The Battle Within

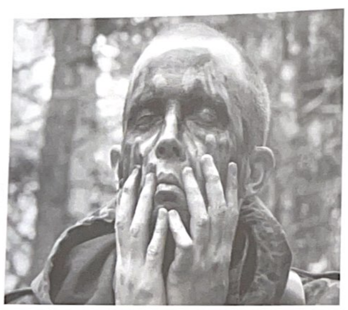
A soldier who just returned from the battlefield in Iraq was experiencing a number of distressing feelings. This is what he reported:

> *I just felt so weak, like I couldn't lift my arms or make my legs move. We were under fire, guys getting hit all around me. I knew I needed to move, to get the hell out of there, but I just couldn't get going. My sergeant was yelling at me—at least I think he was yelling—but I couldn't hear anything except the sound of rushing water in my head.*
>
> *The really strange thing about the whole experience is that my heart was pounding so hard inside my chest I thought I was going to have a heart attack. I couldn't seem to catch my breath either. I was starting to get dizzy to the point of almost passing out.*
>
> *I must have been wounded, I figured at first. I was terrified that I'd been paralyzed, taken shrapnel in my spine or something. I just felt so sick and nauseated. My hands felt so tingly I couldn't even hold my weapon. All I could do was just lie there, and hug the ground. Then I passed out.*

Called **battle fatigue**, shell shock, or combat stress by the military, or traumatic stress by mental health professionals, this soldier is describing exactly what happens to the body during maximum activation of the sympathetic nervous system.

If he is not able to recover from the episode, or if he is continually subjected to additional combat danger without time and resources to pull himself back together, this traumatic stress will become *post*traumatic stress—chronic problems that may become even worse over time. Without treatment, he could suffer flashbacks, nightmares, headaches, memory deficits, depression, relationship problems, inability to hold a job, even a psychotic break.

In case you breathe a sigh of relief thinking you intend to avoid such combat as much as possible, you should know that it isn't necessary to actually be in a war to suffer similar symptoms. Those who have suffered sexual abuse, physical abuse, or survived catastrophes may exhibit comparable disabling symptoms.



Battle fatigue is one kind of extreme stress reaction that results from an overload of perceived danger and nervous arousal. Failure to recover from the experience can result in posttraumatic stress reactions that produce a number of severe symptoms including insomnia, recurrent nightmares and flashbacks, a sense of helplessness, and debilitating depression.

Based on what you learned in the previous chapter about the general adaptation syndrome and the fight-or-flight reflex, you already have some idea of what was going on, physiologically, in this soldier's disturbing responses. His autonomic nervous system, especially the sympathetic division, was working at peak volume. It would be reasonable to surmise, based on his emotional collapse, that he has been repeatedly overexposed to combat stressors for some time.

Unfortunately, once this solider is removed from the battle scene, he may have permanent damage that will continue to affect him in the future. It is entirely possible that he will overreact to stressors once he reenters civilian life. His sleep might be disrupted. He will be far more likely to engage in substance abuse to self-medicate his discomfort. His immune system may be weakened. He may be at greater risk for heart disease and a host of other physical illnesses (Nutt, 2006).

Not only are soldiers and trauma victims subject to the deleterious effects of extreme stress, but studies have indicated that people living relatively ordinary lives experience debilitating anxiety that makes them up to five times more likely to suffer cardiac death (Goble & Le Grande, 2008; Kawachi, Sparrow, Vokonas, & Weiss, 1994; Shively, Musselman, & Willard, 2009). Their physiological systems are strained to the point that they begin to break down, resulting in much higher death rates than in those who have effective coping strategies (Childre & Rozman, 2005).

It is no wonder that stress has become such a focal point of interest considering that it so impairs performance, clear thinking, and decision making. In one study, rats subjected to continual stress became stuck in habitual and ineffective patterns, making it difficult for them to get their basic needs met; once the stressors (shocks, unpredictable events) were removed, the rats were able to regain sufficient concentration and clarity to function at a much higher level (Dias-Ferreira et al., 2009).

Any time you are subjected to extreme stress, whether sudden or chronic, you may very well freeze up and feel unable to respond effectively. This instinctual reaction once served an important survival function in that loud noises or surprises (potential attacks) result in programmed startle-freeze responses, thus camouflaging your presence with predators around: as long as you remain quiet and perfectly still, you are less likely to be detected. The part of the brain responsible for speech (Broca's area) actually shuts down. The problem, however, is that freezing on a test, giving a speech, or in a social situation is not very useful even though your brain misinterprets such situations as life-threatening.

The body reacts to stressors in a number of ways. These effects can be most logically described according to the specialized systems that serve different functions. The major body systems include the following.

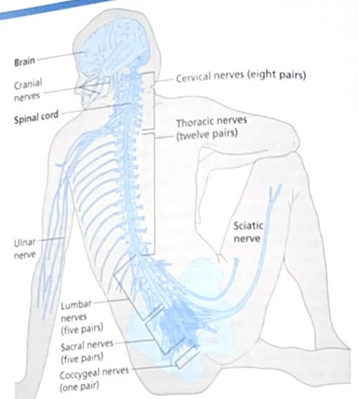
1. The **nervous system** provides overall "executive management" of other systems and communicates orders to coordinate activities.
2. The **endocrine system** works in partnership with the nervous system to control functions.
3. The **circulatory** and **cardiovascular systems** are concerned with transporting nutrients, waste, and other chemical messengers within and out of the body.
4. The **respiratory system** provides oxygen and nourishment to the body's cells.
5. The **immune system** does exactly what it sounds like: provides defense against invaders.
6. The **musculoskeletal system** (including **skin**) provides support and movement for the body.
7. The **digestive system** processes food sources, converting them into usable energy.
8. The **reproductive system** is concerned with sexual functions and reproduction.

A few of these specialty areas are more involved with, and affected by, stress responses than others. We will look most carefully at the nervous and endocrine systems, and then at how stress affects the heart, digestion, muscles, skin, and other organs. Because this chapter introduces so many medical terms related to anatomy and physiology, we have been selective about which ones we highlighted in bold and inserted in the list of key terms at the end of the book. Your instructor may wish you to learn others; if so, he or she will advise you as to which ones are most important.

Nervous System

Stress experience often begins in the brain, even though the stressor often appears in the external environment or outside world. The senses connected to the brain make it

FIGURE 2.1 The central nervous system.



possible for you to know what is happening around you, and within you. Your hearing, sight, smell, touch, and perhaps intuition signal you that danger is near.

The human nervous system is organized into several different subsystems. First, there is a **central nervous system**, which is exactly like it sounds—centrally located and housing the brain and spinal cord (see Figure 2.1). The average adult human brain weighs about three pounds and contains 100 billion nerve cells (neurons) in addition to trillions of "support cells" called glia. The spinal cord is located within the vertebrate column that receives messages from, and sends motor commands to, the **peripheral nervous system**.

The peripheral nervous system is divided into two major parts: the **somatic nervous system** and the **autonomic nervous system**. The somatic nervous system consists of peripheral nerve fibers that receive information from the sensory organs and send information to the central nervous system and motor nerve fibers that communicate with skeletal muscles.

The autonomic nervous system is so named because it operates on "automatic," meaning beyond your conscious awareness and control. It handles many of the regulatory functions that keep you alive—your breathing, blood flow, digestion, and so on. The autonomic system branches off into three other divisions, each with specialized functions: the **sympathetic nervous system**, the **parasympathetic nervous system**, and the **enteric nervous system**. They are all designed to control your various internal organs and glands.

