Children in war-torn countries are often trapped by violence. You see them carrying weapons and walking in menacing packs on newscasts, and you have to wonder. How old are these children—12? 15? Did they volunteer for combat? Are they actually modern-day slaves? Do they even understand what they are doing? One of the most disturbing aspects of recent civil wars has been the rise of child soldiers. Too vulnerable to say no, they maim and mutilate until, often, they wind up getting a taste of their own medicine.

One thing is sure: Few situations are more stressful than combat. War creates immediate and long-term psychological and physiological stresses, ranging from adrenaline rushes and exposure to wounds, disease, and death in the short term, to posttraumatic stress disorder and fatal diseases in the long term. Money spent on the military siphons money from public health services, such as immunization or malaria prevention. Conflict spreads infectious disease. In Uganda, HIV infection skyrocketed during the turbulent 1980s, then fell during the relatively peaceful 1990s. As the medical infrastructure dissolves, rape, anarchy, poverty, and unsanitary conditions all increase. Whereas the stress of combat is known to lower the body’s defenses against disease and to facilitate homeostatic imbalances, much milder stresses can also cause physiological and psychological problems. In this chapter, we examine the body’s initial defenses against stress and pathogens, and look at helpful and harmful responses to the stresses of the environment.


What is Stress?

**LEARNING OBJECTIVES**

- Define stress and the body’s immediate response to it.
- List the innate defenses.
- Explain specific and nonspecific immunity.

**Table 9.1 Innate defenses**

<table>
<thead>
<tr>
<th>Component</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Line of Defense: Skin and Mucous Membranes</td>
<td></td>
</tr>
<tr>
<td>Physical Factors</td>
<td></td>
</tr>
<tr>
<td>Epidermis of skin</td>
<td>Forms a physical barrier to the entrance of microbes.</td>
</tr>
<tr>
<td>Mucous membranes</td>
<td>Inhibits the entrance of many microbes, but not as effective as intact skin.</td>
</tr>
<tr>
<td>Nose</td>
<td>Traps microbes in respiratory and gastrointestinal tracts.</td>
</tr>
<tr>
<td>Hairs</td>
<td>Filter out microbes and dust in nose.</td>
</tr>
<tr>
<td>Ear</td>
<td>Togethers with mucus, trap and remove microbes and dust from upper respiratory tract.</td>
</tr>
<tr>
<td>Lintarl apparatus</td>
<td>Tears, dilutes and washes away irritating substances and microbes.</td>
</tr>
<tr>
<td>Lungs</td>
<td>Washes microbes from surfaces of teeth and nose.</td>
</tr>
<tr>
<td>Mucus</td>
<td>Washes microbes from mouth.</td>
</tr>
<tr>
<td>Defecation</td>
<td>Expels microbes from body.</td>
</tr>
<tr>
<td>Chemical Factors</td>
<td></td>
</tr>
<tr>
<td>Saliva</td>
<td>Washes microbes from mouth.</td>
</tr>
<tr>
<td>Interferons (IFNs)</td>
<td>Protect uninfected host cells from viral infection.</td>
</tr>
<tr>
<td>Vaginal secretions</td>
<td>Slight acidity discourages bacterial growth; flush microbes out of vagina.</td>
</tr>
<tr>
<td>Second Line of Defense: Internal Defenses</td>
<td></td>
</tr>
<tr>
<td>Antimicrobial Proteins</td>
<td></td>
</tr>
<tr>
<td>Interferons (IFNs)</td>
<td>Protect uninfected host cells from viral infection.</td>
</tr>
<tr>
<td>Complement system</td>
<td>Causes cytolysis of microbes, promotes phagocytosis, and contributes to inflammation.</td>
</tr>
<tr>
<td>Transamides</td>
<td>Inhibit growth of certain bacteria by reducing the amount of available iron.</td>
</tr>
<tr>
<td>Natural killer (NK) cells</td>
<td>Kill infected target cells or releasing granules that contain perforin and granzymes.</td>
</tr>
<tr>
<td>Phagocytes</td>
<td>Engulf foreign particulate matter.</td>
</tr>
<tr>
<td>Inflammation</td>
<td>Initiates and destroys microbes and initiates tissue repair.</td>
</tr>
<tr>
<td>Fever</td>
<td>Increases the effects of interferons, inhibits growth of some microbes, and speeds up body reactions that aid repair.</td>
</tr>
</tbody>
</table>

**Pathogens**  
<table>
<thead>
<tr>
<th>Agents that produce disease.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complement system</td>
</tr>
<tr>
<td>Interferon</td>
</tr>
<tr>
<td>Phagocytes</td>
</tr>
</tbody>
</table>

