the Human Body

The study of the human body is very important for the Christian. Our bodies are tools that God has given to us while we live in His world. Knowing how our bodies work will enable us to use them better and take care of them as we serve Him.

19A Section Objectives

- ✓ Explain why the study of the human body is important for Christians.
- ✓ Discuss the differences between humans and animals.
- ✓ Differentiate between anatomy and physiology.
- ✓ Demonstrate proper use of basic anatomical terms.
- ✓ Describe the levels of organization in the human body.
- ✓ Distinguish between the four types of tissues.

19.1 *What Is a Human?*

Before you study about how the human body works, it is important to understand just what a human is. A naturalistic worldview sees humans as the result of an evolutionary process by which our intelligence, emotions, and other characteristics developed over several million years. This view holds that humans are not that different from animals. Christians, however, know that humans *are* different from animals. Genesis 1:27 states that "God created man in his own image." Humans are a special creation of God.

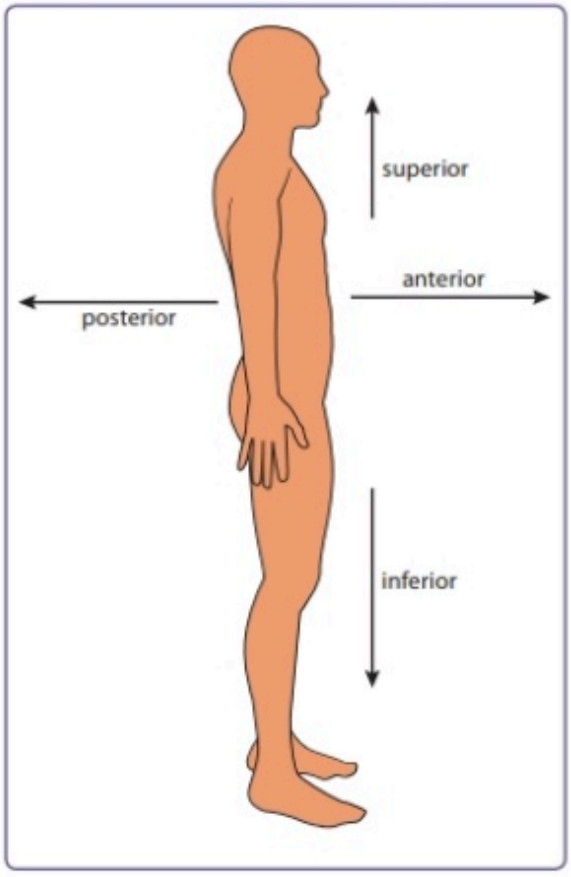
19-1 What makes a human different from an animal?

It is true that humans share some characteristics with certain animals. For example, both humans and animals have the ability to learn. Dogs can be taught to sit, roll over, and shake hands. Children can be taught to tie their shoes, play the piano, and recite multiplication facts. Both humans and many animals display intelligence. But there is a huge difference between what humans can learn and what animals can learn.

There is an even bigger difference between humans and animals than just our intelligence: we have a spiritual nature, and animals don't. Animals can learn to do or not to do certain things by repeated rewards and punishments. However, animals cannot understand the difference between right and wrong as humans can. This is because humans have a conscience. God created man, and man is accountable to God for his actions. We can understand right and wrong and choose between them. Because the first man, Adam, chose to disobey God, all humans since have been born sinners (Rom. 5:12).

However, the Bible does not leave us without hope. God has provided a way of salvation from sin through the death and resurrection of His Son, Jesus Christ (John 3:16; Rom. 6:23). By placing faith in Him, we can have a personal relationship with God and spend eternity with Him.

physiology: physio- (Gk. *phusis*—nature) + -logy (study of)
anatomy: ana- (Gk. *ana*—up) + -tomy (Gk. *tome*—a cutting)



19-2 Common terms of human anatomy

19.2 Anatomy and Physiology

In this unit, you will study how your body works. This is called *physiology*—the study of the functions of a living organism and its parts. To understand how something works, you must first know about its structure. This is called *anatomy*—the study of the shape and structure of an organism and its parts.

Anatomical Terms

Many terms are used in the study of the human body. You should become familiar with the terms listed below before you continue your study of the human body.