We move next to the diencephalon, which houses the **hypothalamus** and the **thalamus** (remember these in particular as we will be referring to them a lot). If you are following this on the figure, we are now at the point where the spine connects into the skull. The hypothalamus, about the size of a grape or olive, plays a disproportionate regulatory role considering its small size. It controls body temperature, as well as regulating emotions, hunger, thirst, and sleep rhythms. It is also the part of the brain that is most involved in responding to stress by controlling the pituitary and autonomic nervous

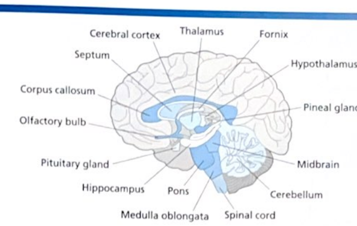


FIGURE 2.2 The major components of the limbic system.

system. The thalamus receives sensory information and relays this information to the cerebral cortex. The cerebral cortex also sends information to the thalamus, which then transmits this information to other areas of the brain and spinal cord.

The **limbic system** consists of such structures as the **amygdala**, the hippocampus, mammillary bodies, and cingulate gyrus. These areas are important for controlling the emotional response to a given situation. The amygdala is located at the base of the temporal lobe and controls anger, fear, and aggressive behavior. The **hippocampus** is important for memory storage and retrieval.

Initiation and Control of the Stress Response

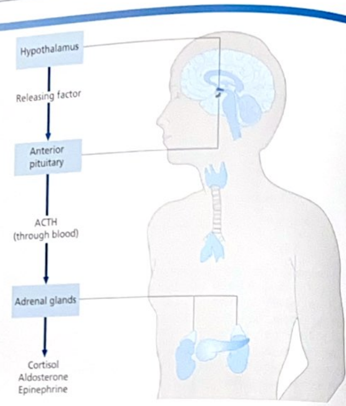
You learned in the previous chapter that the function of a stress response is to secure the safety of the organism. A stressor can be any stimulus, real or imaginary, that is perceived to threaten the existence of the organism. The body follows a predictable sequence of reactions in the face of a stressor.

Step 1. The brain *perceives* danger. It doesn't matter whether the threat is real or a figment of the imagination; the senses bring in distressing information that is interpreted as potentially harmful. Naturally there are false alarms, but the brain is programmed to react defensively. It sends out warnings to all systems to activate emergency conditions (the fight-or-flight response). The Greek word for messenger is **hormone**—chemical signals that are launched from the thymus, pituitary, thyroid, and adrenal glands. They are the scouts, like Paul Revere and his compatriots who were sent out all over the countryside during the British invasion to warn of impending attack. The chemical agents are launched through three separate pathways, making certain to mobilize maximum response to the threat.

Step 2. The first pathway is directed to the muscles, resulting in immediate tension that might be useful for actions such as sprinting, ducking, kicking, punching, biting, and screaming. When the brain perceives a threat, this information comes through the thalamus to the hypothalamus, which in turn activates the autonomic nervous system. For the immediate reaction, the sympathetic nervous system carries signals to the adrenal medulla (i.e., the SAM complex) that secretes **epinephrine** (better known as **adrenaline**) and **norepinephrine** into the bloodstream to be circulated to target organs. These hormones increase the heart rate, raise the blood pressure, accelerate the rate of respiration, dilate bronchial tubes, and inhibit digestive activities. This is the alarm phase, according to Selye, and it involves the autonomic nervous system.

Step 3. If the threat continues beyond a few minutes, the hypothalamus triggers a series of events to prepare the body for the second phase of the stress response that involves more pervasive activation of the bodily functions. At this point, the body realizes that what seemed, at first, to be a short skirmish is now turning out to be a

FIGURE 2.3 The HPA process.



prolonged battle. This second pathway goes to the immune system, preparing for possible wounds.

The anterior (front) hypothalamus releases a hormone called **CRF** (corticotrophin releasing factor), which then stimulates the pituitary gland to secrete **ACTH** (adrenocorticotropic hormone). ACTH then stimulates the cortex of the adrenal glands to produce cortisol (a **glucocorticoid**) and aldosterone (a **mineralocorticoid**). When you put this chain reaction of chemical responses together, what you end up with is a control pathway called the **HPA** (hypothalamus–pituitary–adrenal) **axis**. This is the central core of the body's reaction to stress. It is the resistance phase in Selye's general adaptation syndrome in which the body is engaged in a prolonged battle with the stressor.

As in all high-functioning organisms and machines, redundancy is built into the system to protect against missed cues. Since this system evolved to protect against life-threatening situations in which survival was at stake, it is not a waste of energy to send out triple signals in case something is lost in translation. This third pathway jump-starts the sympathetic nervous system, kicking in gear all the various systems that were described in the previous chapter. Meanwhile, back in the hypothalamus of the brain, orders are being directed to send reinforcements where they will be most needed.

The way the system was designed to operate, the fight-or-flight response is turned off once the physical threat is no longer perceived. This gives the system time to recover and recalibrate itself before the next sign of danger. The only problem is that this capability decreases with chronic exposure to stressors. It is like an engine system that has been revved into the red zone once too often.

The Brain and Stress

The brain is the most important feature in the stress response, directing every other process. It controls the endocrine system and regulates the rate of metabolism. It directs the activity of the cardiovascular system by influencing the autonomic nervous system.

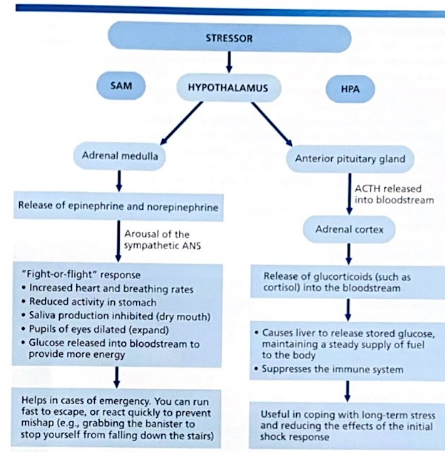


FIGURE 2.4 The chemical and nervous pathways of stress reactivity.

The immune system is also under its direct stimulation by nerves or indirect influence through hormones. Finally, the cerebral cortex interprets external data in particular ways, making almost instantaneous decisions about the most appropriate response.

You have learned how your perception of an experience determines whether it is experienced as stressful or enjoyable. When encountering a similar situation such as the breakup of a relationship, two different people will often have different interpretations, thereby creating different physiological and psychological consequences. One may feel devastated while the other may feel relieved. This is due to your brain making different choices and interpretations.

Despite all the above influences the brain exerts over other bodily systems, it also suffers the consequences of the stress produced by psychological and physiological arousal. The brain areas most susceptible to these effects happen to be the same systems that are activated for the fight-or-flight response, such as the HPA axis and the SAM complex (Bremner, 2005).

The areas of the brain responsible for memory include the hippocampus and amygdala. People who are experiencing severe stress, such as test anxiety, distracting worries, or lingering trauma, tend to make more errors in tasks that require concentration. They have difficulty making decisions. They are more prone to accidents, more inclined toward addiction, and experience a host of physical and psychological complications (Bambling, 2006; Hyman, 2009).

The amygdala is the first structure to be activated during fear responses. It functions to avoid and detect danger and is also involved in forming emotional memories related to fear and social situations. It evaluates threats unconsciously, at lightning speed, before conscious thoughts have time to get into the act.