**Responses to stressors during the stress response Figure 9.1**

**Concept Check**

- Define stress, giving three examples.
- Describe three physiological responses to stress.
- How else can the body protect against pathogens if innate immunity fails?
ou may have heard about the phrase “fight or flight” as a common response to danger. Fight or flight is one of our innate, automatic physiologic responses to stress. It is this response that causes us to feel that sudden rush of adrenaline, that immediate jolt of energy that provides the speed, power, and quickness of wit to remove ourselves from danger. It is initiated by the autonomic nervous system, discussed in more detail in Chapter 7. If this fight-or-flight response fails to remove us from the stress, however, the body continues with a longer response, called the GAS, or General Adaptation Syndrome. This is a series of predictable responses to stress that are an attempt to adapt and deal with the original stressor. The three stages of this reaction are: (1) alarm, (2) resistance, and (3) exhaustion (Figure 9.2).

**DURING THE ALARM PHASE, WE MAY FIGHT OR FLEE**

The alarm phase occurs when the individual detects danger, and the body first starts to deal with it. Alarm is characterized by immediate, almost frenetic, action. The “fight-or-flight” nervous system (also called the sympathetic division of the autonomic nervous system) takes over, and the body jumps into action. Energy reserves are mobilized, blood sugar increases sharply, and the body prepares to defend itself or flee. The alarm phase is controlled by the release of the hormone epinephrine, also known as adrenaline. This is the hormone responsible for our feelings of fear and for “adrenaline rushes.” (*Figure 9.2—Alarm phase*)

In sports, the nervous state before competition shows the alarm phase in action: You experience heightened mental alertness and increased energy usage by the skeletal muscles, as well as a release of energy stored in glycogen and lipids. The circulatory system preferentially shunts blood to the organs, mainly the skeletal muscles, that are useful for fighting or fleeing, and away from the skin, kidneys, and digestive organs. Your body, after all, is acting as if your life depends on leaving the situation—or fighting your way out of it—with maximum haste. To save your own life, is it more important to digest your last meal or to prime your skeletal muscles for action? (After all, if you run too slowly, that last meal may literally be your last meal.)
Shifting the blood flow away from the digestive organs will often produce “butterflies” in the stomach. (An intriguing but poorly understood “enteric nervous system” helps regulate the activity of the digestive system and may also play a role in the nervous stomach.) Although other hormones may be involved in the alarm phase, especially if the stressor is causing blood loss, epinephrine is the key hormone at this point. Epinephrine boosts blood pressure, heart rate, and respiratory rate, all of which speed the delivery of highly oxygenated blood to the skeletal muscles. Sweat production also increases, resulting in what is often called a “cold sweat.” Although changes effected during the alarm phase will help the body operate at peak performance while confronting or avoiding a stressor, these changes are less appropriate as responses to social stresses. Increasing heart rate and blood glucose will not speed up a checkout line, but they will boost your frustration level. We call a severe and inappropriate triggering of the alarm phase a “panic attack.” Occasionally, a person may experience episodes of free-floating panic, with a racing heart, profuse sweating, and an inexplicable feeling of dizziness and nausea. These symptoms are characteristic of panic disorder, a chronic state characterized by panic attacks that often occur during times of prolonged stress, such as during pregnancy, or before hormonal triggers. The breakdown of lipids sustains the high fuel supply even during starvation, as the liver begins converting stored carbohydrates into glucose. In addition, blood volume is conserved by maintaining water and sodium in the body, which can simultaneously raise blood pressure. Potassium and hydrogen ions are lost at abnormally high rates. Some of the glucocorticoid hormones responsible for maintaining the resistance phase inhibit wound healing, so wounds can become infected before they heal, adding to the overall stress on the body. The resistance phase lasts until the stress is removed, lipid reserves are depleted, or complications arise from the altered body chemistry. Poor nutrition, physical damage to the heart, liver, or kidneys, or even emotional trauma can abruptly end the resistance phase.

**THE EXHAUSTION PHASE CAN BE TERMINAL**

Resistance requires us to maintain extreme physiological conditions, and prolonged resistance can lead to the exhaustion phase, which is a polite way of saying, “death through organ failure and system shutdown.” During exhaustion, homeostasis breaks down through the depletion of lipid reserves and the loss of normal blood electrolyte balance. Accumulating damage to vital organs may cause the affected organ systems to collapse. Mineral imbalances, due to sodium retention and potassium loss, may cause neurons to fail and thus result in the failure of skeletal and cardiac muscle.

