Chapter 5: Physiological Processes

Physiological Processes

WHAT'S THE ANSWER?

"I went to see a lady out on old State Highway 711. It was all a big ritual. The room was sort of dark. The only light was provided by candles. She told me she had discovered a technique for telling what people were good at by feeling the bumps on their head. She said bulges projecting from the brain indicated what people were best at. She said I'd be a good dancer and that I'd be able to impress the girls because of my natural abilities." *Is the woman correct? Do bumps on the head indicate a person's abilities?*

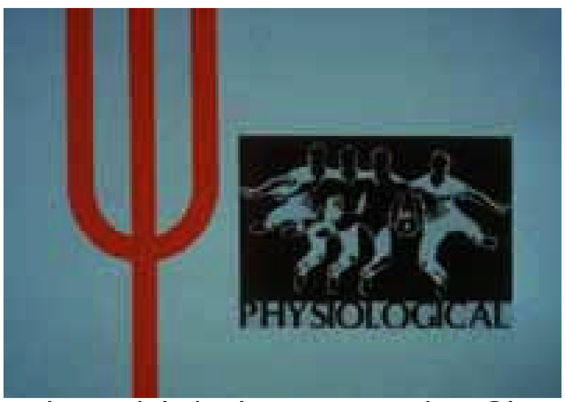
Maybe sometime you've overheard a conversation like this one: Aunt Gerda says to Uncle Bert, "Well, I'm glad she finally had that baby. The child looks beautiful! Her head is a little big, but that runs in his family. They're all smart, you know. Amy's a doctor, Jerry's a vet, and Sheila's a pharmacist. All of them in medicine."

Says Bert, "Yup!"

"But you'd expect that. They've all got large heads, and it takes that to hold all the brains you need to do such things. Big head means a smart person. You can count on it."

Says Bert, "Yup!" *Are they right? Is head size or brain size related to intelligence?*

"I met a man on the street the other day who had a small gadget about the size of a pack of king-size cigarettes in his pocket. We were both waiting for the bus. I asked him what it was. He said it was attached to a sensor under his shirt, and it monitored his blood pressure. He said he had already had two heart attacks. His doctor gave him the device. Every time his blood pressure gets above a certain level, the machine starts buzzing. His job is to get it to turn off again by lowering his blood pressure." *Was the man telling the truth? Is it possible to monitor and control "involuntary" responses like blood pressure?*



The discussion begins most appropriately with an analysis of the general features of the nervous system itself.

All cells in the nervous system share two attributes: irritability and conductivity. The neuron is the basic cell of the nervous system. After a neuron fires it enters an absolute refractory period during which it cannot be fired again. This is followed by a relative refractory period during which the neuron needs stronger stimulation than usual in order to fire. Neurons fire according to an all-or-none principle. If the stimulation is severe, they fire more rapidly. The firing of a neuron greatly changes the electrical potential within the cell. However, to stimulate another neuron a chemical called a neurotransmitter must be released and cross the synapse separating one cell from another. Thus, the entire process of neuron-to-neuron conduction is a complex electrochemical reaction.

A nerve is composed of many neurons, and the nervous system is a complex communications network of neurons, activated by receptors. Afferent neurons carry messages toward higher levels in the central nervous system. Internuncial (associative) neurons carry information within the system at any given level. Efferent neurons conduct messages from the central nervous system toward the effectors, which are muscles or glands.

The nervous system can be divided into the central nervous system (brain and spinal cord) and the peripheral nervous system. The peripheral nervous system is composed of the somatic nervous system (controls voluntary muscles) and the autonomic nervous system. Organs and glands are controlled by both the sympathetic and parasympathetic nervous systems, which are subdivisions of the autonomic nervous system. The sympathetic nervous system expends body resources and gets the organism ready to fight or flee. The parasympathetic nervous system stores body resources in preparation for actions to come.

The spinal cord controls the simplest reflexes, but serves mainly as a message carrier between the peripheral nervous system and the brain. The brain is composed of three parts: hindbrain, midbrain, and forebrain. Responses controlled at each higher level in the central nervous system become more and more complex, less fully automatic, and involve larger amounts of coordinated, voluntary muscle activity. The forebrain includes the thalamus, the limbic system, and the cortex. Most complex sensory-motor reactions are controlled by the cortex, which is also the seat of thought, memory, and language. The cortex is split into two hemispheres, with each hemisphere controlling responses on the opposite side of the body. The halves can work together on complex activities because connections are made through the corpus callosum and through other lower-level connections.

In addition to the nervous system, a system of glands influences how we behave. Eight endocrine (ductless) glands produce hormones which influence other glands and organs of the body. The nervous system, glands, and muscles control human and animal responses.

Long-standing ideas about voluntary and involuntary human behaviors and natural changes in behavior are beginning to be modified. We can alter our conscious awareness in at least four natural ways.

Studies of sleep have attempted to match EEG activity in the brain with changes in behavior. By recording electrical brain waves, four stages of sleep have been defined, as well as a fifth stage called paradoxical (REM) sleep. During REM sleep there is evidence of increased dreaming. The brain is quite active during sleep, but the precise role of dreams during sleep is still being studied.

Biofeedback involves the use of electronic instruments to inform the participant about the activity of one or more of his or her bodily processes -- everything from urine production to brain waves. Meditation is the voluntary production of alpha brain waves by means of concentrated attention. Hypnosis is a more controversial, less understood way to alter the normal state of consciousness. Artificial changes in behavior in normal nervous system functions are also created through the use of drugs: depressants, stimulants, or hallucinogens.

The Nervous System

As you start reading, tell yourself not to blink your eyes. See how far you can read before you have to blink. Pay attention, because if you stop thinking about not blinking, you'll probably blink automatically. You will see later the point we are making with this demonstration.

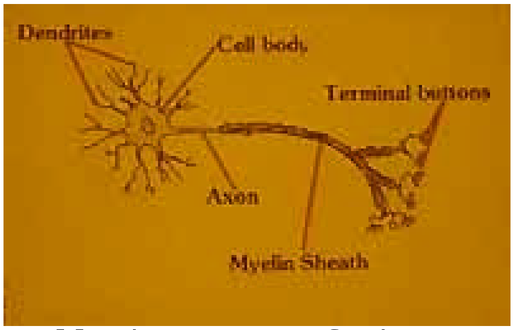
All of the physiological processes within our bodies are coordinated by our nervous system -- it organizes and coordinates all we think and do. We exhibit a huge variety of responses ranging from our emotions to hunger, memories of events long past, and the "instant" ability to withdraw our hand after touching a hot plate by mistake. Ultimately all our responses must be explained in terms of our neurons, our nerves, the organization of our nervous system, our spinal cord, and our brain. Our brain is composed of the hindbrain and midbrain and the forebrain. Each of these is one part of that complex whole called our nervous system.

You haven't blinked yet, have you?

As we study the systems that control our behavior, we examine the neurons, the basic cells of the nervous system. We look at groups of neurons called nerves -- how they are organized and how they are studied. We examine briefly the structure of the brain itself, to determine how it directs the activities of the body. We also consider the glands which introduce various hormones into our blood stream, and we study sleep, one of the most fascinating activities of the nervous system. We also look at practical applications of your knowledge. How can we use our nervous system to influence our behavior -- both natural changes in behavior and artificial changes in behavior? This will lead us into a discussion of biofeedback, meditation, and hypnosis, as well as the use of drugs.

How are your eyes coming along? By this time it is probably beginning to take a great deal of active concentration on your part to keep from blinking. You are overriding a process that your nervous system normally takes care of, but it's getting harder and harder to do so. Keep at it, if you can.

The simplest part of the nervous system is the individual cell called the neuron, the major parts of which are illustrated in the figure. Neurons vary greatly in size. The smallest neurons, probably located in the brain, are less than a millimeter in size. The largest neurons in the system, connecting the brain with the lower legs, may be more than a meter in length.



However, all neurons have two features in common. First, the most basic characteristic is irritability. In response to the proper "stimulation," all neurons will fire. Firing is a process by which ions such as sodium (Na+), potassium (K+), and calcium (Ca++) -- normally kept out of the neuron -- are allowed inside the cell boundaries. Likewise, ions normally kept within the cell are allowed to escape. The result is that the normal electrical charge (called a resting potential) of the neuron is greatly changed for a moment. In response to proper stimulation any neuron will fire.

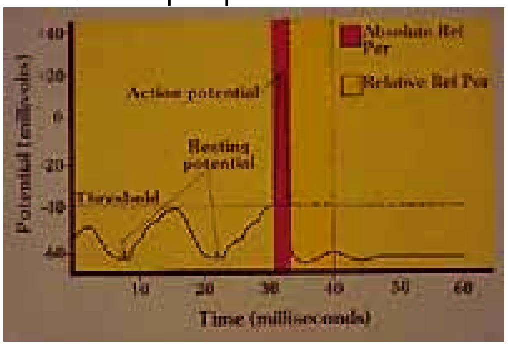
The other feature that all neurons have in common is conductivity. That is, once a neuron fires, that complex change sweeps rapidly from the point of stimulation to the farthest ends of the neuron. In a typical case, the neuron is stimulated and fires at one end. The firing impulse (called an action potential) is conducted in one direction only, from that end to the far end. These two processes, irritability and conductivity, are the basic life processes that all neurons share.

Having examined the nervous system, we learn that its most basic unit is the neuron, numbers of which cluster to form nerves. The nerves, in turn are organized into the nervous system, the director of which is the brain which itself is influenced by and influences the glands. We are capable of creating a wide variety of natural changes in behavior through our nervous system, though drugs can be used also to produce artificial changes in our behavior.

Have you blinked yet? Well, if not, be our guest and blink now. But remember what you've just been through. We talk about it again in a "Think about it" section.