The amygdala receives input directly from the thalamus before the cortex processes the information, producing a series of bodily responses. For instance, you are walking alone in a dark alley at night and see what you think is a snake crawling toward you, ready to strike. Before you have the chance to consider the improbability of this scenario in an urban area, you already feel your heart rate racing and your muscles tense. As you approach closer you see that the "snake" is really a coiled pipe. Your heart rate begins to slow and your muscles relax.

This quick thalamus–amygdala pathway gives you extra time in resolving a potentially harmful situation. It also overgeneralizes the threat, or, in the words of an ancient Chinese saying, "Once bitten by a snake, a straw rope will startle you ten years later." This means that the amygdala is essentially an impulsive reactor, setting off a fear response before there is a moment to consider what might really be going on. It would rather overreact than hesitate and end up dying with the rest of you in the throes of a python attack. By contrast, the cerebral cortex processes the threat more slowly—and accurately.

FOR REFLECTION 2.1

Two different memory systems (adapted from Joseph LeDoux)

There is a famous case in the neurological literature about a woman who suffered from severe amnesia. The hippocampus in this patient was impaired and could not form new contextual memory, leaving her with only a few minutes of conscious memory. When her doctor left her longer than a few minutes, she would forget that she had ever met him before. They would shake hands and greet each other like two strangers.

One day, the doctor carried a pin in the palm of his hand and pricked the woman's hand when they greeted one another in the accustomed way. The woman quickly withdrew her hand. Next time when they introduced themselves, she didn't remember ever meeting the doctor, yet her hand didn't extend to meet his. Her amygdala remembered the emotions of pain even though her hippocampus lost any recollection of that incident!

Another important structure responsible for fear, anxiety, or emotional memory is the **prefrontal lobe**. It forms a partnership with the amygdala, which is the first-response organ. Among humans, the frontal lobes of the brain are the latest in our evolutionary development and unique to our species: they are the source of reflective thought. This is both a benefit and a burden: on the plus side, the frontal lobes of the cortex permit us to scrutinize our surroundings systematically, consider possible threats that might develop in the future, predict the consequences of certain actions we might take, and plan particular courses of action. This is all very well, but such capacity for imagination and forethought also results in our sometimes engaging in improbable and irrational fantasies about things that could happen (Restak, 2004). The frontal lobes are thus our greatest gift when it comes to anticipating and avoiding danger, but also our greatest liability when they become overstimulated.

Scientists have been attempting to unravel the mysteries of the prefrontal lobes for some time, mostly by examining the effects of having this area inadvertently or surgically destroyed. When lesions are formed in this part of the brain, for instance, people are unable to process certain memories effectively.

In the 1950s, Dr Wilder Pennfield used electrical stimulation to map the cortex of conscious human patients who were about to be operated on. One day, he probed the cortex of a patient and the man raised his arm. Surprised by this reaction, Pennfield asked the man what he was doing. The patient shrugged (as best he could under the circumstances) and reported that he just felt the urge to do so. He didn't know why exactly. Pennfield instructed the man to restrain himself next time and touched the same portion of the brain. Again he got the same reaction, even when the man deliberately tried to hold himself back. From this experiment, Pennfield learned that the motor portion of the

prefrontal lobe has the capability to override the signals sent from other systems. It also explains how, even with the best of intentions, you might feel helpless to control certain impulses that are overridden by another source of power.

FOR REFLECTION 2.2

Emotional and cognitive functions of the cerebral cortex

Phineas Gage was a construction worker who was supervising a railroad crew laying tracks in a rural part of Vermont in 1848. Dynamite was used frequently to drill holes in the bedrock. Gage was in the process of setting the charge when he was momentarily distracted. An iron rod that was used to press down the powder was launched like a missile through his cheek, skewering his eye and exiting through the top of his skull.

The force of the explosion knocked the poor fellow off his feet and he briefly lost consciousness. Although most of the left side of his cerebral cortex was obliterated, Gage regained consciousness a few minutes later. His memory remained intact and he could describe in perfect detail what had happened.

A few months later, Gage felt well enough to resume his work. He was still physically strong and highly motivated. Unfortunately, one outcome of his accident was that his personality completely changed. Previously he had been seen as dedicated, hardworking, shrewd, and polite—a good man to have on your side. But since the brain damage he was hard to be around. He swore a lot (which he had never done before) and was seen as impulsive and unpredictable. To his friends and coworkers, he was no longer the same person.

Gage's transformation became a landmark case for understanding the mechanisms of the brain and how the frontal lobes of the cerebral cortex not only house thinking processes, but also influence emotions and the structure of the personality.

Naturally, it is easier to keep your fears in check before they develop into full-blown phobias. Research has demonstrated that it is very hard to wipe out fear memories completely even with an intact prefrontal lobe. That is why a simple treatment process is not very effective with phobias. It also explains why certain inborn fears, such as of snakes, spiders, and falling, are hard-wired into our brains, as throughout the evolution of our species they are the most likely ways that we might become grievously injured. Avoiding each of these dangers requires instant action without conscious thought.

When subjected to prolonged or extreme stress, nerve cells begin to degrade over time. When volunteers are given synthetic cortisol, the hormone most prevalent during stress responses, their memories became seriously impaired (Marieke, Tollenaar, Elzinga, & Walter, 2009; Wolkowitz, Reuss, & Weingartner, 1990). Imagine that you have prepared to give a talk on a particular subject and suddenly the circumstances have radically changed. Instead of facing a half dozen of your classmates in an informal setting, you have been asked to give a formal speech in an auditorium housing 600! Furthermore, you are told that the presentation begins in five minutes. You are led on stage to find there is no lectern; you have no choice but to leave your notes behind. While it is possible you might rise to the occasion, it is far more likely that the rush of stress chemicals in your brain might slow down your thinking a bit, not to mention impair your ability to recall the talk that you had so carefully prepared.

As if memory impairment is not bad enough, excessive glucocorticoids in the system have been shown to actually kill off parts of your brain, taking little bites at a time (Porter and Landfield, 1998). The hippocampus, the region of the brain that controls much of learning and memory, is particularly vulnerable to deterioration. It is a specialist in imprinting new memories: you might recognize as a symptom of Alzheimer's disease that older people can remember the more distant past as if it happened yesterday, but have no distinct memories of what actually happened yesterday. This is devastating, but consider that a reduction in the size of the hippocampus is also associated with severe depression and mental illness (to be discussed in Chapter 4).

Sapolsky (2004) summarizes some of the major effects of hippocampus atrophy that occurs with sustained stress.

1. It can create severe depression, the kind that doesn't go away after a short period of time, but reappears unrelated to any stressor. It is considered endogenous; that is, biologically based, as opposed to triggered by grief or loss.
2. Soldiers or abused children who experience posttraumatic stress have been found to have smaller hippocampus tissue than those who have not experienced it. The more devastating the trauma or crisis, the more deterioration takes place.
3. Cushing's Syndrome is a form of cancer that excretes excess quantities of glucocorticoids, affecting all the usual suspects: memory, blood pressure, sexual functioning, the immune system.
4. There is higher risk of permanent impairment after a stroke. Brain adaptability and healing become compromised when the hippocampus limps along at less than full strength.

The Autonomic Nervous System and Stress

As previously explained, the autonomic nervous system (ANS) regulates all the organs and tissues not controlled by the central nervous system. It innervates the actions of glands, the smooth muscles of hollow organs and vessels, and the heart muscle.

The ANS is divided into two major branches, namely, the sympathetic and parasympathetic nervous systems. The sympathetic system (so named because the Greek physician and writer Galen believed that the brain worked in sympathy with the visceral organs) operates as an "on" switch. Its partner is the parasympathetic system, the "off" switch, which turns down the energy when it is no longer needed.