**POSTTRAUMATIC STRESS DISORDER IS A STRESS THAT SEEMS NEVER ENDING**

After severe stress, such as witnessing or being victimized by warfare, rape, or violent crime, some people develop posttraumatic stress disorder (PTSD). This disorder is a type of stress reaction that may get worse, not better, with time. Biologically, PTSD looks like a prolonged experience of the resistance phase of GAS, with a similar picture of hormonal activation. In addition, research has shown that victims of PTSD show abnormal brain patterns and changes in the volume of certain areas of the brain, especially in the amygdala, a center associated with emotion and fear, and the hypothalamus, the homeostasis center. These changes help explain the symptoms of PTSD: fear, heightened vigilance, panic reactions, inability to concentrate, and memory disorders. PTSD can be treated with psychotropical or psychoactive drugs.

**THE RESISTANCE PHASE IS A RESPONSE TO PROLONGED STRESS**

During the resistance phase, the body concentrates on surviving the stress rather than evading it. The individual is likely to feel tired, irritable, and emotionally fragile. He or she may overreact to simple daily irritants or commonplace events. This phase may begin within a few hours of the onset of stress, after the alarm phase has failed to eliminate the stressor. During the resistance phase, the brain consumes immense amounts of glucose that it obtains from the blood. A series of hormones, including glucocorticoids, epinephrine, growth hormones, and thyroid hormones, ensure that lipid and protein reserves are continuously tapped to maintain the high blood sugar level needed by the brain. The skeletal muscles become more concerned with survival than rapid movement, and they begin to break down proteins in response to other hormonal triggers. The breakdown of lipids sustains the high fuel supply even during starvation, as the liver begins converting stored carbohydrates into glucose. In addition, blood volume is conserved by maintaining water and sodium in the body, which can simultaneously raise blood pressure. Potassium and hydrogen ions are lost at abnormally high rates. Some of the glucocorticoid hormones responsible for maintaining the resistance phase inhibit wound healing, so wounds can become infected before they heal, adding to the overall stress on the body. The resistance phase lasts until the stress is removed, lipid reserves are depleted, or complications arise from the altered body chemistry. Poor nutrition, physical damage to the heart, liver, or kidneys, or even emotional trauma can abruptly end the resistance phase.

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The skin is the largest organ of the human body. It encases the body, protecting it from desiccation (drying out) and preventing the entry of disease-causing microbes. Sensory receptors in the skin monitor the immediate environment, noting light touch, heavier pressure, and temperature. The skin also has vital homeostatic functions such as helping the body regulate water content and temperature. Finally, the skin produces the vitamin D necessary for bone growth and development.

**THE EPIDERMIS IS A DEAD DEFENSIVE LAYER**

The skin is composed of a superficial epidermis and a deeper dermis (Figure 9.5). Underlying the dermis is the hypodermis, where we receive injections with a "hypodermic" needle. The hypodermis is composed of dead cells joined by strong cell-to-cell junctions. These cells are filled with keratin, a waterproof substance that accumulates in the epidermal cells as they progress toward the skin surface. This dead layer provides the skin’s nonspecific defense against invasive pathogens. Few pathogens are attracted to dead cells, and keratin repels waterborne pathogens along with water.

Skin color results from the brown pigment melanin, which is produced by melanocytes in the deepest epidermis. (Figure 9.6) UV light stimulates production of a hormone that in turn stimulates the melanocytes to produce more melanin, resulting in more detailed.

The epidermis is composed of stratified squamous epithelium, but most of the cells are dead. These squamous cells are produced deep within this tissue, in a layer immediately above the dermis. As these cells divide, they continually push the daughter cells upward, away from the nutrient source found in the dermis. Because epithelium has no blood supply, these epithelial cells are nourished by capillaries in the upper dermis.
Skin and Society: Beauty is only skin deep

Ethics and Issues

...Your epidermis is showing! This bit of elementary-school silliness usually embarrasses kids who cannot define “epidermis.” But it is true! Our epidermis is always showing, along with the skin’s accessory organs—hair and nails. Because it’s always showing, many people diligently adorn, sculpt, and color their skin and hair. We push gold and silver through the skin and suspend adornments from our ears, noses, nails, lips, and eyebrows. We mark, scar, and draw on skin to indicate social status or personal expression. We judge others by the appearance of their skin and hair, and we constantly search our own skin for blemishes and disfigurements.

All this time and effort has created a huge market for products to improve skin and hair. Drug stores carry creams devoted to moisturizing, firming, bleaching, fixing wrinkles, and reversing the aging process—as if that were possible. The cosmetic aisle is chock-a-block with powders and creams that claim to perfect skin color, powders to mimic suntan, and various gels, mousses, and sprays. In the United States, cosmetics industry accounts for billions in revenues, and the cosmetics industry accounts for billions in revenues, and various gels, mousses, and sprays. In the United States, the cosmetics industry accounts for billions in revenues, and we have not even mentioned the popularity of tattooing and piercing, especially among the young.