Neurons

The neurons are the most basic components of our nervous system, and, in turn, the neurons are organized into nerves. The firing process in the neuron completely exhausts the neuron’s resources. Before it can fire again, the neuron must at least partially restore the resting potential. The job of the sodium pump is to assure that certain ions must be outside,

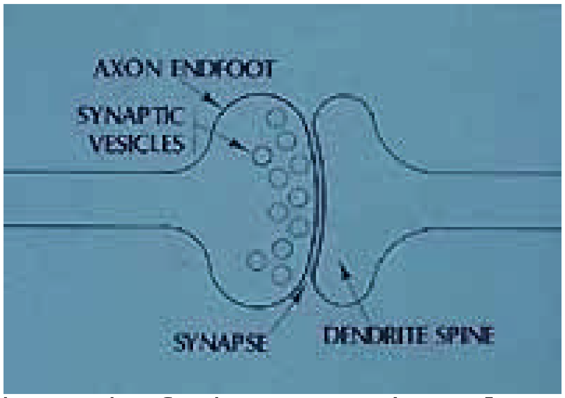


others inside, which causes a slight electrical charge to be reestablished between the outside and the inside. The period during which the cell cannot fire again, regardless of how strongly it is stimulated, is called the absolute refractory period.

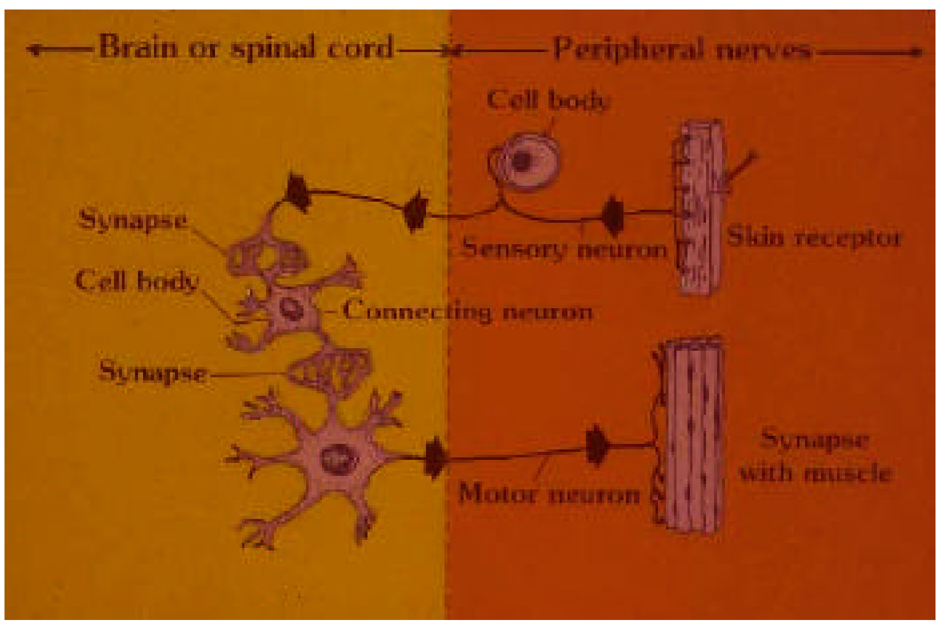
This period is like the exhaustion felt by a long-distance runner just after completing a four-minute mile. He or she could simply be too drained of reserves to attempt another race immediately afterwards. However, without a great deal of rest, the runner could again run a mile -- certainly not in four minutes, but he or she could run that distance again. However, with rest, that same runner could run another mile in close to four minutes.

After the absolute refractory period, the recently fired neuron enters a longer phase called the relative refractory period. During that period the cell will fire again if stimulated, but it takes more than the usual level of stimulation to fire it. Finally, when the cell has fully recovered, it will fire again when given the same level of stimulation as it received originally. There is one big difference between the neuron and the long-distance runner. The runner takes many hours to recover, but the recently fired neuron recovers fully after only a few thousandths of a second. The timing sequence of a neuron firing is demonstrated in the Figure.

A neuron, when stimulated, either fires or does not fire. As long as the negative electrical charge stays below the neuron’s threshold, the cell does not fire. That is, it fires according to the all-or-none principle -- completely, or not at all. Because of that, the only means by which a single neuron can signal severe stimulation is by firing more often. Think about flushing a toilet -- a thought that may bowl you over. When you flush a toilet it doesn’t matter whether you "power" flush the handle with much force or barely depress it enough to start the flush -- either way, the toilet simply flushes. Moreover, while flushing, there’s nothing you can do to make it flush more, or start again, or flush more violently. So it is with a neuron firing.



The junction through which impulses pass between any two neurons is called a synapse. When a neuron fires, the impulse usually starts in the dendrites of the cell. It passes from there through the cell body and then out along a single extension present in each neuron called the axon. When the impulse arrives at the end of the axon, it releases a chemical, called a neurotransmitter, which floods into the synapse. That chemical crosses the synapse and reaches the dendrite of the next neuron. The effect of that chemical on the next cell depends on which chemical has been released. Acetylcholine would stimulate the next cell. Any of a number of other chemicals would inhibit the next cell, making it harder for other neurons to fire it. Any one neuron emits only one kind of chemical from its axon into the synapse. Neurons form many synaptic connections to adjacent neurons, as seen in the Figure.



Transmitting a message across the synaptic gap is the slowest part of the entire conduction process. Drugs may influence the nervous system at the synapse -- helping or hindering it. Signals in the nervous system are electrical within the neuron and chemical between neurons. Thus, a signal transmitted between neurons along a nerve is described as an electrochemical message.

The nerves are organized into our nervous system the director of which is the brain supplemented by influences of our glands. The nervous system can cause a variety of behavioral changes such as falling to sleep which represents one of several natural changes in behavior of which we are capable. Drugs can be used to hinder or facilitate nervous system activity leading to artificial changes in our behavior.

Nerves

Within our nervous system, tracts of clustered neurons form nerves, yet individual neurons still fire on an all-or-none basis. However, each neuron has a different threshold, or level of stimulation above which it will fire. Thus, when the impulses in one nerve are combined, much more information about the stimulus is passed on than in the firing or nonfiring of a single neuron. More severe stimulation means more neurons within the nerve are firing and each one more frequently. The more severe the stimulation, the greater the total activity within a specific nerve. Thus, the nervous system can reflect intensity of stimulation through the firing rate of individual neurons, as well as through the number of neurons firing.

Three different procedures are used to study nerves. These are based on the electrical and chemical nature of nervous activity or on the fact that nerves can't repair themselves. One way of studying the nervous system is to stimulate neurons or nerves electrically and to observe what happens. In the past third of a century scientists have greatly improved their ability to stimulate the nervous system. In fact, they can now reach neurons buried deep within the brain. This is done by operating on an animal (or human), inserting an electrode into the brain, and applying a very, very slight electrical charge (measured in millivolts, or thousandths of a volt) through the electrode. Stimulating certain areas of the brain in this way can cause an animal to overeat to the point of death, or to stop eating completely and thus starve. One of the classic demonstrations of electrical stimulation of the nervous system was conducted by Jose Delgado, as shown in the illustration. We discuss the organization of the nervous system for controlling various behaviors more fully elsewhere in this chapter.

A second way of stimulating the nervous system is through chemical implants called chemtrodes. Both electrodes and chemtrodes are of similar size. Both are anchored to the animal skull so they won't move around after being implanted. However, whereas the electrode is solid, the chemtrode is a hollow tube which permits very small amounts of a chemical to be delivered to a precise point in the brain. Chemical factors in the blood determine many things, including how hungry and how thirsty we feel. The precise role of chemicals in the nervous system and body chemistry has been investigated using processes of chemical stimulation.

Both techniques of stimulation involve very little, if any, damage to the nervous system as a whole. Except for the direct result of the extra stimulation, the normal behavior of the human or animal isn't changed.

A third, more severe method of studying our nervous system involves a process called lesioning. This means that a portion of the nervous system is cut or somehow destroyed. For obvious reasons such research is not usually conducted on humans, but we can study humans who have somehow damaged their brains. War injuries, as well as accidents, have produced a large number of humans with various portions of their nervous system or brain destroyed. One famous accident is described in Feature 4.1.

Feature 4.1

PHINEAS GAGE

Phineas Gage, a railroad worker in Ireland during the middle of the 19th century, was a man who made medical history.

Phineas had a job tamping sand around dynamite in drill holes at a construction site. When Phineas was tamping in a charge one morning the dynamite blew up. The tamping iron was forced upward toward Phineas, who was leaning over the hole at the time. The iron entered Phineas' head at about the center of his left cheek just above his left molar teeth. It forced itself up through his head and brain, and it exited from his skull about halfway between his right ear and the center top of his head.

And how was medical history related to that event? Well, in at least two ways. First, Phineas survived. Second, once he recovered, the easygoing, reliable Phineas became the unpredictable, immature, hard swearing party-goer of the Irish railroad. The tamping iron had destroyed a significant part of the frontal lobe of Phineas' brain, the importance of which is discussed in the brain section of this chapter. His normal living skills—breathing, talking, thinking, eating, and moving about—had not been altered at all. However, it did have substantial effects on his basic personality. Although he did it in an unusual manner, that morning Phineas simply lesioned part of his brain.

Injuries during World War II also yielded knowledge about the brain. A number of soldiers returned with a variety of language difficulties—in understanding or in speaking. It was discovered that most of these soldiers had head injuries. Using X-rays, it was possible to identify two areas of the brain that were always involved when brain injuries caused language problems.

So Phineas Gage was a prophet—100 years ahead of his time.

Tragic as such accidents are, they do at least provide opportunity to study the behavior of those people who have lived through them. This helps psychologists determine what portions of the brain and nervous system control normal responses. In this way, the areas of the brain that control speech, vision, and a variety of other skills have been identified.