The sympathetic system becomes aroused mostly under four conditions. These have been memorized by generations of medical students as the "Four Fs." The first two are easy since you already learned them: Fight and Flight. The third F refers to the accompanying Fright. So, that leaves a certain four-letter word, beginning with F, that is used both as a swear word and as description of copulation. (Well, you can remember *that* one.)

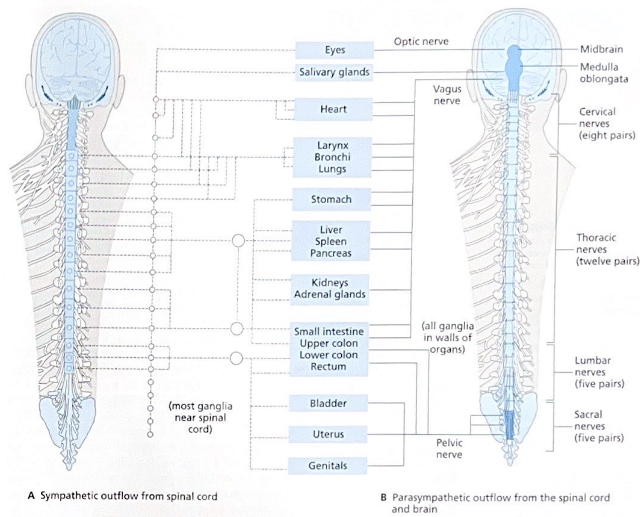
While the sympathetic system accelerates energy expenditure and promotes the stress response, the parasympathetic system slows energy expenditure by promoting energy storage and cell reparation. For example, sympathetic arousal increases heart rate while parasympathetic activation reduces it (see Table 2.1). The sympathetic system is for fight or flight and the parasympathetic system is for "rest and digest." In most cases, the two systems are antagonistic, meaning opposing, in that when one is high in activity the other is low.

The sympathetic system also inhibits other systems not immediately involved in the stress response, such as the urinary, digestive, and reproductive systems. You may have noticed that you have trouble swallowing food before you take an important exam for which you are not quite ready. Your mouth is dry. The parasympathetic system promotes the activity of the digestive tract, constricts blood vessels, and stimulates the formation of urine. When you are relaxed, saliva abounds in your mouth and your appetite is enhanced.

The Endocrine System

As we have mentioned, the endocrine system and nervous system control and coordinate all the other systems in the body. The nervous system controls rapid activity such as

FIGURE 2.5 The effects of sympathetic and parasympathetic nervous system activation on various organs and body systems.



Examples of responses
Heart rate increases
Pupils of eyes dilate (widen: let in more light)
Glandular secretions decrease in airways to lungs
Salivary gland secretions thicken
Stomach and intestinal movements slow down
Sphincters (rings of muscles) contract

Examples of responses
Heart rate decreases
Pupils of eyes constrict (keep more light out)
Glandular secretions increase in airways to lungs
Salivary gland secretions become dilute
Stomach and intestinal movements increase
Sphincters (rings of muscles) relax

voluntary muscle action and intestinal activity through electrical and chemical signals. The endocrine system exerts its control by means of chemical signals whose effects on the body are initiated more slowly and last longer.

The endocrine system produces those potent biochemical substances called hormones via a group of glands. They are carried in the bloodstream to control specific organs. These hormones only affect certain target tissues or organs where specialized receptors are found. This structure is not unlike the communication system of a modern home in which there are telephone wires, cell phone signals, cables, electrical wires, all of which are designed for specific functions to control different systems.

The glands that are most relevant to the stress response are the **pituitary**, **thyroid**, and **adrenal glands** (see Figure 2.6). The pituitary is often referred to as the "master gland" because it controls the others. If we continue with a military metaphor, then the

TABLE 2.1. Effects of the Sympathetic and Parasympathetic Systems on Selected Organs

Effector	Sympathetic system	Parasympathetic system
Pupils of eye	Dilation	Constriction
Sweat glands	Stimulation	None
Digestive glands	Inhibition	Stimulation
Heart	Increased rate and strength of beat	Decreased rate and strength of beat
Bronchi of lungs	Dilation	Constriction
Muscles of digestive system	Decreased contraction	Increased contraction
Kidneys	Decreased activity	None
Urinary bladder	Relaxation	Contraction and emptying
Liver	Increased release of glucose	None
Adrenal medulla	Stimulation	None
Blood vessels to:		
skeletal muscles	Dilation	Constriction
skin	Constriction	None
respiratory system	Dilation	Constriction
digestive organs	Constriction	Dilation

pituitary is the "general" and the adrenal and thyroid are "colonels." The adrenal glands are very important officers in this operation—specialists, so to speak, in stress response. They consist of two small glands located above the kidneys. Each gland has two parts, an inner area called the medulla, and an outer portion called the cortex.

The adrenal gland is involved in two parallel response pathways during the stress response. The first is the SAM complex discussed earlier, and the other is the adrenocortical pathway, which is part of the HPA axis regulated by the hypothalamus and the pituitary. Each of these takes a different route to sound the alarm, just in case one of the "scouts" doesn't make it through.

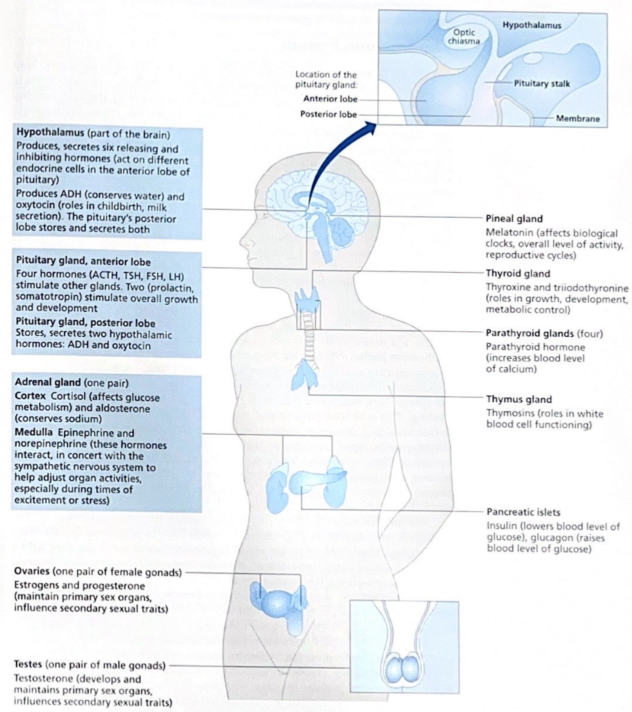
Cortisol is among the most important hormones involved in stress responses. It has several different functions. First, it increases the supply of blood glucose to the body and the brain that can be used as "fuel" for fighting or fleeing. It also turns off all bodily systems not immediately required to deal with a threat. For instance, cortisol turns off insulin so that the liver releases more glucose, thus creating a temporary homeostatic imbalance. It also shuts down reproductive functions and inhibits the immune system. Unfortunately, this extra cortisol in the bloodstream is also associated with increased incidence of hypertension and coronary heart disease because it channels excessive cholesterol into the blood and leads to plaque buildup along the walls of arteries. When endocrine glands become depleted through overproduction of hormones (such as adrenaline), this can lead to medical conditions such as reactive hypoglycemia that can eventually lead to diabetes. On the other hand, if the endocrine system overfunctions, remaining stuck in the "on" position and flooding the body with cortisol, bad things can also happen. When cortisol-based drugs (cortisol is a steroid) are prescribed for diseases such as

FOR REFLECTION 2.3

Based on what you already learned about the way that epinephrine (adrenaline) is released into the blood at 20 times the normal rate under conditions of stress, why do you suppose that immediately after a crisis has passed you feel a need to urinate?