This fascination with skin and hair is not a modern phenomenon. Throughout history, cultures have defined beauty and desirability, then altered the appearance of their skin and hair to achieve it. Egyptians dyed their hair and lips, and various gels, mousses, and sprays. In the United States, the cosmetics industry accounts for billions in revenues, and we have not even mentioned the popularity of tattooing and piercing, especially among the young.

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In a tan. Interestingly, humans, regardless of race, have the same number of melanocytes; different levels of melanin production account for the different skin colors. Melanocytes are less active in those with pale skin. In those with dark skin, highly active melanocytes produce lots of melanin, even with low sunlight exposure. In evolutionary terms, dark skin is an adaptation that protects tropical people from the intense sun. White skin is adaptive closer to the poles because it allows the entry of enough ultraviolet light to produce vitamin D. Skin cancer is a serious concern for anyone who has ever exposed their skin to sunlight. See the Health, Wellness, and Disease feature “Skin cancer” on page 266 for an in-depth discussion of this disease.

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The bottom layer of skin, the dermis, is composed of loose, irregular connective tissue. The dermis has a large blood supply and extensive innervation. The accessory organs of the skin (hair, glands, and nails) lie in the dermis. The top portion of the dermis is arranged in ridges and whorls (Figure 9.7). These ridges on the fingertips, palms, and toes make fingerprints (see I Wonder box on page 270).

The dermis is the source of nutrition for the epidermal cells. The skin is the primary physical barrier.
Skin cancer is common in the United States. In 2004, 1 in 65 Americans was diagnosed with some form of skin cancer. The good news is that skin cancer occurs in the epidermal cells, and is easily detected at an early stage. As with all cancers, those tumor cells eventually begin to multiply rapidly and uncontrollably. Skin cancer is related to sun exposure because the ultraviolet radiation in sunlight damages the DNA in epidermal cells.

To avoid skin cancer, reduce sun exposure by using a lotion with an SPF of at least 15. SPF, for Sun Protection Factor, indicates the degree of protection; higher numbers offer more protection. The two basic types of SPF are zinc oxides that reflect the sun's rays and chemicals that absorb the UV rays. Dermatologists prefer the zinc compounds because reflection is safer than absorption close to the skin's surface.

Basal cell carcinoma (BCC) is the most common cancer in humans, accounting for over 1 million cases per year in the United States alone. This cancer develops in the basal or deepest cells of the epidermis, usually in places that are routinely exposed to the sun. The appearance can vary, but the tumor usually has a slow-growing and shiny or scaly bump. A wound that repeatedly heals and opens may be a form of BCC. These cancers rarely metastasize, or spread to other tissues, but dermatologists still recommend that they be removed.

Squamous cell carcinoma (SCC) is a tumor of the upper layers of the skin. These cancers usually develop a cruddy or scaly covering and grow rapidly. The threat of metastasis is much higher with SCC than with basal cell carcinoma, so SCC tumors should be removed as soon as possible. Approximately 16 percent of skin cancer cases are SCC.

Melanomas are the most aggressive skin cancers, rapidly spreading to the lymph nodes and other tissues, but they comprise only 4 percent of all diagnosed skin cancers. The cancerous cells are melanocytes—ironically, the same cells that protect us from harmful UV radiation. Cancerous melanocytes divide rapidly and spread to the dermis. A melanoma is a dark spot on the skin that can be identified with the "ABCD" guidelines:

A = asymmetry. A noncancerous mole is usually round, and both sides match each other. Melanoma grows in all directions, but at different speeds, creating an irregular (asymmetrical) appearance.

B = border. A noncancerous mole has a distinct border that you could easily trace with a pen. Melanomas often have scalloped borders, or areas where they fade into the surrounding skin.

C = color. A noncancerous blemish has a uniform color, but melanomas tend to have several colors in one blemish. One tumor may have areas that are dark blue-black, brown, red, or even white.

D = diameter. Melanomas are often larger than noncancerous blemishes. A spot that is larger than a typical pencil eraser may be a melanoma. You should know your own skin well enough to recognize suspicious blemishes. If any of these descriptions apply, consult a medical professional for evaluation, biopsy (cellular examination), and treatment if necessary.