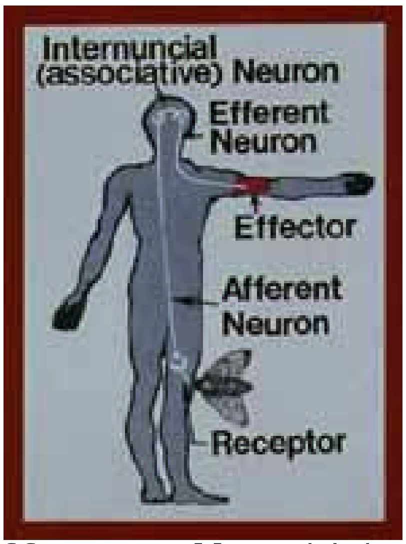
These three techniques -- stimulation, either electrical or chemical, and lesioning -- all involve actively altering the nervous system in some manner. Another method of study, based on the electrical nature of neuronal activity, requires no such alterations. Using a machine called an electroencephalograph (or more simply, an EEG) it is possible to measure the normal electrical activity of the nervous system. Electrical impulses occur in regular patterns, which change according to the state of the organism. For example, a sleeping human shows a very different pattern of nervous system activity from that of the alert, wide-awake organism. Various EEG patterns are discussed more fully elsewhere in this chapter.

These cycles of electrical activity are frequently called "brain waves." In reality they are simply the recording of the changes in electrical activity in the nervous system as the organism performs different acts. Neurons forming nerves organized into the nervous system are directed by the brain, though influenced by our glands. That system is ultimately capable of producing a variety of natural changes in behavior and indirectly a number of artificial changes in behavior.

Organization in the nervous system

The nervous system is a complex communications network controlling the body's internal environment as well as its responses to the world around it. How does this most important system work? The nervous system is controlled by the brain which, in cooperation with our glands, impacts a variety of changes in behavior of which we are capable. These changes include sleep, and variety of other natural changes and artificial changes moderated by the nervous system.

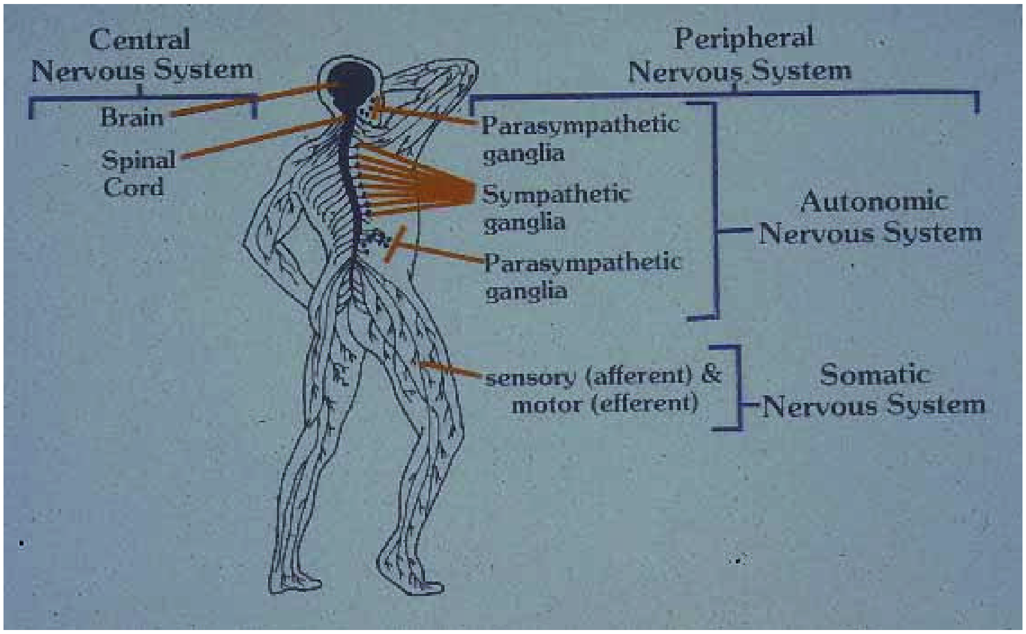
The processes of our nervous system are set in motion by stimuli from the receptors. Receptors are a variety of cells–ranging from cells in the eye for vision to cells in the foot for touch and pain. They react to certain aspects of the physical environment. For example, when a mosquito bites you, it is a receptor that detects the bite. (Receptors are discussed in detail in the Sensation and Perception chapter.)



Control of the body is achieved through the effectors, muscles or glands to which the nervous system connects. The glands secrete hormones that influence the body's internal environment. Muscles usually respond by action. In our example, it would be the effectors that slap the mosquito.

How are messages carried from receptors to effectors? Basically, three types of neurons are involved: (1) There are afferent cells, which conduct nerve impulses from the receptors toward the brain or spinal cord. These are the points in the body where a decision (voluntary or involuntary) is made as to what the response should be. (2) There are the internuncial, or associative, neurons, which are responsible for many things, including what we commonly call thought. These carry information within the system. Finally, (3) there are the efferent cells, which conduct nerve impulses away from the decision points to the effectors. Thus, the nervous system -- composed of afferent, associative, and efferent neurons -- is a network of neurons connecting the receptors with the effectors.

If we classify the nervous system on the basis of the location of its parts, the division is quite easy as seen in the drawing. The central nervous system includes the brain and spinal cord -- the portion of the nervous system encased in the backbone. The brain and -- to a lesser extent -- the spinal cord are the decision-makers. The peripheral nervous system is everything else. This includes all afferent nerves bringing messages in to the spinal cord from the receptors as well as the efferent nerves leaving the spinal cord for various organs or muscle groups. The peripheral nervous system is a relay system.

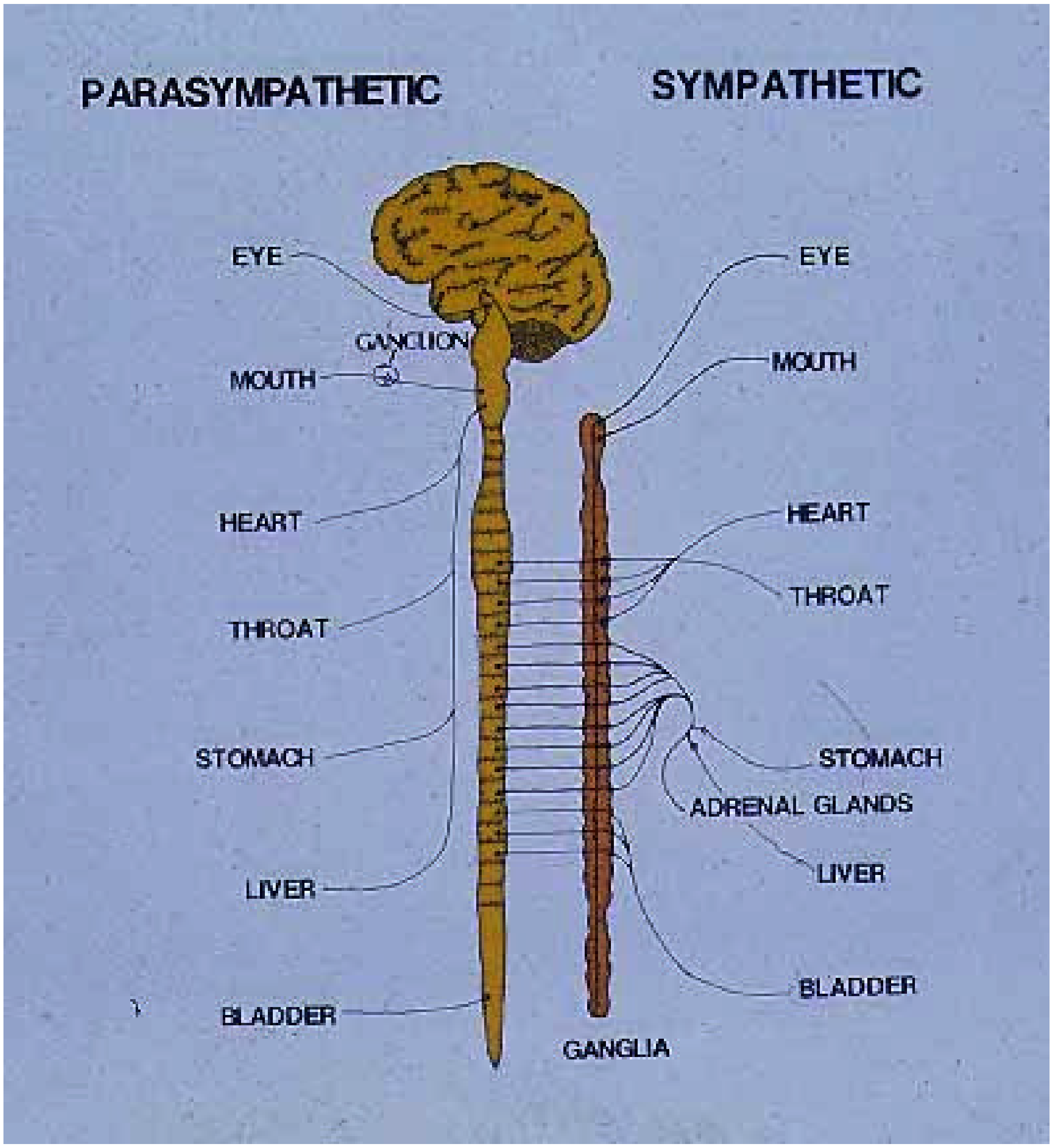


The peripheral system can also be divided into two groups of nerves on the basis of the function they serve. The somatic nervous system controls voluntary muscles and movement. The autonomic nervous system controls the glands and organs of the body.

Is that all? Well, no. There's one more division we need to consider. The autonomic nervous system is composed of the sympathetic nervous system and the parasympathetic nervous system. Both of these systems have connections to the same organs and glands, but for very different -- yet related -- purposes.

Basically, your sympathetic nervous system becomes active when you are in danger or are about to engage in something like an athletic contest. Heart beat increases, digestive processes slow down, and blood flow is increased to the muscles. You are ready for extreme physical exertion -- whether that be running away from an enemy, catching the game-winning pass, or what have-you. Thus, the sympathetic nervous system is focused on using body resources, particularly in times of need.