Answer at the end of the chapter.

FIGURE 2.6 The endocrine system.



cancer, arthritis, and asthma, common side-effects include intestinal bleeding and ulcers, as toxic levels begin to eat away at the stomach lining. The endocrine system maintains a very delicate balance in which too little, or too much, cortisol can prove destructive.

The Immune System

Just like the Department of Homeland Security, the immune system is designed to stop foreign invaders. Rather than identifying human terrorists, the body's immune system is calibrated to recognize and respond to invading agents such as fungi, parasites, bacteria, and viruses. In addition to defending against attacks, the immune system also conducts surveillance activity in order to prepare for any future assaults. In this way it seeks to destroy any suspicious-looking cells before they mutate to cancer. Based on intelligence gathered during previous attacks, it also initiates immunity systems that will protect against similar infections in the future. In other words, it has a memory that keeps track throughout your lifetime of all those invaders that have tried to colonize your body.

The first barriers to the invasion of infectious agents are the skin and mucous membranes. The intact skin prevents many microbes from entering the body. The mucous membranes lining body cavities secrete substances to entrap small particles like spider webs.

Once the harmful agents penetrate the first barriers of the immune system, it is necessary to activate other mechanisms to neutralize or kill them. The challenging job of the immune system is to tell the difference between cells that are normal parts of the body and those that are invading microbes. These immune responses are made possible by circulating white blood cells (lymphocytes and phagocytes) that develop in the bone marrow and in the thymus gland. There are three categories of lymphocytes: T cells, B cells, and natural killer cells (NK), each of which operates to assist cells in trouble. As the name implies, NK cells are the most aggressive—your first line of defense against mutant and virus-infected cells or diseases that threaten your health.

During an immune reaction, the body mounts two types of reactions: *nonspecific* and *specific*. One nonspecific reaction is familiar to you in the form of inflammation or swelling. This is an acute physiological response to tissue injury caused by such factors as chemicals, heat, trauma, or bacterial invasion. The damaged tissue secretes substances that increase the blood circulation and make capillaries leak fluids, causing the region to become swollen and inflamed. This is not unlike climbing the highest hill (or in this case building one) and then lighting a signal flare to attract help. These secretions attract phagocytes to destroy the invading microbes and remove the dead tissue from the breakdown of the body cells.

The immune system produces two types of specific reaction: chemically mediated (through B cells) and cell-mediated (through T cells). When a microbe invades the body, it is first recognized by macrophages and if they cannot dispatch the culprit, they call for T cells to assist. This puts out a general alarm that leads to the production of NK cells, which attack and destroy the invading agent.

The other strategy employed through chemical means is to call on B cells to produce antibodies, which are specific proteins that don't much like the invaders. They mobilize to target the foreign cells, searching and destroying until given the all clear sign.

So, what is the connection between stress and the immune system? Research has long established that chronic stress can weaken the immune system and all the things it does to protect you. Specifically, chronically high levels of cortisol are associated with a decrease in the body's natural immune response, a decrease in DNA repair mechanisms, and an increase in autoimmune mechanisms (Stojanovich, 2010; Stojanovich & Marisavljevich, 2009). To understand the mechanisms of stress influence on diseases, we will examine the interconnections among the brain, immune system, endocrine system, and illnesses.

Immunity and Stress

In the past, scientists focused on the investigation of the immune system in relative isolation, as if it were a discrete system that functioned independently and autonomously. It

was not until the 1980s that the connections between the immune and nervous systems were gradually clarified. The study of the interactions between the immune system, the endocrine system, the nervous system, and behavior is called **psychoneuroimmunology (PNI)**, also known as **psychoneuroimmunoendocrinology (PNIE)**. It was formed as a discipline because unless endocrinologists, neurologists, and psychobiologists began collaborating, they were likely to miss a large piece of the puzzle (Ader, Cohen, & Felten, 1995; Kendall-Tackett, 2010; Leonard & Myint, 2009).

In an earlier section, you learned about the communication between the nervous system and the endocrine system through neurotransmitters and hormones that have to be combined with receptors of cell membranes of target tissues or organs. You may wonder how the immune system communicates with the endocrine and nervous systems so effectively. In fact, the chemical messengers of the immune system are cytokines, large proteins that are secreted by immune cells and glial cells of the brain. The cytokines activate specific receptors on immune, endocrine, or neural cells. Cytokines can either increase or decrease inflammation.

Inflammation is a double-edged sword. The good function is the body's way to fight against infection, irritation, toxins, and foreign molecules. White blood cells and cytokines are unleashed to protect your body in a rapid immune response. However, when the immune system is under chronic stress, it will rev up the process of sending more and more proinflammatory cytokines into the systems and causing all kinds of diseases. You have learned that stress can be real or imaginary; therefore, even imaginary stressors can cause inflammation in your body through the release of proinflammatory cytokines (Zachariae, 2009). Recent research shows that many diseases—heart disease, diabetes, depression, multiple sclerosis, Alzheimer's, and autoimmune disorders—are strongly associated with inflammation (Kiecolt-Glaser et al., 2007; Leonard & Myint, 2009; Pace, Hu, & Miller, 2007).

VOICE OF STRESS 2.1

Twenty-three-year-old college senior

At age fifteen when I was starting high school I was overwhelmed with transferring from an average classroom setting to a honors classes. I didn't deal with this transition very well. I started to get terrible stomach aches that were eventually diagnosed as colitis. The doctor said it was totally from nerves.

For about a year I felt so sick I could barely go to school at all. I couldn't even leave the house sometimes because I was afraid I'd throw up or have to use the bathroom. I stopped eating much and lost a lot of weight.

Then I started to get more stressed because my family didn't believe that my pain was real. They thought I was just making it up so I didn't have to go to school.

I learned after that I would have to be very careful with stress in my life or my body would act up again. I felt really proud about how I recovered but ever since that time I have to guard against things building up too much or I'll get stomach aches again.

The major question to consider is, how is the immune system actually suppressed in the face of a chronic stressor? In the earliest years of stress research, Selye noticed that the thymus gland atrophied among rats that underwent chronic stress (Selye, 1946). It was found that stress suppresses the formation of new lymphocytes and their release into the bloodstream. This inhibits the production of new antibodies. Chronic and uncontrollable stress leads to the secretion of excessive blood cortisol, hypertension, and increased inflammatory changes in the HPA axis. Also, chronic stress produces so many changes in the SAM system that unhealthy metabolic changes will occur including diabetes, obesity, and hypertension.

If stress takes a toll on the immune system and wears it out, what are the consequences for the host body? **Autoimmune diseases** are those in which the body actually attacks itself. The sensors that detect foreign invaders become confused, signal false alarms, and worse of all, lose the ability to distinguish genuine enemies from friendly forces. Rheumatoid arthritis is one such disease in which the immune system, depleted and exhausted by stress, begins attacking the connective tissue. This results in inflammation and extreme pain in the joints and other parts of the body.

Autoimmune diseases can affect all the systems of the body, especially the nervous system (multiple sclerosis), muscular system (lupus), gastrointestinal system (colitis), circulatory system (Behcet's disease), endocrine systems (Graves' disease), and skin (psoriasis). In each case, the effects of stress have so disoriented and exhausted the immune system that it loses the ability to locate appropriate targets.