Skin cancer is related to sun exposure because the ultraviolet radiation in sunlight damages the DNA in epidermal cells.
Blood, having transferred its heat to the skin, returns to the heart somewhat cooler. This additional heat does not remain at the skin because when sweat evaporates, it reduces core body temperature by removing the energy required to vaporize water (water’s heat of vaporization = 540 calories/gram). During average activity, your sweat glands produce approximately a coffee cup (150 ml) of fluid per hour. Athletic activity increases this volume tremendously; up to 2.5 liters of fluid per hour can be lost during strenuous activity in hot weather. In the 2003 Tour De France, Lance Armstrong lost a full 8 percent of his body weight during a hot, intense, one-hour race. This extreme fluid loss took a toll on his performance and overall health, and Armstrong needed two days to recover. For optimal performance and general health, endurance athletes must hydrate before and during competition. In the 2003 Tour De France, Lance Armstrong needed two days to recover. For optimal performance and general health, endurance athletes must hydrate before and during competition.

**Hair—An Evolutionary Relic?**

What is hair, and why does it grow where it does? Although we think of hair mainly as the coarse structures projecting from and protecting our head, hair actually covers most of our bodies, including our face, shoulders, back, and belly. Humans are not really “hairless apes,” although most of our hair is fine and sparse compared to that of the other apes. Hair serves as an insulator as well as protection for the eyes, nostrils, and ear openings. On our heads, hair prevents heat loss from blood flowing beneath the scalp. On a man’s face, hair indicates sexual maturity.

Hair is formed from the division of specialized epidermal cells in the hair follicle, located in the dermis. Just as new epidermal cells push older cells outward, the growing hair shaft pushes older cells away from the blood supply. By the epidermis, the hair shaft is composed of dead cells.

Human hairs are attached to a small slip of skeletal muscle called the arrector pili muscle (Figure 9.11), which can lift the hair erect, away from the skin. In fur-bearing animals, the arrector pili muscles raise the hairs to trap an insulating layer of air against the skin. Our body hair is too meager to maintain a layer of insulation. Raised fur along the spine of most mammals signals aggression, and we are taught to move slowly away from a dog whose “hackles are raised.” But in humans, arrector pili muscles produce “chicken skin” or “goose bumps,” which is no better at preserving heat than for signaling aggression! When our “hackles are raised,” we do not look large or menacing, but we may feel our skin “crawl.” This phenomenon is associated with fear, because the arrector pili muscles are innervated by the sympathetic nervous system.
I WONDER...

Could I be falsely accused based on fingerprint identification?

From an early age, we are taught that we are individuals, unique in our own right. As proof, we learn that no one else has the same pattern of whorls and ridges on their fingertips.

Fingerprints interested our ancestors. At least one cave painting shows the whorls and patterns on a hand. Babylonian merchants used thumbprints for identification in business transactions, and ancient Chinese merchants signed pots and plates with their thumbs. The first scientific mention of fingerprints was in 1686, when anatomist Marcelo Malphighi noted the intricate patterns of whorls and ridges. In 1823, another anatomist described nine patterns of fingerprints, but he did not claim that each person's prints are unique.

Fingerprints were first used to identify individuals in 1856 in India. A European magistrate, Sir William Hershel, began asking native Indians to press their index hand to the back of legal contracts, such as bills of sale and court documents. Ironically, the Indians believed that touching the paper instilled some personal connection to the contract, which was, to them, more convincing than their signatures.

To make a fingerprint identification, an examiner will compare two or more fingerprints and try to match a certain number of points on them. However, the standards for identification are vague. In 1918, experts decided that finding 12 matching points on a fingerprint was conclusive, but this was not written into law, and no state requires a minimum number of matches. In some criminal cases, mismatches have caused wrongful accusations and convictions. After a 2004 terrorist bombing in Madrid, Spain, for example, an Oregon attorney was erroneously jailed due to a partial fingerprint identification.

With a large number of matching points, a fingerprint identification is likely to be correct, but because there is no absolute, scientific standard for fingerprint identification, courts should still require substantiating evidence to convict. Despite the claims that each person's fingerprints are unique, fingerprint identification is not nearly as scientific or as foolproof as DNA fingerprinting, a process that grows directly from the science of genetics.
We Have Other Innate Physical Barriers

**LEARNING OBJECTIVES**
- Describe the four types of membranes in the body.
- Explain how each membrane functions as a physical barrier.

The skin is our first line of defense against pathogenic invasions, but other membranes also serve as physical barriers against invasion. A membrane is a simple organ composed of a layer of simple or stratified epithelium supported by connective tissue (Figure 9.12).

Like the cutaneous membrane, mucous membranes provide nonspecific immunity. This is essential because mucous membranes line any cavity open to the exterior, including the mouth and digestive tract, the respiratory tract, the urinary tract, and the reproductive tract. Instead of being covered in keratinized dead cells, these tracts are covered in mucus that retards pathogens. The mucus, secreted by the epithelial cells of the membrane, constantly washes the membrane. Often, larger volumes of fluid wash these membranes as well. Urine flows across the urinary tract membrane; vaginal secretions flow out of the body across the mucous membranes of the female reproductive tract; and saliva continuously washes the oral cavity.