- *Anterior* means "toward the front" (stomach side). For example, the stomach is anterior to the backbone.
- *Posterior* means "toward the back." For example, the shoulder blades are posterior to the collarbones.
- *Superior* means "upward, toward the head." For example, the heart is superior to the stomach.
- *Inferior* means "downward, toward the feet." For example, the legs are inferior to the chest.

Levels of Organization

Your body is made of trillions of cells. But those cells do not work independently of each other. They are highly organized to perform specific functions. (See pp. 76–77.)

Tissues. Cells are grouped into tissues. A *tissue* is a group of cells that work together to perform a certain function.

Connective tissues serve to support, connect, and protect other body structures. Examples include bone, blood, fat, and lymph tissues.

Epithelial (EP uh THEE lee ul) *tissues* line the external and internal surfaces of your body. Your skin and the linings of your internal organs are examples.

Muscle tissue contracts either to move your body or to move substances through your body.

Nerve tissue receives and transmits electrochemical impulses to coordinate the functions of the body. The brain, spinal cord, and nerves are examples of nerve tissue.

Organs. *Organs* are groups of tissues that work together to perform a certain function. Your stomach is an organ. It is lined with epithelial tissue for protection. Blood, a connective tissue, brings oxygen and nutrients to the stomach cells. Muscles churn the food you eat. Nerves in the stomach coordinate all these processes.

Organ systems. Organs with similar functions are grouped together into *organ systems*. For example, your digestive system includes your stomach, intestines, liver, and several other organs. Obviously, organ systems can overlap. Your heart is part of your circulatory system, yet it is also a muscle in the muscular system. All your body's systems are interdependent. God designed them to work together, and all are important

Think About It

Can you think of other organs that belong to more than one body system? How do scientists decide which system to classify the organs in?

for survival. Table 19-1 is an overview of the organ systems and the chapter sections they can be found in.

19-1 Human Organ Systems

Organ system	Section number	Major functions	Examples
integumentary	19B	protection	skin
skeletal	19C	support, protection, and movement	bones
muscular	19D	movement	muscles
circulatory	20B, 20C	transport blood and other substances throughout body	heart, blood vessels
immune	20D	protect against disease	lymph nodes
excretory	20E	eliminate wastes, maintain water balance	kidneys
respiratory	21A	exchange gases between blood and air	lungs
digestive	21B	absorb food, eliminate wastes	stomach, intestines
nervous	22A, 22B	coordinate and control movement, process sensory information	brain, eyes, ears
endocrine	22C	regulate body functions	glands that secrete hormones
reproductive	—	produce offspring	ovaries, uterus, testes

19A Section Review

1. How are humans different from animals?
2. (True or False) Anatomy is the study of the functions of a living organism and its parts.
3. The eyes are _____ to the mouth.
   a. anterior
   b. superior
   c. posterior
   d. inferior
4. The _____ is anterior to the _____.
   a. head; abdomen
   b. knee; ankle
   c. chest; shoulder blades
   d. vertebral column; heart
5. What is a tissue?
6. Blood and bone are
   a. epithelial tissues.
   b. muscle tissues.
   c. nerve tissues.
   d. connective tissues.
7. What type of tissue lines the internal and external surfaces of your body?
8. List the eleven organ systems of the human body.
9. According to Table 19-1, what organ systems are used in the protection of the body?
   a. integumentary and excretory
   b. muscular and skeletal
   c. immune and digestive
   d. integumentary and skeletal

19B Section Objectives

- ✓ Describe the layers of human skin.
- ✓ Explain how the skin protects the body and helps regulate body temperature.
- ✓ Explain how skin color is produced.
- ✓ Compare the benefits and drawbacks of exposure to sunlight.
- ✓ Differentiate between the three types of burns.

integumentary: in- (L. *in*—in or on) + -tegumentary (L. *tegere*—to cover)
pathogen: patho- (Gk. *pathos*—suffering) + -gen (Gk. *genes*—born)

epidermis: epi- (upon) + -dermis (skin)

Would You Believe?

Although it is only 1 mm to 2 mm (0.04 in. to 0.08 in.) thick, the skin is the largest organ of your body. It makes up about 6% of your body weight, and it covers about 1.9 m² (20.5 sq ft) on an adult.