The parasympathetic nervous system is connected to the same organs as is the sympathetic nervous system, but activity of the parasympathetic system has very different effects. It slows the heartbeat, increases the digestive processes, and diverts blood from the muscles toward the stomach and intestines. The parasympathetic system tends to restore body resources in preparation for the next event. Activity of each of these nervous systems has essentially opposite effects. However, together the parasympathetic and sympathetic nervous systems precisely control the organs and chemical balance in the body.



The nervous system coordinates the activity of individual Neurons which cluster to form nerves. The nerves are directed by the brain, which exercises control over our glands. to produce a variety of natural changes in behavior and indirectly various artificial changes in behavior.

The brain

Our nervous system is organized to process and deliver neural messages. The message delivery system is the peripheral nervous system. Let's now look at the decision-making apparatus: the spinal cord and brain, including the major operating divisions of our brain, the hindbrain and midbrain and our sophisticated forebrain. In simple animals, it is possible that as few as three neurons (afferent, associative, and efferent) may be involved in responding to stimuli from the environment. However, for even the simplest responses in humans, the story is much more complex.

Take the knee-jerk reflex as an example. A tap on the knee activates many afferent neurons. Through them and the afferent neurons with which they interconnect, the stimulation reaches the lower portion of the spinal cord. There little processing is involved. Through very few associative neurons, the incoming message is transferred to efferent, or outgoing, neurons. These connect to the effectors, in this case muscles in the leg, and your leg kicks out almost immediately. Very few sensory stimuli in humans are processed that rapidly and converted so assuredly into a particular reaction.

In fact, sensory messages are usually relayed to the spinal cord and up to the brain, where active processing is involved before any action takes place. Psychologists have long recognized the importance of the brain in most human decision-making -- both voluntary and involuntary. Even before psychology became a formal science, the importance of the head had been recognized, although incorrectly as suggested in the Figure. In the early 1800's the phrenologists thought that lumps on the head indicated that a person had unusual ability in skills controlled by the area of the brain under the lump. The "Think about it" that follows describes the assumptions made by phrenologists and how they turned out.

Think About It

The question: Do lumps on the head indicate a person's abilities? Is there any relation between parts of the brain and specific talents or functions?

The answer: Early in the 19th century Franz Joseph Gall (1758-1828) and later G. Spurzheim (1776-1832) developed a process called phrenology, to study the mind and its functions. The phrenologists asserted that bumps in the outer skull covered enlargements of the brain beneath them, as shown in the drawing. It was further stated that enlargements in specific areas of the brain meant a person excelled in the abilities controlled by that area.

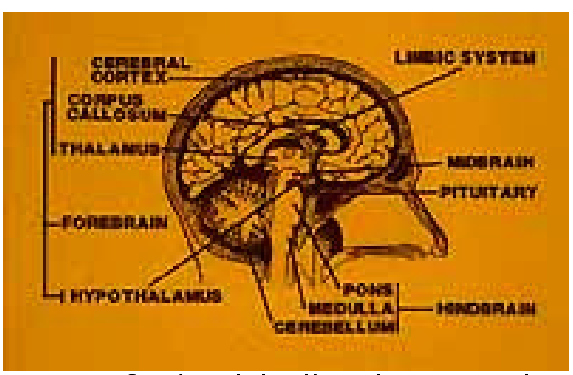
As it turned out, swellings on the outside of the brain were not directly related to the shape of the outer surface of the skull. Neither could it be proven that enlargement of an area in the brain meant improved capabilities of whatever function was controlled by that area. The phrenologists' assumption that specific body functions are controlled by specific areas of the brain seems to be generally correct for certain skills. Evidence regarding this last point is still being sought and examined. The phrenologists had some interesting ideas about the lumps on your head, but subsequent research did not confirm their theories.

However, we should note that some ideas of the phrenologists were not entirely out of place. Evidence shows that certain body functions are controlled by specific areas of the brain in both humans and animals. All animals require nervous systems that can cope with the same basic physical demands. Thus, all animals are capable of eating, drinking, and moving about without losing their balance. To a lesser extent such processes as sleeping and reproduction are similarly controlled.

What distinguishes humans from other (lower) organisms is not the specific areas of the human brain, but rather the relative development of these specific areas. In humans, as in most animals, the brain is a large group of neurons and nerves in one part of the body. The human brain includes some 10 billion neurons. Yet, it can be divided into a number of areas that are easy to identify. Each controls different responses of the total organism.

As the governing portion of the nervous system, the brain is divided into three main sections, each with different responsibilities: the hindbrain and midbrain and the forebrain. These three sections of the brain combine to exercise control over our glands to produce a variety of natural changes in behavior and, less directly, artificial changes in behavior.

The Hindbrain and Midbrain



The brain, as the controlling portion of the nervous system, is composed of three principal sections: hindbrain, midbrain, and forebrain, with the hindbrain being closest to the spinal cord. The relations among various parts of the brain are illustrated in the Figure. Part of the hindbrain, at the top of the spinal cord forms the lower part of an area called the brain stem. The brain stem relays afferent messages from many of the sensory organs to higher levels in the brain. It also relays efferent messages from those levels to the effectors. In general, control of the most basic processes of life -- breathing and heartbeat -- occur at the lowest levels of the brain. As you move upward through the brain, increasingly complex process are found. Thus, an act of imagination -- what would your bedroom look like redecorated in green with colonial furniture? -- occurs in the forebrain. The Think About It addresses a related question regarding brain structure and function.

Think About It

The question: Aunt Gerda was talking to Uncle Bert about the children of one set of parents. She concluded from her quick analysis that big heads meant smart people. Was she right? How about brain size? Is brain size related to intelligence?

The answer: The answer to the first question is no, but the answer to the second question is maybe. As you read, even 150 years ago the phrenologists tried to demonstrate that head size was directly related to intelligence or ability in some direct way. The evidence argues heavily against this idea.

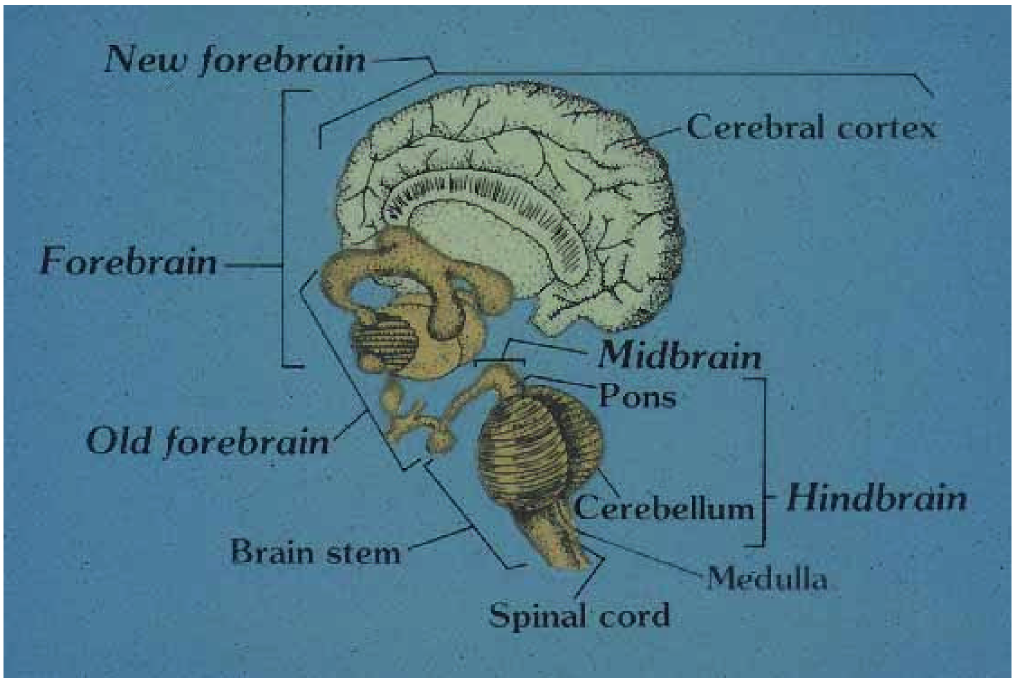
However, during the 1960's it was found that the size of rat and mice brains is related to the kind of environment in which they are raised. The brains of rats raised alone in standard wire-mesh cages were smaller than those of rats raised in an enclosed natural environment that included other rats.

The cortex of the enriched-environment rats grew about five percent more than the rest of the brain. In addition, the cell body of the neurons grew 13-14 percent larger and the glial cells (which nourish the neuron) increased about 14 percent. Both of these factors probably indicate increased nervous system activity. So we answer with a maybe. Bigger heads do not mean smarter animals or people. But animals with a more enriched environment create larger (not more) neurons and have at least a slightly enlarged cortex. Of course, it is much too early to conclude from this that an enriched environment leads to a larger brain. That possibility is still being assessed.

The hindbrain performs a number of reflex actions, including such responses as blinking the eyes. In addition, some of the most basic processes of the body, such as breathing and heart rate, are controlled in the brain stem. Another part of the hindbrain, not in the direct line of communication from the spinal cord to the forebrain, is the cerebellum. One of the main tasks of the cerebellum is controlling posture, balance, and the muscle tone of voluntary muscles all over the body.

The midbrain is located just above the hindbrain, forming the upper part of the brain stem. Like the hindbrain, it also serves to relay both afferent and efferent messages. The midbrain performs some of the same kind of reflex responses that are controlled by the hindbrain. However, the midbrain also controls more complex responses such as walking. In addition to the hindbrain and midbrain, the brain also contains the forebrain which is primarily responsible for controlling our glands and producing a variety of natural changes in behavior. Indirectly, depending on our intent, we can also create a variety of artificial changes in behavior.