Another variation of immune dysfunction occurs when rather than attacking the body itself, the immune system overreacts to relatively benign stimuli. For example, allergies form when the body perceives dust, pollen, and mold as serious enemies. Stress exacerbates conditions such as asthma and inflammatory disorders.

The immune system is concerned not only with warding off enemies but with acting as all-round guardian of maximum longevity. It is perhaps not all that surprising that stress reduces your lifespan in measurable ways. In one study conducted with women who were suffering prolonged stress, it was found that the parts of their immune cells that are devoted to reproducing themselves (the ends of chromosomes) were significantly deteriorated. This is considered one way that scientists measure aging. This condition not only increases the risk of contracting physical diseases but also signals significantly reduced lifespan, by as much as ten years (Nautiyal, DeRisi, & Blackburn, 2002).

VOICE OF STRESS 2.2

A twenty-four-year-old waitress and college student

My boyfriend and I just broke up and it's been unbearable. Not only did I lose the love of my life, but I had to find a new place to live. And fast! Well, while dealing with the move, the breakup, and having to change schools, I started to notice that I wasn't sleeping well. The next thing I knew I could see my hair was getting thinner. I would wake up on my friend's couch, and find clumps of hair on my pillow!

I absolutely freaked out—I could see bald patches on my head! I went to see a doctor and she ran every test in the book. She sent me to a specialist. It turns out that my body had a bad reaction to the stress that I had been going through. They said the stress triggered the alopecia. Imagine that, a bad enough reaction to stress that I start to go bald! I had to have 20 cortisone shots in my skull, plus some relaxation training, before my hair started to grow back.

The Cardiovascular System

The cardiovascular system delivers oxygen, hormones, nutrients, and white blood cells throughout the body by circulating blood. The heart, a fist-sized series of muscles that is nothing more than a pump, powers everything. As we alerted you in the previous chapter, just like any mechanical device, the heart has a finite lifespan—80 years, more or less, which is pretty good for any pump. Depending on how hard and how fast it is required to run, under what conditions it is forced to operate, and how it is cared for, it can last significantly shorter or longer than its advertised specifications. Unlike most other pumps, the heart is subject to both automatic and manual operation. It can be speeded

up or slowed down at will, just by thinking about an image of a South Pacific beach, an impending deadline, or an attractive classmate. The heart is also capable of independent action as it continues to beat steadily, thumping away when you are awake or asleep.

As you learned earlier, one immediate response to a stressor is accelerated heart rate and increased blood pressure. To accelerate the cardiovascular system, the body cranks up the sympathetic nervous system to release epinephrine and norepinephrine and causes the adrenal glands to secrete more glucocorticoids and mineralocorticoids. In addition, the thyroid gland gets into the act, teaming up to help increase blood pressure and heart rate. At the same time, the kidneys decrease urine production, thereby increasing the blood volume. During stress reactions, blood thickens and clots tend to form more easily, resulting in increased likelihood of strokes.

When the stressful situation is over, the parasympathetic system is activated to bring the metabolic rate down through lowering the heart rate, dilating blood vessels, and returning more blood to the gut. Yet, when you experience chronic stress, the cardiovascular system is kept working overtime without regular breaks, creating a condition of **hypertension,** or chronically elevated blood pressure. It is estimated that 15% to 20% of the adult population is faced with this disease.

Elevated blood pressure is harmful to the heart and the blood vessels in a number of ways. When blood is returning to your heart with greater force, it makes a stronger landing on the muscle, causing a thickening and enlargement over time. Once this occurs, the heart requires more blood than the coronary arteries can supply.

The connecting places where large vessels branch into smaller vessels bear the brunt of the increased blood pressure. Repeated crushing against these spots causes wear and tear, eventually leading to tissue damage. Once the smooth lining of the vessel begins to form little craters of damage, inflammation results. These craters become a gathering site for circulating platelets, fats, cholesterol, glucose, and other material in the body. Over time, the blood vessels will become fragile and clotted, leading to **arteriosclerosis** (heart disease). As the vessels become further infused with plaque, calcium, and other fatty acids, they harden and lose elasticity. Coronary events (as heart attacks are called) may soon follow.

High blood pressure combined with arteriosclerosis (plaque/cholesterol) is very dangerous. Greater force is pushing blood through pipes that are on the verge of rupture. When the rupture occurs in the brain, it is a cerebral hemorrhage leading to a stroke or apoplexy. When a coronary artery ruptures, a heart attack or a myocardial infarction occurs, because a part of the heart dies from lack of oxygen. Scientists have learned that many factors contribute to the development of arteriosclerosis and hypertension. High saturated fats in diet provide a significant source of bad cholesterol. Lack of exercise, and little time for relaxation, further increase the allostatic load on the body. Other contributing factors include smoking, heredity, and diabetes. Yet more than anything else it is often psychological factors that predispose some people to have fatal heart attacks: half of all such victims did not have elevated cholesterol but rather manifested certain behavioral and attitudinal traits that are associated with chronic stress (Underwood, 2005).

Let's review to this point: the heart is a pump; the arteries and veins are pipes. Stress increases the fluid pressure within this circulatory system, over and over, straining the walls, the valves and seals. Stressed blood is thicker with platelets that are needed to provide emergency clotting and with fatty nutrients needed for energy. This leaves behind deposits (called plaque) in its wake, creating weakening in the linings, inflammation, and higher concentrations of cholesterol. Where does all this lead? Stress increases the risk of heart disease, stroke, and high blood pressure. No matter how much you control your diet or take drugs, stress leaves behind a combination of chemicals that clog your arteries and slowly restrict the functioning of the pipe system. That means your heart now has to work even harder to deliver the necessary oxygen and nutrients to other areas. And what do you think *that* does to its longevity?

Perhaps you recognize that this is all very much like a sump pump located in the basement of a building. The pump is activated only when the water level rises to a predetermined level, then it whirrs into operation until the level is brought down, returning to a resting state. When such a pump malfunctions, or when the water keeps flooding in faster than the pump can operate, the mechanical parts wear out—stress fractures its weakest parts. This is what happens to your heart during prolonged stress.

The Gastrointestinal System

The gastrointestinal (GI) system is a biological mechanism that breaks down foods into their chemical components. This makes it easier for the body to create energy and form muscle, bone, blood, skin, or other tissue. The first stage of digestion takes place in the mouth, where solid food is chewed and crushed by the teeth while saliva enters the mouth from three glands on each side of the face. Saliva is rich in an enzyme that starts the conversion of starches into simple sugars and assists the swallowing of the food.

The now mashed substance is further compressed and liquefied as it makes its way through the esophagus to the stomach. More squeezing takes place while the nutrients are absorbed into the system as needed. At the very bottom of the esophagus is a ring of muscle called the sphincter. This valve opens to release food into the stomach then shuts again, preventing food from backing up as sometimes happens when a garbage disposal breaks down.

The stomach serves as a storage tank for swallowed food while it continues to break down the material into even smaller parts. These secretions include hydrochloric acid and pepsin, a chief protein-splitting enzyme. The food substances then pass into the small intestine where secretions of juices will assist with a more complete breakdown of these proteins, fats, and carbohydrates and the absorption of the usable parts. The unused and undigested parts will be pushed into the large intestine and moved by muscle contractions into their final destination out of the body through the anus.

Like most other systems in the body, this whole nutritional process of metabolizing food sources is controlled in the brain, particularly in the hypothalamus which signals hunger responses. You can therefore appreciate that the GI system would also be affected by the stress response.