19B The Integumentary System

Your *integumentary* (in TEHG yoo MEN tuh ree) *system* includes your skin, hair, and nails. Your skin is one of your body's major defenses. Unless your skin is cut or damaged, few disease-causing organisms (*pathogens*) (PATH uh junz) can penetrate the skin. Although we often think of skin as thin and easily damaged, it is actually quite strong. It functions well in keeping your insides in and other things out.

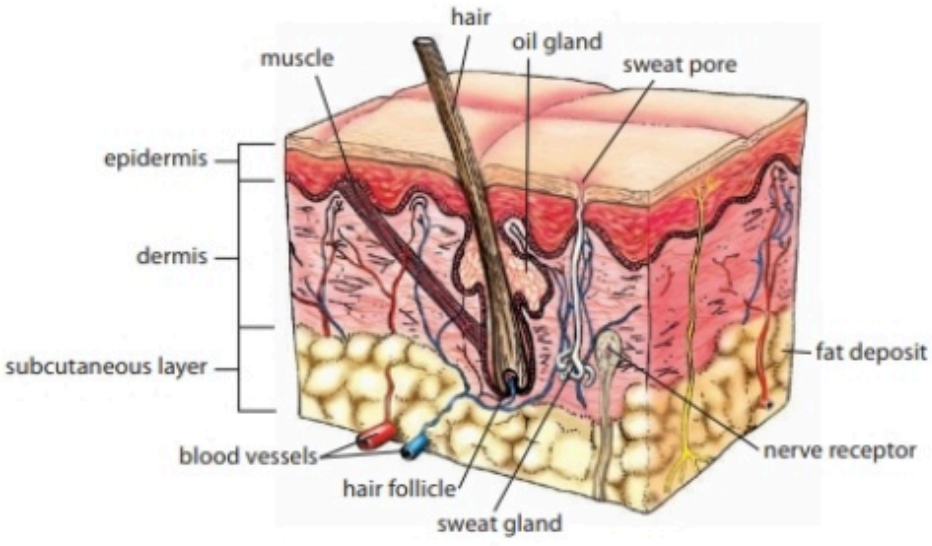
19.3 What Your Skin Is Made of—Anatomy

Skin is made up of two layers—the epidermis and the dermis. Beneath the dermis is a layer of fat and fibers called the subcutaneous layer.

Epidermis

The outer layer of skin, called the **epidermis** (EP ih DUR mis), is made of epithelial tissue. The surface of the epidermis consists of dead cells. Living cells are underneath the dead ones, along with nerve endings such as pain receptors. The dead cells on the surface of the skin are constantly shed as you wash and as your clothing rubs against your body. The living cells of the epidermis continuously replace these dead cells. The living cells divide by mitosis to form new cells. These new cells become filled with a protein substance called *keratin*. They then die and are pushed outward to be shed.

The skin at the tips of your fingers and toes is soft and sensitive. Before you were born, the epidermis near these spots thickened and developed nails to protect your fingers and toes.



19-3 The anatomy of human skin

Dermis

The inner, thicker layer of the skin is the **dermis** (DUR mis). The dermis consists mostly of connective tissues. It contains many blood vessels, nerve receptors, and hair follicles. Sweat glands, oil glands, and wax glands are also found in the dermis. Special cells in the dermis make fibers, which are woven around and between all these structures to connect them together. These structures must be considered when designing a prosthesis. If sweat or oil builds up on the skin where the prosthesis connects, it can cause irritation and even damage to the skin.

The dermis also contains *hair follicles*—structures from which hair develops. As the cells in the hair follicles divide, the

hair grows. The part of the hair deep in the follicle is alive, but the part of the hair above the epidermis is composed of closely packed, dead, keratin-filled cells.

Oil glands next to each hair follicle secrete oil that keeps the skin and hair soft, flexible, and water resistant. Pores in the epidermis release the oil onto the skin surface. The skin in your ear canals contains glands that produce a white substance that later turns into dark, sticky earwax. Earwax protects the ear by repelling insects and trapping foreign objects. It also keeps the eardrum and the skin of the inner ear from drying out.

Health Hint—Acne

Sometimes pores become blocked with oil and other materials. When this happens, the oil glands can become inflamed, resulting in *acne* (ACK nee). Scientists do not understand everything about what causes acne. They do know, however, that cleanliness, bacteria, diet, hormones, and heredity can all be involved. Keeping your face clean and using topical medications are good ways to limit acne.