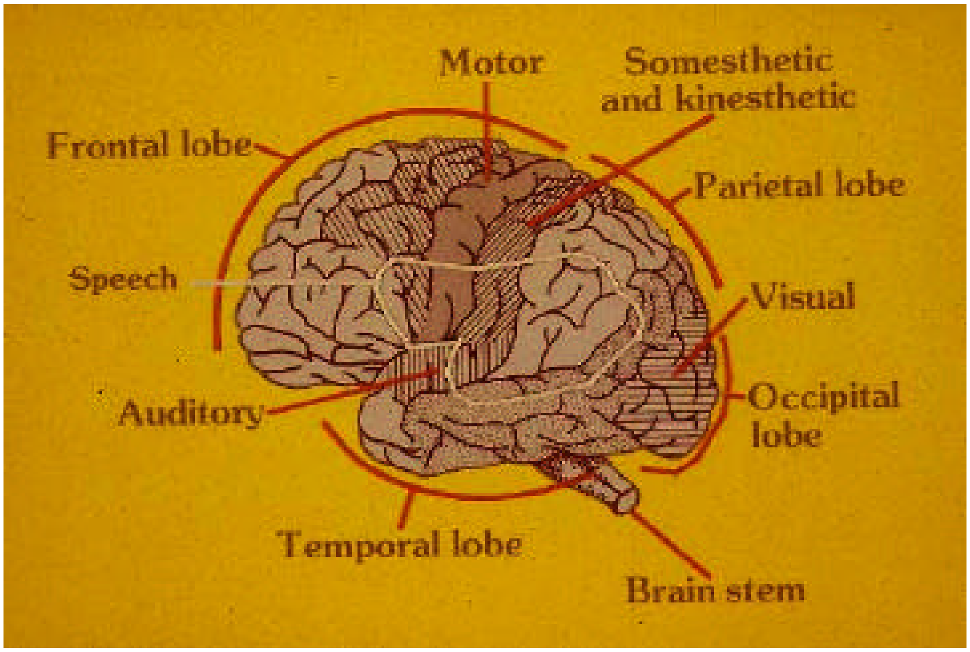
The forebrain



In addition to the hindbrain and midbrain, the brain also contains the forebrain, the most complex and the biggest part of the human brain, as illustrated in the Figure. [Editor: Refer to same figure as in preceding section] Because of differences in function, the forebrain is often divided into two components -- the old or classic part of the forebrain and the new portion, the neocortex or cortex. In the classic part of the forebrain, there are three parts. The first of these, the thalamus, is the last relay station through which afferent messages will pass. It serves as a major "switching point." Messages from all the senses except that of smell are relayed from here directly to a specific area of the highest part of the forebrain, the cortex.

A second portion of the classic forebrain is the limbic system, of which the most important part is the third portion, or hypothalamus. The hypothalamus itself has been found to be involved in a huge variety of complex human processes. Many of its activities are unconscious and automatic. It is liberally laced with blood vessels so that it is able to react to the state of the body by monitoring the blood. The hypothalamus controls eating, drinking, and certain sexual activities as well as more fully automatic adjustments such as temperature. Thus, many of the activities which the hypothalamus influences are motives.

Through the autonomic nervous system, to which it is directly connected, the hypothalamus controls the operation the body's organs. Electrical stimulation of the hypothalamus can cause a hungry animal to stop eating, a full animal to continue eating, and a variety of other surprising responses.



Although it oversimplifies things a bit, we can say the brain stem, thalamus, and hypothalamus are the highest points in the brain at which reflex or automatic responses are controlled. As we move from the spinal cord to the forebrain, we move from areas controlling automatic responses to those controlling more complex, voluntary responses.

The most complex part of the forebrain is the cortex itself. Areas within the cortex are called lobes. There are four lobes, three of which are separated by deep valleys, or fissures. (See illustration.) The frontal lobe is found, as you might guess, at the front of the brain. The back of the frontal contains the motor cortex, which controls body movement. During brain surgery, stimulating this part of the brain may cause involuntary bodily movements.

To the sides of the frontal lobe are the areas of the brain controlling speech. The front of the frontal lobe seems to be used mainly for abstract mental activity. Lesioning large parts of the frontal lobes seems to have little effect on bodily functions. However, it may seriously alter more subtle thought processes -- the explanation for the bizarre behavior of one Phineas Gage, a railroad worker who destroyed a significant portion of his frontal lobe in an accident. The Think About It discusses one body function that can be indirectly impacted by frontal lobe activity -- blinking your eyes.

Think About It

The question: At the beginning of the chapter we asked you to keep from blinking for as long as you could. If you kept this in mind as you read, you probably found you could go for quite some time without blinking. However, the longer you went, the more attention you had to devote to the effort. Since blinking is one of many things you do without thinking about it, how were you able to override that process? What parts of the brain were involved in that process of voluntarily controlling what is usually involuntary and automatic?

The answer: We must vastly oversimplify the operation of the brain in order to answer this question. The eyeblink is normally controlled by the hindbrain. It requires no conscious or voluntary thought by any higher portion of the mid- or forebrain. However, a voluntary override of that process can be accomplished by a decision made in the frontal cortex. As the eyes become more and more dry and as dust particles start to bother them, these signals are received in the sensory area at the front of the parietal lobe. As long as the efferent (downward) motor messages from the motor area at the rear of the frontal lobe are blocked by the frontal cortex, you should be able to keep from blinking. But, the moment you don't pay close attention, the automatic response (initiated by the hindbrain) will cause your eyes to blink.

At the back of the cortex is located the center for vision, the occipital lobe. The temporal lobe, located to the side of the brain, and separated from the rest by a fissure, is mainly concerned with hearing. The parietal lobe, located across the back top of the brain, receives messages from the skin receptors and from sensors in the muscles and joints.

When you examine a complete human brain, you note right away that it is composed of two apparently equal halves. These halves are called hemispheres. While they look alike, they have some interesting differences in function. Events that occur to the left side of the body -- a pin prick, a feeling of heat or cold -- stimulate the right cortex. Events on the right side stimulate the left cortex. Yet, in vision we don't see two different worlds, we see one image. This blending is done by associative, or internuncial, neurons that connect the two hemispheres mainly through something called the corpus callosum.

Both monkeys and some humans have had their corpus callosum (and in some cases also connections even deeper down in the nervous system) cut through completely. Thus, the left hemisphere could no longer communicate with the right hemisphere. Some truly amazing results were then obtained, as described in Feature 4.2. There can be a lot of truth in the saying that the right hand doesn't know what the left is doing! The corpus callosum insures that each hemisphere is informed of the other -- otherwise you wouldn't be able to clap your hands.

Feature 4.2

THE SPLIT BRAIN

Since the early 1940's there has been much work on how thinking is influenced when the corpus callosum is cut to create a "split brain." The left half controls language for 92 percent of all right-handed people, but also for 69 percent of left-handers. Thought in this hemisphere follows in a logical way from problem to solution. The right half tends to function much more abstractly, but not always in a logical sequence. This hemisphere coordinates motor behavior and artistic (painting or music) efforts.

Severing the brain's corpus callosum separates the right and left halves and prevents communication between them. However, under normal circumstances that lesion does not alter behavior. To detect what changes may occur, one psychologist asked persons who had undergone the split-brain operation to focus their eyes on a spot. Then he flashed a red or green light in the left visual field. This was received by the right part of the retina (as described in Chapter on Sensation and Perception) and relayed to the right hemisphere. The subject was asked to say which color had been flashed. But, language is controlled by the left hemisphere—the one that did not see the light. So what happened?

Most of the subjects guessed wrong. However, if allowed more tries, they got better and better at correcting themselves. Following an error the subject would frown shake his or her head—motor actions controlled by the right hemisphere. Then the subject would correct the error!

The left half of the brain that was trying to guess by using language was separated from the half that knew the answer. So the right half, not having control of language, used a motor response (head-shaking and shoulder shrugging) to signal that an error had been made. A fascinating demonstration of the different capabilities of the left and right hemispheres.

The brain, as the director of the nervous system, operates through the hypothalamus to exercise control over many of our glands. These influences produce a variety of effects, including natural changes in behavior such as sleep and artificial changes in behavior such as those produced by drugs.

Glands

Besides the workings of the nervous system, there is another set of physiological processes that also affect our behavior. These are the functions of the glands, both exocrine (ducted) and endocrine (ductless). An analogy may help. Think of the body as a pipe -- wrapped around the alimentary (digestive)canal. The exocrine glands secrete through the walls of the pipe to the outside (e.g., sweat) or inside (e.g., saliva); the endocrine glands secrete into the circulatory system within the wall of the pipe.

The exocrine (ducted) glands produce many different products, including sweat, saliva, and tears, as well as sperm and eggs. They secrete into a duct which carries their product either to the skin (e.g., sweat) or to an internal cavity (e.g., saliva). These glands are not of much interest to psychologists. They tend to be influenced by behavior (when you eat, you salivate), but they do not tend to alter behavior.

The endocrine (ductless) glands produce hormones which are secreted directly into the bloodstream. They may affect an organ or another endocrine gland, or they may directly influence behavior. These glands secrete hormones upon being stimulated by other hormones or by the nervous system.

As seen in the Figure, there are eight endocrine glands, two of which (pituitary and adrenal) have two parts. All the other endocrine glands are controlled by the pituitary, often called the master gland. The pituitary is controlled to some extent by chemicals released by the hypothalamus. As a master gland it secretes a number of hormones that influence the glands and organs. Control of the pituitary gland by the hypothalamus makes good sense, since the hypothalamus itself responds to chemicals within the blood stream. So, monitoring the blood chemistry, the hypothalamus can directly stimulate the pituitary gland through neural connections and hormonal influence. The pituitary stimulates the other glands.

Men and women have all these glands in common save one pair, as shown in the Figure. Men have testes, which produce the male sex hormone, while women have ovaries, which produce hormones related to female sexual characteristics. Both these glands (collectively called gonads) respond to gonadotropin, a hormone released by the pituitary gland.