Serous membranes are found within the ventral body cavity and include the **peritoneum** lining the abdominal cavity, the **pericardium** lining the heart, and the **pleural** membrane lining the lungs. Serous membranes are double membranes, with one layer attached to the organ and the other to the wall of the cavity. Imagine punching a half-filled punching ball. The walls of the bag that surround your hand represent the inner membrane, and the rest of the bag becomes the outer membrane. In the body, serous fluid would lie between these layers, permitting smooth movement of the covered organ.

All movable joints, such as the knee or elbow, are lined with a synovial membrane. Like the serous membrane, synovial membranes secrete slippery, lubricating fluid. However, synovial membranes secrete fluid into the space the membrane surrounds rather than between the two layers of the membrane as in serous membranes. The main function of both of these two slippery membranes is to permit movement of underlying organs (the beating heart, the expanding lungs, the moving bones at a joint) without damaging nearby tissues. Synovial and serous membranes, unlike cutaneous and mucous membranes, do not function as physical barriers. (Synovial membranes were discussed in greater detail in Chapter 4.)

**CONCEPT CHECK**
- List the four types of membranes in the human body.
- Where are mucous membranes found, and what is their purpose?
- Why do serous membranes have two layers?
Chemical Barriers Can Defeat Bacteria

**Learning Objectives**
- Describe the activities of the complement system and interferon.
- Explain the function of local hormones as they relate to innate defenses.

Despite the “fortress wall” of skin and mucous membranes, bacteria and other pathogens can often enter the body and cause homeostatic imbalances. When this happens, internal defenses immediately try to combat the pathogens. Innate defenses destroy pathogens without distinguishing between—or even recognizing—them. In contrast, specific immunity protects against particular threats. Specific immunity must be acquired through contact with the pathogen or purposeful introduction of the pathogen to the immune system as in vaccination.

Our nonspecific chemical defense against bacteria is called the complement system (Figure 9.13). This series of chemical reactions brings together a group of proteins that are usually floating freely in the plasma. These proteins are stacked in a specific order to create a “complement” of proteins that functions like an antibacterial missile. When a bacterial invasion is encountered, the complement complex assembles, attaches to the bacterial walls, and impales the cell with the protein complex. With the bacterial wall breached, osmotic pressure forces water into the bacterium, destroying its chemistry and killing it.

Complement is effective against bacteria but not viruses. When cells are infected with a virus, their defensive response is to produce interferon (Figure 9.14). Interferon is a “local” or paracrine hormone that is secreted to affect nearby cells. It is a chemical warning, similar to the tornado warning sirens of the Midwest or the tsunami warnings in coastal communities. When cells detect interferon in the extracellular fluid, they prepare for viral invasion. Ideally, the viral infection can then be limited to a small area, allowing it to run its course with little effect on overall body functioning.
other classes of nonspecific defenses also function to destroy pathogens without distinguishing among them: fever, inflammation, and phagocytes.

Fever is defined as a change in the body’s temperature set point, resulting in an elevation in basal body temperature above 37.0°C (98.6°F). Proteins called pyrogens reset the body’s thermostat to a higher temperature. Fever may harm the pathogen directly, but it is more likely it aids defensive mechanisms by raising the metabolic rate. For every 1°C rise in body temperature, your metabolic rate increases by 10 percent. At elevated temperatures, enzymes and repair processes work faster, so proteins are mobilized more rapidly. In addition, your spleen mobilizes more quickly, and specific immune cells are activated or irritated cells release compounds that destroy the pathogen or phagocytose (consume) the pathogen. It is a localized, not whole-body, method for increasing the body’s defenses.

Inflammation is similar to fever in its goal, but it is a localized, not whole-body, method for increasing enzyme function. In situ (in place) swelling, redness, heat, and pain are associated with inflammation. Damaged or irritated cells release prostaglandins, proteins, and potassium, which trigger inflammation when released into the interstitial fluid. The benefits of inflammation include temporary tissue repair, blockage of continued pathogen entry, slowing of pathogen spread, and quicker repair of the damaged tissue. The redness associated with inflammation of the skin shows how capillaries become “leaky,” allowing blood to bring immune-system cells and other compounds to injured or diseased tissues.

Inflammation can be triggered by many factors, including pathogen entry, tissue abrasion, chemical irritation, or even extreme temperatures. For example, mosquito bites stimulate inflammation in almost everyone. The red, hot, itchy welt actually represents a local inflammation resulting from the lady mosquito’s poor table manners. As she completes her meal and withdraws her proboscis, she spits into the skin, releasing cellular debris and salivary chemicals that initiate an inflammatory response.