Subcutaneous Layer

The **subcutaneous** (SUB kyoo TAY nee us) **layer** below the dermis is not really a part of the skin. It consists of loosely arranged fat cells and fibers. The fat cells help cushion and insulate your body. The fibers attach the skin to the muscles under the skin. Blood vessels are also found throughout the subcutaneous layer.

subcutaneous: sub- (L. *sub*—under) + -cutaneous (L. *cutis*—skin)

The fibers of the dermis and the subcutaneous layer are connective tissues that are elastic. As a person ages, these fibers begin to lose their elasticity. This is similar to the way a rubber band becomes less elastic after it has been used a lot. The loss of elasticity causes the skin to sag and wrinkle.

19.4 *How Your Skin Protects You—Physiology*

God designed the structures of your skin to protect you. The barrier formed by your skin keeps harmful chemicals and pathogens out while holding in the fluids and substances of your body. Structures within your skin sense factors in your environment and provide you with information that you need to survive. Other skin structures form under special circumstances to protect you from physical injury.

Functions of the Integumentary System

- Sensation
- Protection
- Temperature regulation
- Manufacture of vitamin D

Sensation

The nerve receptors of the skin respond to cold, heat, touch, pressure, and pain. In the dermis a nerve loops around the root of each hair follicle. Whenever a hair is bent, the nerve receptor is stimulated, and you sense that the hair has been touched. In this way, your hair helps make you aware of things near your body.

Most hair follicles also have a small muscle attached to them. When the muscle contracts, the hair stands on end, causing goose bumps. Temperature and some emotions, such as fear, can trigger the formation of goose bumps.

Protection

Your skin protects you from more than dangerous chemicals and pathogens. Working with tools such as shovels and rakes exposes your skin cells to friction that can damage skin's delicate structures. The skin that is subjected to friction and pressure responds

19-4 What is the difference between a callus (a) and a blister (b)?

Would You Believe?

On a normal day, with no strenuous activity, you lose about 237 mL (8 oz) of water through sweat. On a hot day, with strenuous activity, you can lose almost 7.6 L (2 gal) of water! The moral of the story? Drink plenty of water to stay hydrated!

by producing more cells in that area. The thickened epidermis helps protect the deeper layers of the skin. An area of skin with thickened epidermis is a *callus*. Calluses often form on your feet when you go barefoot or when skin is exposed to rubbing or pressure (such as when you wear a new pair of shoes).

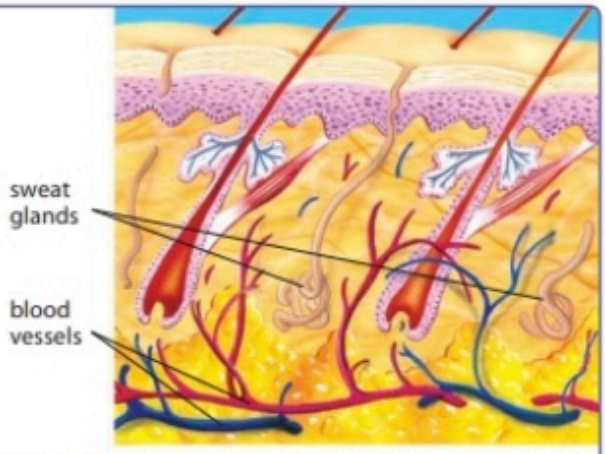
Blisters form when the skin is exposed quickly to excessive friction or intense heat. Friction causes the epidermis to separate from the dermis. Intense heat can damage the dermis and also cause the layers to separate. Fluid, mostly water, collects in the space between the separated layers. Over time, the water is absorbed into the dermis, and new epidermis forms to heal the injury.