As already noted, three systems -- the nervous system, the glands, and the muscles -- are the major factors responsible for the ways humans and animals react. Psychologists usually do not study the muscles since they are simply effectors responding to the nervous system. Thus, from a psychological point of view, understanding the nervous system and glands is enough to explain the physiological bases of behavior. Our glands and nervous system are the primary sources of influence impacting various natural changes in behavior such as sleep, biofeedback, meditation, and Hypnosis.

Natural Changes in Behavior

Let's look at some physiological processes that occur primarily because of changes in our nervous system. The influences of the nervous system which impact behavior usually lead to immediate effects. By contrast, our glands usually stimulate long-term effects -- such as the gain of secondary sexual characteristics during adolescence in response to gonad-produced hormones.

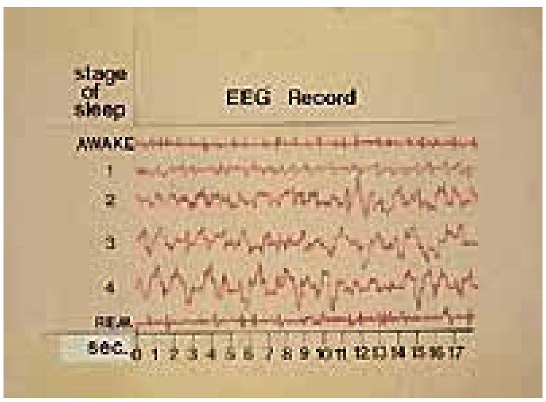
Changes in our immediate behavior can be brought about in two different ways. Natural changes in behavior resulting from alterations of nervous system activity include sleep, biofeedback, meditation, and hypnosis. These changes are under the control of the individual, though in an unusual way. Whereas we can tense our muscles and increase our physical exertion and accomplishment, it is not possible to will ourselves actively into sleep or (typically) a hypnotized state.

Though controversial, meditation and biofeedback, by contrast, are acts of focused will achieved by a goal-seeking human. These effects require voluntary cooperation of the person who is being influenced. Moreover, artificial changes in behavior (including those brought on by drugs) at first involve the active cooperation of the person. However, once the process is underway, the person may lose some or all control over what is taking place.

Sleep

For humans sleep is one of the most fascinating of all natural changes in behavior. The average human is actively engaged in sleep -- full-time doing nothing else -- for 20 to 25 years of his or her total lifetime. Sleep research attempts to relate nervous system activity to what happens during sleep.

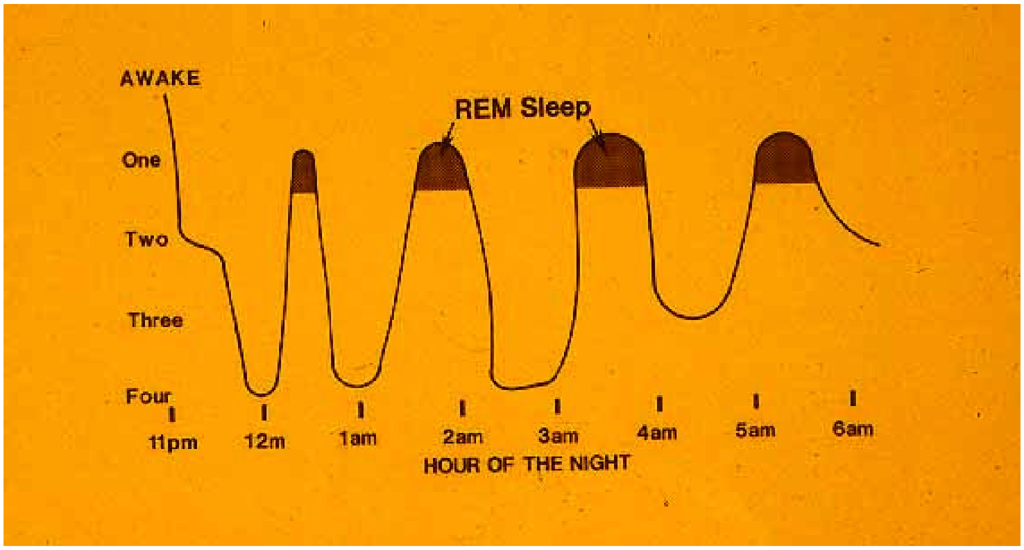
The EEG, or electroencephalograph is our most important guide to the understanding of sleep. By attaching the EEG electrodes to the human scalp as seen in the Figure, it is possible to record the electrical activity of a large number of neurons in the brain beneath. These EEG recordings show that



cells tend to fire more or less together in the alert, awake human. The electrical activity, therefore, appears as "waves" of activity, or cycles of increasing and then decreasing neuronal firings. The cycles occur very rapidly -- up to as many as 40-42 cycles per second when the person is awake.

However, if we continue to record the brain's electrical activity as the person goes to sleep, we find activity in the brain begins to change. In fact, if we examine the EEG records of someone going from fully awake to deep sleep, we find four stages through which we all pass, and a fifth we enter when soundly asleep after 90 minutes or so. (See the illustration.)

It turns out that a very regular 90 minute cycle of electrical activity exists throughout the night, as depicted in the Figure. We drop fairly rapidly to Stage Four, the stage of deepest sleep. However, we seem to climb out of it into a modified version of Stage One sleep, a fifth stage called paradoxical sleep or emergent Stage One. The EEG record in paradoxical sleep appears as though the participants were awake, yet they are as difficult to awaken as someone whose EEG record indicates they are in Stage Four sleep.



Someone noticed that during paradoxical sleep participants' eyes seemed to be moving -- almost as if they were open and the participant were looking around. It was soon discovered that these rapid eye movements (more simply called REMs) occur at a particular time. What happens if you awaken participants who are showing REMs and whose EEG records indicate they are in this paradoxical sleep? About 70 percent of the time they will report that they have been dreaming.

This was an important discovery! All sorts of questions pop to mind. Does everyone dream? It turns out that yes, just about everyone dreams. Typically, those who report they never dream have a problem remembering that they dreamed. If such people are awakened when they are showing REMs, they too will usually report that they have been dreaming.

Well, then, how important is dreaming? What would happen if we woke people every time they started showing REMS, to prevent them from dreaming? People who are deprived of REM sleep become more short-tempered, more distractible, and less able to concentrate on their everyday responsibilities. In addition, after such people are no longer being awakened when they show REMs, they engage in much more REM sleep than usual. This rebound effect suggests that they are making up for lost time or, more precisely, making up for lost REM sleep.

And, finally, is sleeping really a quiet state? Is the brain "shut down" in some way, or less active during sleep? The evidence says no. What seems to happen is that incoming stimuli are blocked instead of being relayed to alert higher centers of the brain. The brain remains active, but simply does not respond to incoming stimuli.

How the brain continues to function is shown in the example of parents who sleep near railroad tracks. A train going by, even though it makes a lot of noise, won't wake them up at all, once they have become used to the sound. Yet, if the child of those parents cries out during sleep, one or both parents may awaken in an instant to check the child. Hopefully, the squeak of a floorboard stepped on by a burglar will have the same effect. Sleep is but one of the natural changes in behavior we can exhibit. Others include biofeedback, meditation, and hypnosis

Biofeedback

Among natural changes in behavior, one of the most controversial, yet potentially beneficial is biofeedback. For many years psychology divided all human behavior into voluntary and involuntary responses. Voluntary responses included, as you might expect, any responses that involved active control of muscles: a swing of the arm, a wink of the eye, and so forth. Involuntary responses included heart beat, blood pressure, and EEG wave patterns, as well as more subtle responses such as urine production by the kidneys.

It had long been assumed that humans could not control, except in a very limited way, involuntary responses. At least that was what was believed until participants were allowed to observe their "involuntary" behavior, such as brain waves, on an oscilloscope. Now that's not a new idea, but the next step was. One psychologist decided to reward participants every time they could increase the occurrence of alpha waves on the oscilloscope. What was the result?

By watching their EEG, people were able, by a conscious effort, to make the alpha waves appear! We know that alpha waves, with a frequency of 6-8 cycles per second, usually occur only in the fully relaxed or dozing participant. It is too early to jump to the conclusion that learning to increase alpha wave activity will create a more relaxed, healthy person. However, the suggestion has led to some intensive research efforts.

Biofeedback refers to the use of electronic instruments to show the participant the activity of one or more of his or her bodily processes -- heart beat, respiration, or what have you. Scientists' early enthusiasm for biofeedback cooled somewhat during the 70's since results were not always easily duplicated, a topic analyzed in the Think About It section.

Think About It

The question: Is it possible to monitor and control "involuntary" responses like blood pressure?

The answer: It is becoming increasingly clear that some responses earlier thought to be involuntary can be actually modified, if not fully controlled. The first use of biofeedback techniques to help someone control involuntary responses involved controlling heartbeat and blood pressure. Early worries have been largely dispelled that other responses (such as breathing or muscle tension) might have been altered, indirectly effecting a change in heart functioning.

Whether or not a heart can be directly controlled is really just a technicality. To the person with high blood pressure, any device that warns him or her when the blood pressure is increasing may assist that person in altering behavior to reduce the demands on the heart. It isn’t the direct control but the necessary effect—less demand on the heart—that counts.

However, the rapid growth of behavioral medicine reaffirms the growing number of successful results in using biofeedback to treat even such severe problems as loss of blood pressure in paralyzed hospital patients. Biofeedback offers hope for increasing our life span by reducing internal body stress. Biofeedback is only one of the natural changes in behavior we exhibit. Others include sleep, meditation, and hypnosis

Meditation

In recent years one of the most attention-getting natural changes in behavior has been the study of consciousness. Consciousness is a concept that is not easy to define. You and I are aware of ourselves. We are aware of our ability to think and experience. That awareness is defined by many as consciousness.

Meditation, a type of deep, concentrated thought, is related to consciousness and focuses on some of these problems. For example, many societies (including our own) offer means by which to "expand" consciousness. There is a marked similarity in the means by which this may be achieved in societies otherwise dissimilar, as seen in the Figure.