Let's return to the stage where food first enters your mouth. Have you ever had difficulty swallowing food, especially when you were feeling nervous about something? As you learned before, the fight-or-flight reflex shuts downs all nonessential systems, including digestion, since it would be too late to create new sources of energy quick enough to be useful. This is why saliva secretion drastically decreases and your mouth feels dry.

Emotional stress also causes stomach cramps as a result of contractions that take place when the digestive process is suddenly halted (see Voice of Stress 2.3). During conditions of chronic or repeated interruptions, all the stomach acids that are useful for breaking down solid foods begin to eat away at the linings of the digestive tract. This can lead to ulcers and other stomach problems.

VOICE OF STRESS 2.3

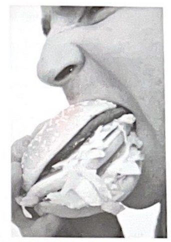
A student in his mid-twenties

I get real moody when I'm stressed. But when I'm dealing with something really serious, like financial problems or a relationship problem, I literally cramp up! I mean I get abdominal cramps that are so painful that I can't even function. Sometimes it gets so bad I have even had to pull my car over to the side of the road for fear of crashing. Then I get diarrhea that turns me into a complete wreck.

I've been through every type of medical test possible. I even had a probe inserted to examine my insides. All the doctors say is that I have to keep my stress level down. I realize that but it just feels out of my control sometimes. When I get in a fight with my wife, or it comes time to pay my tuition for college, or finals are coming up, I just feel the cramps coming on.

Disruption of digestion breaks up the rhythm of the operation. Once repeatedly halted and restarted, the assembly line can move too quickly, providing insufficient time for the food substance to dry out through water absorption. The result: diarrhea. Alternatively, the system can move too slowly and the material dries out so much that constipation takes place.

Of course during stress situations the last thing in the world your body is thinking about is eating a meal or going to the toilet. You've got more pressing business to take care of—like a snake attached to the heel of your foot or an enemy with a weapon in your face. Right after the perceived danger is over, you may find yourself voraciously hungry to replenish the energy depleted, especially with fast foods that have plenty of starch and fat to provide quick nutrient sources. That is one reason why stress can lead to obesity: donuts, chocolate, ice cream, and pancakes are called "comfort foods" because they literally reduce the stress that is still circulating in the body from the activation of perceived threat.



Foods high in starch and fat are craved during periods of stress to replenish what the body believes is an emergency. These foods quickly enter the bloodstream, producing surges in blood sugar that the body believed were crucial to fight or run. If such an energy binge is not actually needed, then the excess sugar becomes converted into fat.

You are waiting nervously for a boyfriend or girlfriend to call, afraid that something has gone wrong; maybe the relationship is over. You pace back and forth, anxious, stressed, jumping at the sound of any noise that might signal the phone ringing. You stare at the phone over and over willing it to ring. But it remains silent. What could have gone wrong? It's clear he/she probably doesn't love you after all. Surely you can recognize that this is a fully fledged stress response even in the complete absence of any direct threat; it is all in the mind. It will come as no surprise, however, that the chosen coping strategy is to go for the double chocolate ice cream in the freezer. This craving is actually the body's signal that it needs more immediate energy sources if this stress battle is going to become a long siege.

Once the all-clear sign is given, the gastric juices rush back to work, behind in their jobs as if they missed a whole week's work. A host of gastrointestinal disorders are caused by stress. In its mildest form you may feel a queasy stomach, the result of hormonal flooding, or perhaps temporary diarrhea. During prolonged bouts of stress, the consequences become far more serious and chronic: irritable bowel syndrome and hypoglycemia to mention a few, most of them the result of excessive stress hormones that remain in the system long past the point they are doing you any good.

The Musculoskeletal and Skin Systems

The skeletal system makes up the framework of the body and allows us to move when our muscles contract. It stores minerals (such as calcium and phosphorus) and releases them into the body when they are needed. The skeletal system also protects internal organs and produces blood cells. Different types of muscle enable motion, generate heat to maintain body temperature, move food through the digestive tract, and contract the heart. In total, the human body has more than 600 such muscles.

Muscles have just two states: contraction and relaxation. Under normal circumstances, that works out fine. But when you are under chronic stress, the nervous system issues faulty commands to contract muscles that really are not needed. It is as if you are in a trench on a battlefield, ready to charge. Every few minutes you get an order to prepare yourself to jump out and run. False alarm. You relax for a moment and gather your breath. But then there it is again, that damn alarm signal, telling you to prepare for immediate attack. You keep getting the signal over and over again, relentlessly, never sure whether it is a real alert or just your imagination.

What happens to your muscles under such conditions? They fatigue, begin to ache, and become tight like coiled wires. Pain and discomfort ensue. In fact, this is the surest way to know whether you are feeling stress in the first place, when you can feel the tension in your muscles, especially those in your neck, face, shoulders, and back.

Most of the time this is all going on without your awareness. You don't realize that your muscles are tight. Perhaps only later do you feel a headache coming on or notice that your hands are sweaty. Most of all you feel soreness in your neck and back. This unnecessary muscular contraction is called **bracing**.

The skin is a part of the immune system (keeping bad things out of the body), and it joins forces with muscles and bones to provide support. Skin actually forms the largest organ of the body and provides the body with the first barrier that protects you from invading microbes and loss of water from the moist internal tissues. It helps control the body's temperature and excretes some wastes, and serves as a major sensory organ, registering pressure, pain, and temperature.

The stress response is manifested through the skin system in numerous ways. As you have no doubt noticed, under conditions of stress you start to sweat. Your armpits feel wet. You can feel droplets falling down your back. Your brow and palms collect moisture. The skin is doing all it can to cool what it believes is an overheated body while running or fighting. The increased moisture also improves electrical conductance which can be measured by a galvanometer (a lie detector).

The Reproductive System

As if stress does not wreak enough havoc within other body systems you hold dear, sexual functioning and fertility are also strongly impacted. Sexual dysfunctions are most commonly classified as psychological in origin (estimated at 90–95%), especially those that have to do with "performance." In the case of a man, this is related to attaining and maintaining an erection, as well as continuing the sex act long enough to satisfy one's partner.

There are sexual dysfunctions that have an organic cause; that is, they result from neurological diseases or side-effects of medications. Most problems, however, are caused by psychological factors such as stress, lifestyle, and relationship issues. That is one reason why sexual dysfunctions such as premature ejaculation and erectile dysfunctions in men, and orgasmic dysfunctions in women, are almost always treated within the context of the couple's relationship. After all, when a man can't have an erection with his partner (but he can with others or during masturbation), he is communicating a message. Likewise, if the woman can't have an orgasm with her partner, or a man has an orgasm too quickly, there are certain messages associated with those behaviors as well.

When you consider how much of sexual arousal and performance is regulated by the endocrine system, limbic system, sympathetic (stimulates orgasm) and parasympathetic (stimulates arousal) nervous systems, as well as desire as created in the cerebral cortex, it is easy to see why sexual activity would be affected so profoundly by physiological stress. Unbalanced hormone levels affect sexual interest and arousal. High blood pressure jeopardizes vascular functioning (useful during erections). High blood sugar (associated with chronic stress syndrome) reduces testosterone levels.

Then, given how much of sexual experience is mentally based, meaning the thoughts and feelings that accompany the physical act, it is nearly impossible to attain/maintain an erection or enjoy an orgasm if the whole time your head is filled with anxious thoughts like: "Oh my God, what if I don't get hard?" or "I've got to come. What if I don't come? Does that mean there's something wrong with me?"