Regulation of Body Temperature

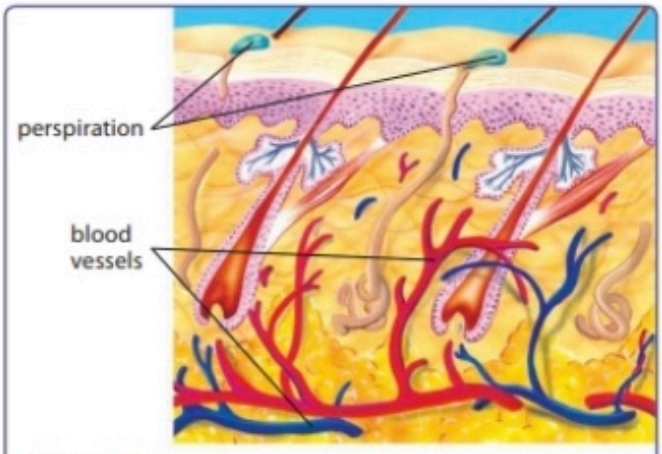
Another important function of skin is to regulate body temperature. The blood vessels and the sweat glands in the skin work together to maintain your body temperature. On hot days and at times when you are very active, the blood vessels in the dermis dilate (open wide) to allow more blood to flow near the epidermis. (See Figure 19-5.) As the warm blood from within your body comes close to the surface, its heat is released through the epidermis. At the same time, the sweat glands secrete *perspiration* (sweat) through tiny pores on the surface of the epidermis. Since sweat is mostly water, it evaporates quickly, cooling the surface of your skin.

When your body becomes cold and needs to conserve heat, the blood vessels in the skin constrict (contract to become thinner), and the pores of the sweat glands close. When this happens, your skin becomes pale, dry, and cold.

When you are warm inside but your skin is exposed to cold (like when you are active outside on a cold winter day), blood is sent to your skin to help keep the skin warm. This is why your nose and cheeks turn red while you build a snowman. These automatic changes in the skin help regulate the body's temperature.



At normal body temperature there is only enough blood supplied to keep the skin cells alive. Sweat glands are minimally active, and the skin's blood vessels are not enlarged.



When the body becomes warm, the skin's blood vessels enlarge to carry warm blood near the surface for cooling. As perspiration evaporates, it cools the skin.

19-5 The skin helps regulate body temperature.

19.5 Skin Color

A dark pigment called **melanin** (MEL uh nin) causes much of the color of human skin. Special cells in the epidermis produce melanin and pass it on to other cells of the skin. Skin that produces only a little melanin sometimes appears pink because the color of the blood shows through the epidermis. Freckles are clumps of cells that contain more melanin than the rest of the skin. People with darker skin have a greater amount of melanin in their skin. Some people have more *carotene* (KEHR uh TEEN), a yellowish pigment, in their skin. This combination of pigments results in a yellowish brown skin color.

melanin: (Gk. *melas*—black)

No one should ever look down on another person simply because that person has a different skin color. Differences in hair or eyes or skin color are all features that are part of God's design. They don't make one person better or worse than another. Acts 17:26 reminds us that God made all the nations from one man (Adam). Jesus made only one distinction between people—those bound for heaven and those bound for hell. He commanded us to tell everyone about Him (Matt. 28:19) and to love all people just as much as we love ourselves (Luke 10:25–37).

19-6 The differences in skin color among human beings are due only to the different amounts of melanin in the skin.

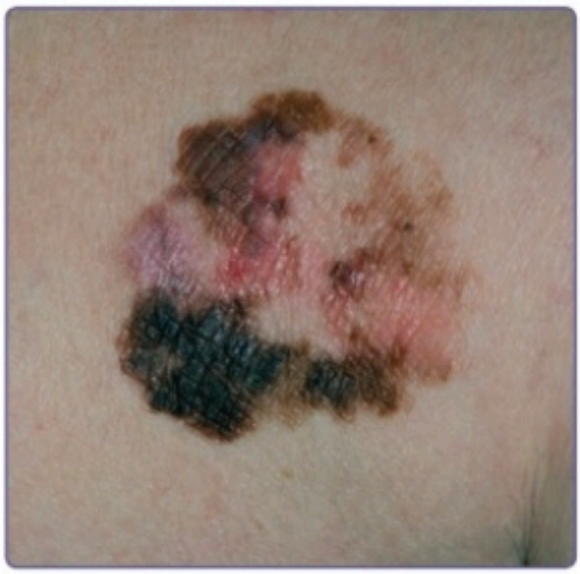
Too Much Sun

A little sunlight is good for your skin since invisible ultraviolet rays of the sun are used by your skin to produce vitamin D. However, excessive exposure to sunlight may result in sunburn. When you get a sunburn, the ultraviolet rays of the sun kill some of your skin cells. As your body replaces these cells, the increased blood flow to your skin causes redness and soreness.

The ultraviolet rays in sunlight can also cause skin cancer. This happens because the ultraviolet rays can cause somatic mutations in the DNA of skin cells (see p. 136). Some of these mutations may cause skin cells to undergo rapid and uncontrolled cell divisions called *cancer* (see p. 94).