In Zen meditation one question (called a koan) serves as a point of focused concentration, sometimes over a period of years. Yoga uses one word (called the mantra), which is said time and again in the early stages of meditation. This word has or gains great personal meaning. A third kind of meditation has the participant direct his or her attention to an object (called a mandala).

It is not easy to define when a meditative state of "higher consciousness" is achieved. All approaches use the same method: they limit the awareness of body feeling and the environment to a single object or concept. Meditation is an altered state of consciousness exactly because of this narrowed attention. However, it is a naturally altered state, requiring nothing more than the will to achieve it.

In our study of the EEG wave patterns we learn that the alpha wave pattern occurs when the participant is awake, but resting calmly with eyes closed. It has been found that people in meditation often show the alpha wave pattern with their eyes open or shut. This is impossible for the nonmeditator to achieve. Clearly, those who are meditating have their attention so focused that they don't notice anything else, even with their eyes open. By measuring a number of physiological processes while someone is meditating, it has been possible to study the differences produced during sleep, meditation, and hypnosis. Such comparisons are shown more fully in Table 5.1; these observations are expanded upon in Feature 5.3

Table 5.1

Comparison of changes in several physiological functions during meditation, sleep, and hypnosis

PHYSIOLOGICAL MEASURE	MEDITATION	SLEEP	HYPNOSIS
Oxygen consumption	Mixed evidence of a drop	Drops half as much as in meditation, but takes 4 hours or more to do so.	No noticeable change from waking state
Carbon dioxide in blood stream	No noticeable change from waking state	Increases	Depend on the suggested state
Rate of respiration	No noticeable change from waking state	Decreases	Depends on the suggested state
Rate of respiration	No noticeable change from waking state	Decreases	Depends on the suggested state

Metabolic rate	Decreases	Remains constant	No noticeable change
EEG wave patterns	Alpha waves predominate	No alpha waves	No noticeable change from waking state
Electrical skin resistance	Large increase at a rapid rate	Small increase (half that found in meditative state) at a slow rate of change	Depends on the suggested state
Heart beat	No change or slight increase		Depends on the suggested state
Blood pressure	No change from waking state	Drop	Depends on the suggested state

Feature 5.3

MEDITATION: WAVES OF RELAXATION?

What happens to the physiology of a mediator? Two psychologists in the early 70's studied 36 people experienced with transcendental meditation, a variety of yoga. Oxygen consumption, carbon dioxide elimination, blood pressure, temperature, skin conductivity, and other functions were measured before, during, and after meditation. During meditation oxygen consumption dropped 16 percent, while carbon dioxide elimination dropped almost 15 percent below pre- and post-meditation levels. Both the rate and volume of breathing dropped about 22 percent, suggesting that basic body metabolism had been slowed.

More recent summaries of research conducted during the late 70's and early 80's contradict these findings. Although meditation is well accepted, there is scant evidence that it effectively reduces somatic (body) arousal any more than simple resting. Learning the actual physiological effects of meditation is important, since it is used both personally and professionally.

How does the physiology of the meditating human compare with that of the other two naturally modified states, hypnosis and sleep? (See the Table.) Generally speaking, the body functions of people under hypnosis measure the same as if the subjects were actually performing the suggested action or thought while they were awake. There is little physiological similarity among the three states.

Again, as was true of biofeedback, meditation is of much interest to modern-day psychologists. Meditation seems to allow a person to be aware of stressful situations, yet to control their damaging impact on the body. It also increases the apparent ability of people to "tune-out" non relevant perceptions. Meditation is controversial, however, because during the 1980’s some psychologists began to dispute earlier findings. It was suggested that it was possible to replicate the findings related to meditation in the table mentioned earlier simply by asking people to relax -- not sleep, but relax -- in a quiet environment for 30 minutes or more. Now, some argue meditation is simply the result of relaxation, others view it as a more complex, elevated state of focused concentration. Either way relaxation is a natural change in behavior we may show. Others include sleep, responses to biofeedback, and hypnosis.

Hypnosis

In recent years perhaps the most controversial natural change in behavior has been hypnosis. It is a natural means of altering the normal state of consciousness. Is there a separate, identifiable hypnotic state? Can people who are hypnotized be made to do things against their will or against the law? Are superhuman feats possible when hypnotized? Can people actually be made to forget that certain things have happened? Can they be made to do things after they have been hypnotized -- things of which they are not even aware? Such questions have formed the basis for many studies of hypnosis. These studies, especially when considered along with recent studies of meditation, are beginning to give some answers.

Experiments have shown, for instance, that hypnosis works equally well with men or women and that even a five-year-old can be hypnotized. They have also confirmed that people vary widely in the ease with which they can be put under. People with unusually high powers of concentration are easiest to hypnotize. They are able to focus their attention on a book, their own thoughts, or even the demands of a hypnotist, and ignore other stimuli.

Some psychologists doubt that the hypnotic state really exists. They explain it as resulting from the "suggestibility" of some people. Others don't question the existence of hypnosis, but are investigating differences in personal attributes, such as the ability to attend to only a limited number of stimuli. Still other attempts to explain it have focused on differences in the social environment. The physiological evidence as presented in the Table, argues against the existence of a special hypnotic state. Obviously, more research is required.

Superhuman feats cannot be performed either during or following hypnosis. Feats performed while hypnotized turn out, upon careful analysis, to be well within human capabilities. This is especially true if people are willing to swallow their pride and momentarily "let themselves go."

It is clear that people can behave following hypnosis as though they have actually forgotten a fact, or cannot hear a certain word or see a certain action. This is called post-hypnotic suggestion. Even the label itself suggests an explanation for the event. The participant must be a cooperative person, willing to follow the hypnotist's instructions. However, more work is needed here, too, before we can understand what really happens and why.

Will people who have been hypnotized do things against their own will or against the law? The evidence is mixed. In the main it seems to show that no, they won't. But, an action may be presented as being required by events of which the hypnotized person has not previously been aware. Then it is possible to get people to perform actions which they would not otherwise have performed.

This last point makes the next one particularly important. Can people be hypnotized against their will? The answer is no. Being very open to suggestions and having a strong "capacity for total attention" are important traits in the participant to be hypnotized. However, without his or her active cooperation no such hypnosis is possible. A person must work actively to place conscious processes under the hypnotist's control. Dentists have removed molars under hypnosis with no additional pain-killer; doctors have removed spleens. Hypnosis is a natural change in behavior some -- but not all -- can achieve. Other such changes include sleep, responses to biofeedback, and meditation.

Artificial Changes in Behavior

Changes in our basic physiological processes caused by our nervous system fall into two broad categories. Natural changes in behavior involve nothing other than conscious control being exercised over voluntary and involuntary behavior. In that sense sleep, biofeedback, meditation, and hypnosis are natural methods for altering basic body processes. But the nervous system can also be influenced by artificial means. Once these artificial techniques have been applied, the nervous system typically cannot control their effects. Various types of drugs that influence our behavior include depressants and stimulants as well as hallucinogens.

The power of drugs to influence the body is easy to demonstrate. The most basic function of the nervous system is the electrochemical process called neuronal firing. Put simply, one of the most direct ways to influence the body -- everything from vision to nerve conductivity -- is to introduce chemicals which hinder or help the nervous system. Therein lies the importance of drugs.

A stimulant is any drug that increases activity in the nervous system or in any function of the body. In contrast, a depressant is any drug that reduces activity in the nervous system or slows down some body function. The effects of some drugs are difficult to classify by observation. For example, alcohol seems to stimulate, although it is actually a depressant.

Hallucinogenic drugs often produce changes in the normal senses (hallucination), sometimes without altering the person's awareness (or consciousness) of those changes. There is much disagreement as to how these drugs actually function. There is some evidence that they are stimulants. Yet, some of the effects clearly result from depression of normal body processes. The hallucinogens are not just stimulants or just depressants -- they produce some of both effects in a series of physiological reactions not yet fully understood.

The nervous system that controls us is very complex. If control of a function is located at a particular point in the central nervous system, then stimulant or depressant drugs that act at that point will affect that function. The Figure summarizes the broad range of behavioral effects that may result from various dosages of stimulants, depressants, or hallucinogens. We all use drugs in one form or another. What are the effects of depressants and stimulants? What are the effects of hallucinogens? Among the many processes impacted by drugs are our abilities to exhibit normal sensation and perception.

USING PSYCHOLOGY: The effects of depressants and stimulants

Artificial changes in behavior are often sought either through the use of depressants and stimulants or through the use of hallucinogens. One of the most widely used depressants, and perhaps the most widely abused, is alcohol. Beer contains the least alcohol, wine has a higher concentration, and distilled liquors have the highest concentration of all. A person must typically drink up to 10 times the volume of beer to equal the effects of one drink of distilled liquor. However, all alcoholic beverages eventually produce the same results in the human body. It is well known that it is the percentage of alcohol in the blood that counts.

What are these results? The main effect of alcoholic beverages on the human body is registered on the brain. As the percentage of alcohol in the blood rises, the highest levels of the brain -- the cortical areas -- become depressed. Higher mental processes -- thinking, feeling, problem solving -- are first to be lost. As more alcohol is consumed, lower areas in the midbrain become affected. Soon a person is increasingly unable to talk and reason clearly.

The person feels relaxed and acts with fewer restraints, but this occurs because the cortex is increasingly depressed by the alcohol. When you lessen the activity of the cortex, you remove controls. With no inhibitions the person may seem more free and active. However, as lower brain centers are affected, even the sense of balance is in time lost. Inability to "walk a straight line" is a traditional (although unscientific) way by which drunkenness is defined.

More extreme depressants include all of the narcotics. These drugs (ranging from opium and morphine to codeine) affect the central nervous system. They depress the functions of the sensory cortex and the thalamus and thus provide a false sense of well-being and relief from anxiety and pain. However, in a short time, as the effects spread, the person may become increasingly drowsy and finally fall asleep. Too large a dose may depress the automatic activities normally controlled by the brain stem, and death can result from respiratory failure.