Phagocytes are a final nonspecific defense for dealing with stressors. The root phagos means “to eat,” and you already know that rye translates to “cell.” Phagocytes, therefore, are eating cells, or cells that devour the tissues, engulfing and removing anything that does not belong there. Phagocytes, the first cellular line of defense against pathogens, remove all and any dead or dying cells, cellular debris, and foreign material, classifying them as a nonspecific defense. Phagocytes come in different sizes. Macrophages are quite small and are mainly found in the nervous system. Macrophages are large, actively patrolling cells. They arise from blood cells and travel through every tissue of the body looking for foreign material. Macrophages escape the bloodstream by squeezing between the cells of the vessel wall, a process called diapedesis. Some tissues have resident, or “fixed,” macrophages, whereas other tissues get patrols of wandering macrophages passing through, like security guards making the rounds at a mall.

In the opening of this chapter, we took a look at the stresses associated with war. Fortunately, not all of us will experience that level of stress, but we all face stress in our lives, and most of us cope with it successfully. The routine activities of the body dealing with stress and pathogens have amazing complexity and efficiency. Usually we are conscious only of our nervousness or tiredness as we deal with stresses, not the myriad defensive activities taking place in our bodies.

Although these defenses seem able to cover any pathogen that comes along, humans still succumb to illness. Stresses can overwhelm our defense mechanisms, and our nonspecific defenses are unable to protect us. Pathogens can slip past our protective membranes and overcome the effects of complement or interferon, inflammation, or fever, escaping detection until the problem is too large for nonspecific responses. At that point, the body requires specialists from the immune system, which is the topic of the next chapter.
CHAPTER SUMMARY

1. What is Stress?
   Humans face many types of stress from physical, emotional, social, or microbiological sources, and we have many systems to deal with them, including the skin, whole-body and localized reactions, and a variety of chemical and physical mechanisms to reduce, eliminate, or survive stress.

2. The General Adaptation Syndrome Helps Overcome Stress
   The body can respond to stress with the three stages of the General Adaptation Syndrome: alarm, resistance, and exhaustion. During alarm, the fight-or-flight mechanism predominates. This stage either removes the body from the stressor or is unsuccessful. If unsuccessful, the resistance phase begins. Here blood ion concentrations are pushed far from homeostasis in an attempt to maintain elevated blood glucose. Should resistance continue for a prolonged period of time, the body will reach exhaustion. During exhaustion, the body treats from the fight and tries to recover from the altered ion balances created in the previous stage. At this stage, organ systems and the organism itself can die.

3. The Skin Is the Primary Physical Barrier
   The skin, the primary physical barrier, is composed of the stratified squamous cells of the epidermis and underlying connective tissues of the dermis. Hair, nails, and glands are accessory organs. Sensory structures in the dermis detect pressure, temperature, and pain. Glands secrete oil or sweat onto the surface of the skin and hairs. The sweat glands help maintain thermal homeostasis. Nails and hair serve protective functions.

4. We Have Other Innate Physical Barriers
   Four types of membranes provide an important part of innate immunity. The cutaneous membrane is our skin. Serous membranes in the ventral body cavity permit movement of underlying organs, and include the peritoneum lining the abdominal cavity, the pericardium lining the heart, and the pleural membrane lining the lungs. Mucous membranes provide nonspecific immunity in cavities open to the exterior, including the mouth, digestive tract, respiratory tract, urinary tract, and reproductive tract. Muscles, secreted by the epithelial cells of the membranes, relay pathogens on mucous membranes. Synovial membranes secrete a slippery, lubricating fluid to permit movement of underlying bones at joints.

5. Chemical Barriers Can Defeat Bacteria
   The complement system fights bacteria by destroying their cell walls. Interferon, secreted by cells that are infected by a virus, is a chemical warning that helps nearby cells prepare for viral invasion.

6. Other Classes of Innate Defenses Alter the Environment around the Pathogen
   Fever raises the body temperature so that chemical reactions will act more quickly, and it is therefore effective against a wide range of threats. Inflammation is a series of reactions that allow more blood to reach the site of infection to help with tissue repair, block the entry of more pathogens, and slow the spread of pathogens. Phagocytes are cells that remove circulating pathogens, as well as any cellular debris created during infections.