When skin is exposed to sunlight, it produces extra melanin, resulting in a tan. Tanning is the body's way of trying to protect the skin from the harmful ultraviolet rays of the sun. Melanin absorbs some of these rays before they can damage the cells. This is why the body produces more melanin. Sunbathers who expose themselves to the sun in an effort to look better are actually forcing their bodies to use this means of protection. As a result, they increase their risk of developing skin cancer. Because such tans require skin cells to be replaced much faster than normal, they also cause the skin to age prematurely.

Some studies indicate that it is the sunburns obtained before you turn 20 that produce the greatest risk of melanoma, one of the most dangerous types of skin cancer, later in life. So how much sunlight do people need each day? Many scientists say you need about 15 minutes of sun exposure most days to produce enough vitamin D—but this amount can vary from person to person.



19-7 Excessive exposure to sunlight increases the risk of skin cancer.

Facets of Life Science: Burns

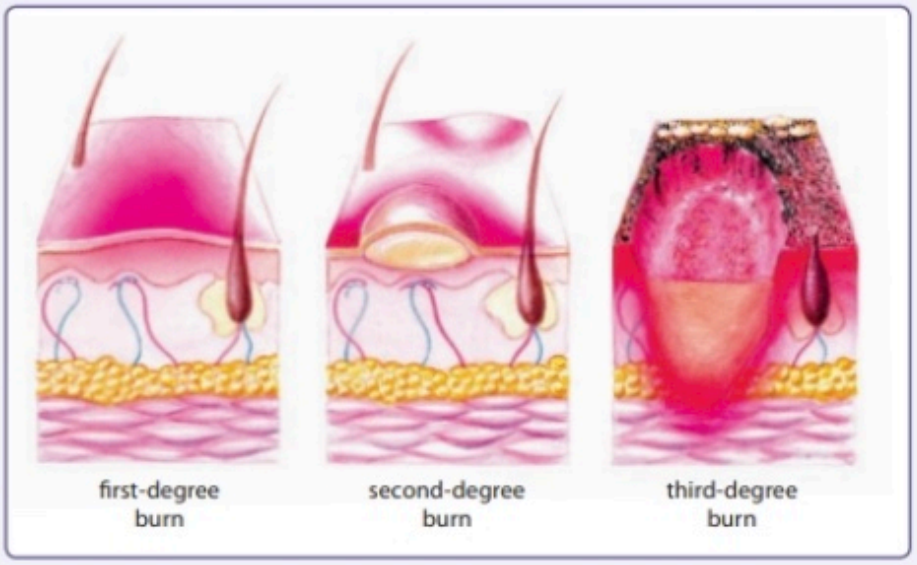
Remember the last time you had a sunburn? Your skin probably turned red, itched, and maybe even blistered. All burns destroy body tissues. Minor burns, such as sunburn caused by the sun's ultraviolet rays, damage the outer layer of the skin, whereas more severe burns destroy deeper tissues. Touching hot metal or liquids is usually the cause of severe burns, but not always. Some burns have quite unusual causes.

Some chemicals cause burns by reacting with the skin's oil or sweat, or even the skin itself. The intense heat given off by these reactions destroys the surrounding cells. For example, phosphorus pentoxide is used in manufacturing fertilizers, baking powder, and other household products. This chemical reacts with the water in sweat to produce phosphoric acid and large amounts of heat.

Most chemical burns should be rinsed with large amounts of water. Phosphorus burns, however, should be soaked in water since rinsing them can cause tissues to slough off. Soaking the burn dilutes the acid so that it no longer burns.

A chemical burn

Electrical burns occur when a strong electrical current passes through a person's body. The current usually enters at one point and leaves at another small point on the opposite side of the body. Between these two points it fans out, destroying many tissues inside the body. Electrical burns are always much worse than they look.



Ultraviolet rays, x-rays, and highly radioactive substances can cause radiation burns. A radiation burn interferes with the functions of cells, prevents them from reproducing, and often kills them. The scar tissue that replaces the destroyed cells cannot carry on the functions of the original cells. Sunburn is a mild ultraviolet radiation burn.