Stimulants vary greatly in their effects. One group of stimulants -- the amphetamines -- cause the heartbeat to increase, the pupils of the eyes to dilate, and the organism in general to feel flushed, active, alert and "high."

At the same time the digestive processes are slowed down, so that the body is more active but eating less (thus the use, or misuse, of amphetamines in losing weight). When the person stops taking the amphetamines, the digestive system rebounds and the result is nausea and vomiting. With too large a dosage, the person may hover between sleep and unconsciousness as the body attempts to restore its chemical balance. Artificial changes in behavior can also be achieved through the use of hallucinogens. A related question concerns the effects of hallucinogenics? Among the many processes impacted by both stimulants and depressants are our abilities to achieve normal sensation and perception.

USING PSYCHOLOGY: The effects of hallucinogens

Artificial changes in behavior may be created through using stimulants or depressants or such changes are sometimes sought through the use of hallucinogens. The hallucinogenic drugs are very difficult to classify as depressant or activating. They may be a little of both.

In small dosages there is little doubt that the hallucinogens produce mild stimulation of the central nervous system. Generally, a person under the influence of one of these drugs is more excitable and alert. This may result from stimulation of the lower brain centers or depression of some of the higher inhibitory centers. However, despite the increased activity, the person is less able to receive and interpret sensory stimuli.

This combination of increased activity and decreased sensitivity to external stimulation lends increased importance to prior thoughts and experiences stored in memory. The person may indulge in flights of fancy -- immune to outside stimulation and more or less totally at the will of internal thoughts.

One of the most widely recognized drugs this group is marijuana. It is the most widely used. Because of the isolation from external stimuli experienced by marijuana users, the mood or environment in which they originally take marijuana may affect how they will experience it.

At the other extreme is LSD. This drug is extremely powerful -- so powerful, in fact, that controlling the effects of the drug is very difficult. Varying even slightly the amount consumed will lead to wide differences in the results. The many changes in behavior resulting from LSD occur because there are many sites that are affected by it. It causes the pupils to dilate and the heartbeat to increase, and it affects the synapses (junctions between neurons) in the central nervous system. The sensory cortex is stimulated but restraints are lost. Information from the senses gains in importance. The mechanisms that normally handle sensory input and processing are so activated that synesthetic experiences ("hearing" a color, "feeling" a sound, and so forth) are commonly reported.

It was at one time thought that LSD might be used to create various personality abnormalities to aid the study of how to prevent or cure them. The drug does produce response patterns very similar to some aspects of abnormal human behavior. Many hospitals have admitted drug users whose symptoms resemble psychotic behavior. However, the research with abnormalities temporarily created by LSD and related drugs has been very disappointing so far. No insight into illness or clear-cut results have been obtained.

So at this point we can simply note that drug usage can and usually does have profound effects on the body, many of which are unpredictable and possibly dangerous. Any altering of the function of the nervous system by drugs will produce detectable or even dramatic changes in behavior. The effects of drug use depend mainly on the type of drug involved and the primary site of action of that drug within the nervous system. One of the most obvious processes impacted by hallucinogins is our ability to achieve normal sensation and perception.

REVIEW QUESTIONS

The Nervous System

1. What is the most basic part of the nervous system? What two characteristics does the part have?
2. How does the nervous system transmit information?
3. What methods do psychologists use to study the nervous system?
4. Name three types of nerves and their functions.
5. What are the major divisions of the nervous system?
6. Name the parts of the brain and what they do.
7. What are the differences between the right and left hemispheres of the brain?

Glands

1. In addition to the nervous system, what system controls human behavior?
2. What is the role of the hypothalamus?

Natural Changes in Behavior: Sleep

1. What is the relationship between brain activity and sleep?
2. Describe REM sleep and its possible functions.

Natural and Artificial Changes in Behavior

1. What are some natural means of altering the operations of the nervous system? What are some artificial means?

Artificial Changes in Behavior

1. What are the effects on behavior of the three classes of drugs?

ACTIVITIES for Physiology

1. Reflexes are among the simplest "built-in" response patterns on which humans rely. Less sophisticated animals (such as your family ‘s pet dog or cat) also rely on reflexes. You may have noticed an unusual one in dogs. If a dog is lying on its side, you can rub its flank -- the depression on the side just front of the rear leg. And what happens? The dog will start moving its rear leg reflexively, as if it were scratching itself. How many of your own reflexes can you name and demonstrate?

2. In Chapters covering developmental physiological processes we talk about heredity and environment as factors influencing performance. Consider the following: Are there physiological limits as to how high humans can jump or how fast they can run? Are there any psychological limits? You might contact a faculty member in your physical education department or discuss with an athlete how diet, exercise, and training can influence an athlete's performance.

3. It is very important in this activity that you not read the last part until you have completed the first part. Find an object that is some distance from you -- five meters (16 feet) or more. Focus on it, keeping both eyes open. Line up your index finger so that it seems to be between you and the distant object at which you are looking. Holding your finger steady, and continuing to focus on the distant object, close one eye and then the other. Now stop and try the demonstration before reading any further.

What did you find? For one eye the finger will block your view of the distant object; for the other your finger will appear to be to one side of the object you're viewing. If you are right-handed, then you were probably unconsciously using your right eye to line up your finger with the distant object. In short, you tend to be right- or left-eyed in the same way you are right- or left-handed. Was this true for you? Try this with fellow students. For how many is their dominant eye on the same side as their preferred hand? What is demonstrated here is lateral (hemispheric) dominance.

4. Aphasia is any physiologically-based brain damage that causes difficulties with language. If you are interested in a very complex illness that reveals many interesting facets of how the brain processes language, consider learning more about aphasia or observing aphasics. A local hospital or a Veterans Administration hospital would be a good starting point for your search. What are the differences between aphasias related to the reception of speech (hearing), the production of speech (speaking), the reception of words (reading), and the production of words (writing)?

5. We now know that we tend to move our eyes when we dream. If you can find a parent, brother, sister or roommate who will cooperate, encourage this person to take a nap for a least 90 minutes. Watch his or her eyes and -- with prior agreement, of course -- awaken him or her when you see evidence of eye movement. Ask if the person was dreaming; the odds are high that he or she will have been. You could volunteer to take the nap yourself, or ask a cooperating person not to awaken you tomorrow morning until they see your eyeballs moving underneath your eyelids. Alternatively, if you always awake to an alarm clock at the same time each day, set your alarm clock 10 minutes earlier one morning, and you may well catch yourself dreaming.

INTERESTED IN MORE on PHYSIOLOGY?

BENSON, H. & KLIPPER, M. (1976). *The Relaxation Response*. New York, NY: Avon. A description of a simple method of relaxation and meditation. Easy reading; accurate guidance for control of anxiety.

CARLTON, P. L. (1983). *A Primer of Behavioral Pharmacology: Concepts and Principles in the Behavioral Analysis of Drug Action*. San Francisco, CA: W. H. Freeman. This is

tough reading but important material. Emphasizes problems and methods of analyzing behavior as it is influenced by drugs.

HEBB, D. O. (1972). *Textbook of Psychology, 3rd ed.* Philadelphia, PA: Saunders. Written by a Canadian who is a past president of the American Psychological Association, this book is designed to be an introductory psychology text. It is a classic in its field, and it simplifies many explanations of perceptual, learned, and emotional experiences in basic physiology. Excellent reading.

HILGARD, E. R. (1977). *Divided Consciousness: Multiple Controls in Human Thought and Action*. New York, NY: John Wiley& Sons. Analyzes a wide range of research on forgetting, dreaming, and hallucinations, as well as on people who suffer multiple personalities. Includes a lengthy discussion of hypnosis and what is meant by "consciousness."

JONES, K. L., SHAINBERG, L. W., & BYER, C 0. (1973). *Drugs and Alcohol, 2nd ed*. New York, NY: Harper & Row. A readable discussion of the effects (and sources) of a wide variety of drugs and alcohol. It includes a comparison of the physiological reactions and behavioral effects of many "popular" drugs.

LAURIE, P. (1971). *Drugs: Medical, Psychological and Social Facts, 2nd ed*. New York, NY: Penguin. The title tells it all.

NARANJO, C. & ORENSTEIN, R. E. (1971). . New York, NY: Viking. Includes an excellent review and description of various types of meditation.

NETTER F. H. (1958). *The Ciba Collection of Medical Illustrations. Vol. I., Nervous System*. Ciba Pharmaceutical Co. Detailed, large illustrations of the form and distribution of the nervous system. Beautiful drawings.

RAY, O. S. (1972). *Drugs, Society and Human Behavior, 2nd ed*. St. Louis, MO: C. V. Mosby. Broad coverage of drug use, the basic actions of drugs, and even substances not usually thought of as drugs (such as coffee).

R0SE, S. (1976). *The Conscious Brain*. Vintage Books. This unusual book analyzes physiology as it relates to behavior rather than the other way around. Memory, sleep, and emotion are among the topics covered.

SHAPIRO, D. (1980). *Meditation*. Chicago, IL: Aldine. Discusses studies of the influence of meditation on subjective and cognitive responses as opposed to the somatic arousal responses discussed in this chapter.

SPRINGER, S. P. & DEUTSCH, G. (1981). *Left Brain, Right Brain*. W. H. Freeman. Looks at a wide array of issues related to split brain; also answers implications of the burning question, "What paw does your dog shake hands with?"

TEYLER, T. J. (1975). *A Primer of Psychobiology: Brain and Behavior*. San Francisco, CA: W. H. Freeman. Free of technical terminology, this brief, readable introduction to structure and function of the brain and nervous system emphasizes behaviors such as learning, language, and consciousness.

WOOLRIDGE, D. E. (1963). *The Machinery of the Brain*. New York, NY: McGraw-Hill Book Company. A highly readable book intended for the average lay person interested in the human brain. Describes the major brain areas and their functions.