KEY TERMS
- apocrine p. 000
- complement system p. 000
- dermis p. 000
- eccrine p. 000
- epidermis p. 000
- melanocytes p. 000
- microspheres p. 000
- pathogens p. 000
- phagocytes p. 000
- interferon p. 000
- keratinized p. 000
- follicles p. 000
- inguinal p. 000
- lymphocytes p. 000
- pathogen p. 000
- serum p. 000
- epinephrine p. 000

CRITICAL THINKING QUESTIONS

1. Marie sat quietly in the back of the class feeling relaxed, even though this was her first college class. “Here goes; this is the beginning of my future,” she excitedly thought. As the teacher walked to the front of the room, Marie suddenly felt dizzy and broke into a cold sweat. What was happening to her? What is the natural course of these events?

2. Swimming in the ocean may expose a bather with an open wound to staphylococcus infection. What characteristics of the skin normally prevent these infections? How does an open wound compromise these defenses?

3. Everyone gets a common cold once in a while. Usually, this is caused by a rhinovirus (nasal virus) that may infect the nose, sinuses, ears, and/or bronchial tubes (lungs). What defenses must this virus overcome to cause an infection? If you wanted to manufacture a compound to defend against the common cold, which natural biochemical defenses would you try to mimic?

4. One of the first symptoms of menopause in women reaching the end of their reproductive years is “hot flashes.” Without warning, hot flashes raise the body temperature and cause sweating and thermal discomfort. From what you understand of fever, what is happening biochemically during a hot flash?

5. Could a hot flash help defend against pathogens? What is the difference between the raised temperature of a hot flash and a true fever?

6. Suppose you lacked all innate or nonspecific defenses. First, list exactly what you would be missing. Second, for each item, describe how life would be different without that mechanism. For as many of the listed items as possible, invent some behavioral changes that would promote your survival.
SELF TEST

1. Which of the following can be classified as stressors?
   a. Eating a heavy meal
   b. Coming down with strep throat
   c. Beginning a new college semester
   d. All of the above are stressors

2. Innate immunity includes all of the above EXCEPT:
   a. skin and mucous membranes.
   b. phagocytes.
   c. antibodies and immune cells.
   d. complement system.

3. The phase of the general adaptation syndrome that begins with a large dumping of epinephrine into the system is:
   a. the alarm phase.
   b. the resistance phase.
   c. the exhaustion phase.
   d. All of the phases include dumping epinephrine.

The following six questions all relate to this figure.

4. Identify the structure indicated B on this diagram.
   a. Epidermis
   b. Hypodermis
   c. Dermis
   d. Adipose tissue

5. The function of the structure indicated by E is to
   a. produce sweat.
   b. raise the hair follicle.
   c. produce oil.
   d. protect the dermis.

6. Which structure is directly responsible for thermal homeostasis?
   a. A
   b. C
   c. D
   d. G

7. The nonvascular layer of skin is indicated by the letter
   a. A
   b. B
   c. C
   d. E

8. The sebaceous gland, which produces oil that lubricates and softens, is indicated by the letter
   a. B
   b. C
   c. D
   d. F

9. Sweat cells filled with keratin would be found in which area of the skin?
   a. A
   b. B
   c. C
   d. G

10. The function of melanocytes is to
    a. produce keratin.
    b. maintain internal temperature.
    c. produce dark pigments to absorb light.
    d. store energy for later use.

11. The sensory organs in the dermis that detect light touch are the
    a. Meissner corpuscles.
    b. Merkel discs.
    c. Pacinian corpuscles.
    d. nociceptors.

12. True or False: Oil glands are located everywhere on the skin, including the face and lips.

13. This image shows
    a. an oil gland.
    b. an apocrine sweat gland.
    c. a sebaceous gland.
    d. an eccrine sweat gland.

14. The two structures that protect and reinforce the skin are the
    a. hair follicles and nails
    b. sweat glands and hair follicles.
    c. nails and oil glands.
    d. sweat and oil glands.

15. Which type of membrane is shown in part A of the figure below?
    a. Mucous membrane
    b. Serous membrane
    c. Cutaneous membrane
    d. Synovial membrane

16. The chemical defense system that destroys bacteria is called
    a. immunity.
    b. complement.
    c. interferon.
    d. phagocytosis.

17. The idea behind _________ is that the temperature increase they cause will raise metabolic rates and speed activity of the immune system.
    a. prostaglandins
    b. interleukins
    c. pyrogens
    d. complement systems

18. The type of innate defense against pathogens seen in this figure is
    a. inflammation.
    b. fever.
    c. interferon.
    d. phagocytosis.

19. The job of a phagocyte is to
    a. patrol tissues and remove pathogens.
    b. patrol and monitor the health of the nervous system.
    c. remove dead or dying cells.
    d. All of the above.

20. The innate defense classified as a chemical barrier is
    a. the cutaneous membrane.
    b. phagocytes.
    c. fever.
    d. interferon.