Weather forecasts often include the UV index, which is the amount of UV (ultraviolet) radiation that is expected at a particular point on the earth's surface when the sun is highest overhead. Therefore, the UV index on a particular day will be different for different parts of the world. It is calculated by determining the elevation of the sun, the amount of ozone in the stratosphere, and the amount of cloud cover. The scale of the UV index ranges from 0 (night) to 15+ (tropics on a cloudless day). A UV index up to 5 means there is a low to moderate risk from sun exposure. Values of 6 and up indicate a high (6–7), very high (8–10), or extreme (11+) risk.

Anytime you plan to be outside for an extended period of time, you should use sunscreen to protect yourself from UV radiation. It is best to use sunscreen that has an SPF (sun protective factor) of at least 15. Sunscreens help prevent skin damage by absorbing, reflecting, or scattering UV radiation.

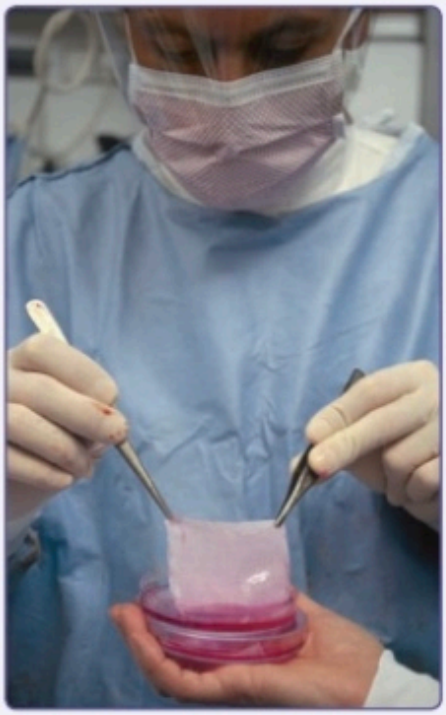
Whether or not a burn is serious depends on two factors: how deep it is and how much body surface it covers.

- A *first-degree burn*, such as a mild sunburn, damages only the outer epidermal layers of the skin. This results in redness and sometimes pain. The best way to treat first-degree burns is to apply cold water (not ice since too much cold could damage tissues) for at least half an hour. This treatment relieves the pain and prevents heat from continuing to damage the tissues. After this treatment, first-degree burns should be covered with clean, dry dressings.

This sunburn is a first-degree burn.

- A *second-degree burn* damages the upper part of the dermis as well as the epidermis. It causes red or pink blistered skin. Touching a second-degree burn turns the skin white and causes pain. As a second-degree burn heals, the skin often becomes firm and leathery because of water trapped beneath the epidermis. Small second-degree burns can be treated with cold water and covered with gauze. Larger burns should receive medical treatment. A victim who has second-degree burns over more than 75% of his body has almost no chance of recovering.
- A *third-degree burn* destroys both the dermis and the epidermis. The skin, if it is still present at all, is waxy white, red, brown, or black and does not turn white when touched. Touching a third-degree burn causes no pain because all the nerve endings in such burns have been destroyed. Immediate medical treatment should be obtained for third-degree burns. A victim with third-degree burns over 50% of his body has a poor chance of surviving.

Serious burns can be treated by applying chemicals that form crusts over the burned area while the tissues heal naturally. They also can be treated by transplanting pieces of skin from other body areas. Synthetic membranes are now used for some temporary transplants. These temporary transplants help reduce pain and stimulate scar tissue formation, but they do not remain part of the body. Another treatment for severe burns is to cover the burned areas with artificially grown skin. In this treatment a small amount of undamaged skin is taken from the patient. The skin cells rapidly grow and reproduce in a laboratory. The resulting skin is then grafted back onto the patient.



Cultured skin graft being prepared for use

19B Section Review

1. Your skin is part of the body's _____ system.
2. What are the two layers of the skin? Which is the outer layer? What type of tissue composes each layer?
3. What is acne?
4. (True or False) The subcutaneous layer is not actually part of the skin.
5. An area of thickened epidermis is a(n) _____.
6. Besides perspiration, how else does skin function to keep you cool?
7. The dark pigment that colors people's skin is called
   a. keratin. c. vitamin D.
   b. adipose. d. melanin.
8. Mention one way that sun exposure can help you and one way that it can harm you.
9. (F) A burn that damages the epidermis and the upper part of the dermis is a _____ burn.
   a. first-degree c. third-degree
   b. second-degree d. fourth-degree