Even if, with all the obstacles just described, a couple does manage to complete a sex act to a satisfactory conclusion, that still may not end the ordeal. Both menstruation and ovulation cycles are affected by stress, as are the frequency of miscarriages, and preterm labor. A laundry list of stress-related factors can sabotage reproductive functioning: lack of hormones (progesterone), too much of a hormone (prolactin), impaired blood flow, flooded corticols affecting glands (ovaries, testes), and the loss of libido or sexual desire, the most common sexual disorder of all. It is sad but true that many contemporary couples report that they are just too busy, too tired, and too stressed to have sex.

Not All Doom and Gloom

You learned in the previous chapter that stress, in itself, is neither a problem nor a health hazard; it is chronic, unremitting stress that presents a severe health hazard with all the

terrible things that happen to various body systems previously described (and summarized in Table 2.2). You will learn more in Chapters 13 and 14 about how performance can be actually *enhanced* by moderate levels of stress in certain circumstances. For now, we would like to tell you some good news: the positive changes and adaptations that take place within the body.

TABLE 2.2. Diseases and Medical Conditions Affected or Exacerbated by Stress

Asthma	Allergies
Diabetes	Heart disease
Stroke	Ulcers
High blood pressure	Hypertension
Multiple sclerosis	Infertility
High cholesterol	Obesity
Cancer	Depression
Alzheimer's disease	Addison's disease
Constipation	Irritable bowel syndrome
Hypoglycemia	Fibromyalgia
Common cold	Menstrual irregularity
Eczema/psoriasis	Hives
Sexual dysfunction	Premature aging
Chronic fatigue syndrome	Chronic pain
Colitis	Arthritis
AIDS	Epstein-Barr disease
Miscarriage	Dwarfism
Anorexia	Canker sores/herpes

Let's start with the most obvious: stress is often fun. Why else would you ever take any risks to deliberately stoke up your adrenaline levels and heart rate? Why would you ever voluntarily get on a roller coaster? Why would you drive fast and increase the probability of an accident? Why would you sometimes do stupid or dangerous things (that you *know* are misguided at the time)? Why would anyone ingest drugs like amphetamines or cocaine that specialize in activating hormonal overload?

The brain creates pleasure and pain. Glucocorticoids, those same chemicals that can create havoc in excess, can also stir up **dopamine,** another hormone that greases the skids of the pleasure pathways in the brain. When dopamine is activated in moderate, brief intervals (like during the ride on a roller coaster), it is experienced as pleasurable. When it becomes sustained and repetitive, chronic anxiety can result. It's another case of too much of a good thing.

Stress in moderate doses can act as a motivator to get things done. It heightens awareness to the point that performance can increase. It helps you assess and respond to potential threats. All these conditions are seen as positive if your system can return to normal functioning within a reasonable period of time (Muller, Kohn, & Stein, 2005). Note that short-term stressors may actually boost the immune system while long-term stressors weaken it, making you more susceptible to chronic diseases (Segerstrom & Miller, 2004). Recent research in psychoneuroimmunology has examined the beneficial effects of acute stressors on health. It has been found that acute stressors can activate innate immunity through increasing trafficking of immune cells to the site of challenge and by inducing long-lasting changes in immunological memory (Campisi & Fleshner, 2003; Viswanathan, Daugherty, & Dhabhar, 2005). Edwards et al. (2006) showed that acute physical and mental stress increased antibody responsiveness in women before influenza vaccination.

At regular intervals, a healthy dose of stress activation keeps the body, and all its systems, well tuned. That is one reason why we enjoy stimulation in our lives, and why boredom can kill us as easily as too much excitement. The same sort of conditioning that prepares an athlete for a competitive race also helps you to stay in shape for any real dangers you might face. You've got to keep all systems operating at peak functioning, and that's not going to happen during a sedentary, sheltered life in which you avoid all possible dangers or risks. The key, again, is moderation.

There are basically four conditions that separate "good" stress (eustress) from "bad" stress (distress) (Lazarus, 1993; Levine, Baade, & Ursin, 1978), as follows.

1. *Extent of uncertainty.* Too many unknown factors increase stress levels. That is why people like to travel to places that are novel and different, but not *so* different that they seem completely out of the realm of experience. Wandering around a strange city is enjoyable if it is within the limits of your uncertainty tolerance; becoming hopelessly lost goes a step too far.

2. *Amount of relevant information available.* Data, preparation, homework, and rehearsal are crucial not only to performing well but also to enjoying the experience. When you are called upon to perform in challenging circumstances, you attempt to reduce the stress associated with uncertainty by arming yourself

with as much information as you can, but not so much that you take away all element of surprise. You might, for example, study maps and guidebooks about a place you intend to visit but you wouldn't want to watch a three-hour video that shows everything you are about to see.

3. *Amount of control.* Too much control over a situation means no surprises, no delights except through the satisfaction of predicting the inevitable. At some stages of life, and levels of functioning, children (and impaired adults) will engage in repetitive activities over and over, reveling in the sameness of things, providing a semblance of order to an otherwise chaotic inner world. To most people, however, control already rules too much of our lives—work schedules, study schedules, family obligations. This can be a good thing in that it keeps you organized and on track, thereby reducing the stress of uncertainty. But there are also times when you love to surrender control and let yourself go—not completely, but enough that you feel greater freedom.

4. *Interpersonal conflict.* We include a whole chapter on this subject because it is so often a source of stress in people's lives. In one sense, such relationship difficulties also result from uncertainty, lack of reliable information, and loss of control. Ask people to describe their biggest problems in this area and they will often point to friendships, family, and love relationships in which they feel misunderstood or disrespected.

FOR REFLECTION 2.4

Complete this exercise either on your own or in small groups.

What is the common factor in all of the elements just described that distinguish good stress—the kind that is enjoyable and stimulating—from the kind that is destructive and painful? Look at each of the factors separately and then try to determine a common denominator. Try to come to a consensus in your group, or form your own conclusion if you are doing this on your own.

The answer is at the end of the chapter.

In later chapters we will talk in greater detail about ways that you can prevent the bad kind of stress and manage it when avoidance is not possible. Already you can see from this overview that the best strategy is one in which you attempt to exercise as much control as possible over situations that you might find stress-inducing. This is more easily said than done, especially when such control involves the unpredictable environment and other people's behavior.

SUMMARY

The stress response, in all its various manifestations within the body, is essentially feedback. The nervous system, and all its components, exists to help the organism protect itself against harm. All of its alarm functions are designed, then, to get us to alter our behavior in such a way that we reduce threats. When those danger signals are ignored, then the nervous and endocrine systems mobilize recruits from all over the body to turn up the heat—whatever it takes to get your attention and get you to stop doing what you are doing that is not working very well, or to start doing something else. In the words of one writer, "Stress doesn't kill us—but it makes everything that does kill us much worse" (Lehrer, 2010, p. 132).

We have reviewed each of the major systems of the body and discussed how they operate and how they are affected by stress. While you may be feeling a bit anxious yourself about all the complex physiology and anatomy terms that have been introduced, as well as the dense material packed into a relatively small space, you have just learned the foundation for much of what you need to understand about how stress operates in the body. We urge you to study this material with more than the usual level of attention and dedication. We promise that these concepts will come up again in the chapters that follow.

FOR REFLECTION 2.5

Time to take a deep breath

The content of this chapter was particularly dense and challenging. A lot of terms, and many physiological concepts were introduced that require years of study in order to understand well. Don't sweat the small stuff or get caught up in the details. Think about the big picture regarding what happens to your body during stress reactions.

Clear your mind for a moment.

Take a deep breath.

Now, write down what you remember from this chapter that strikes you as most important and useful.