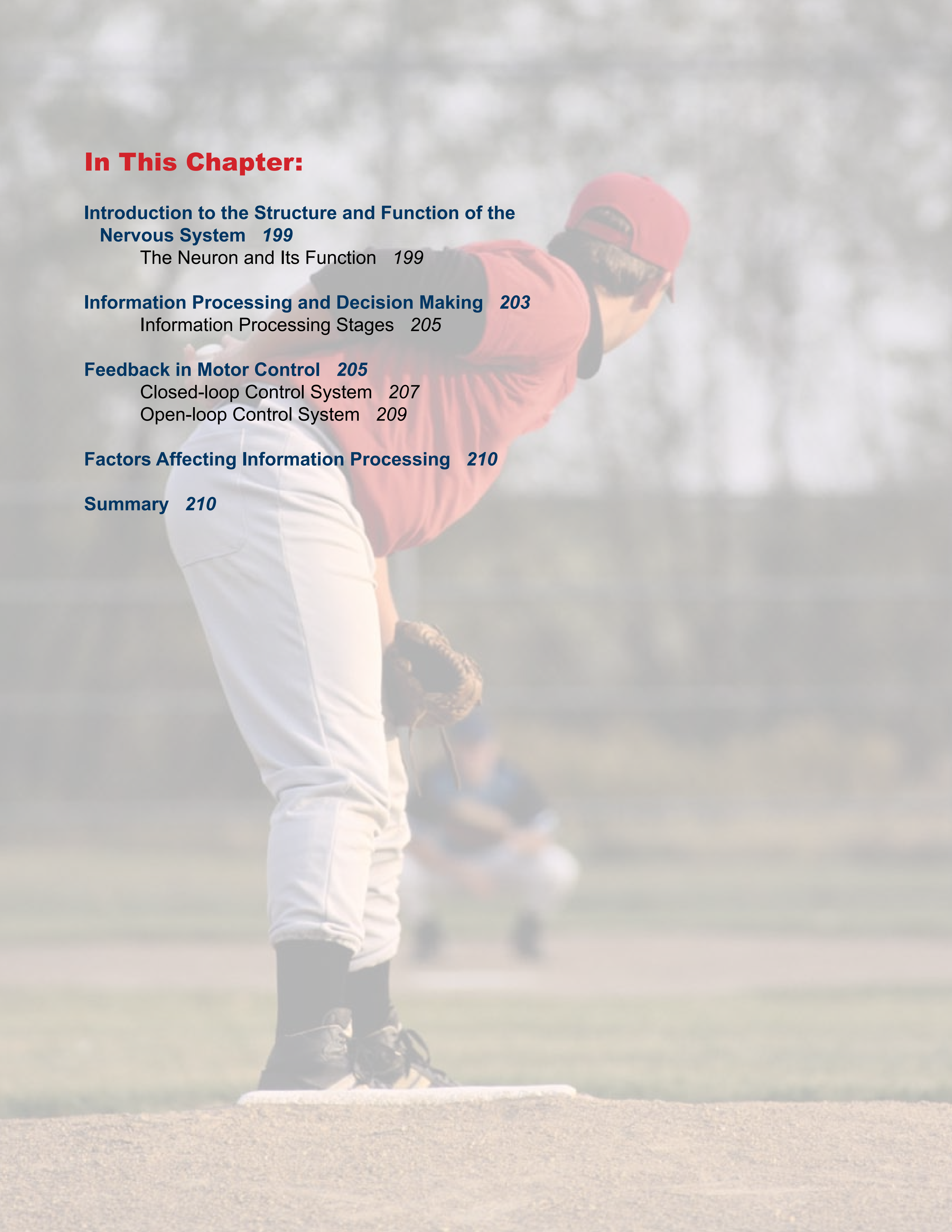
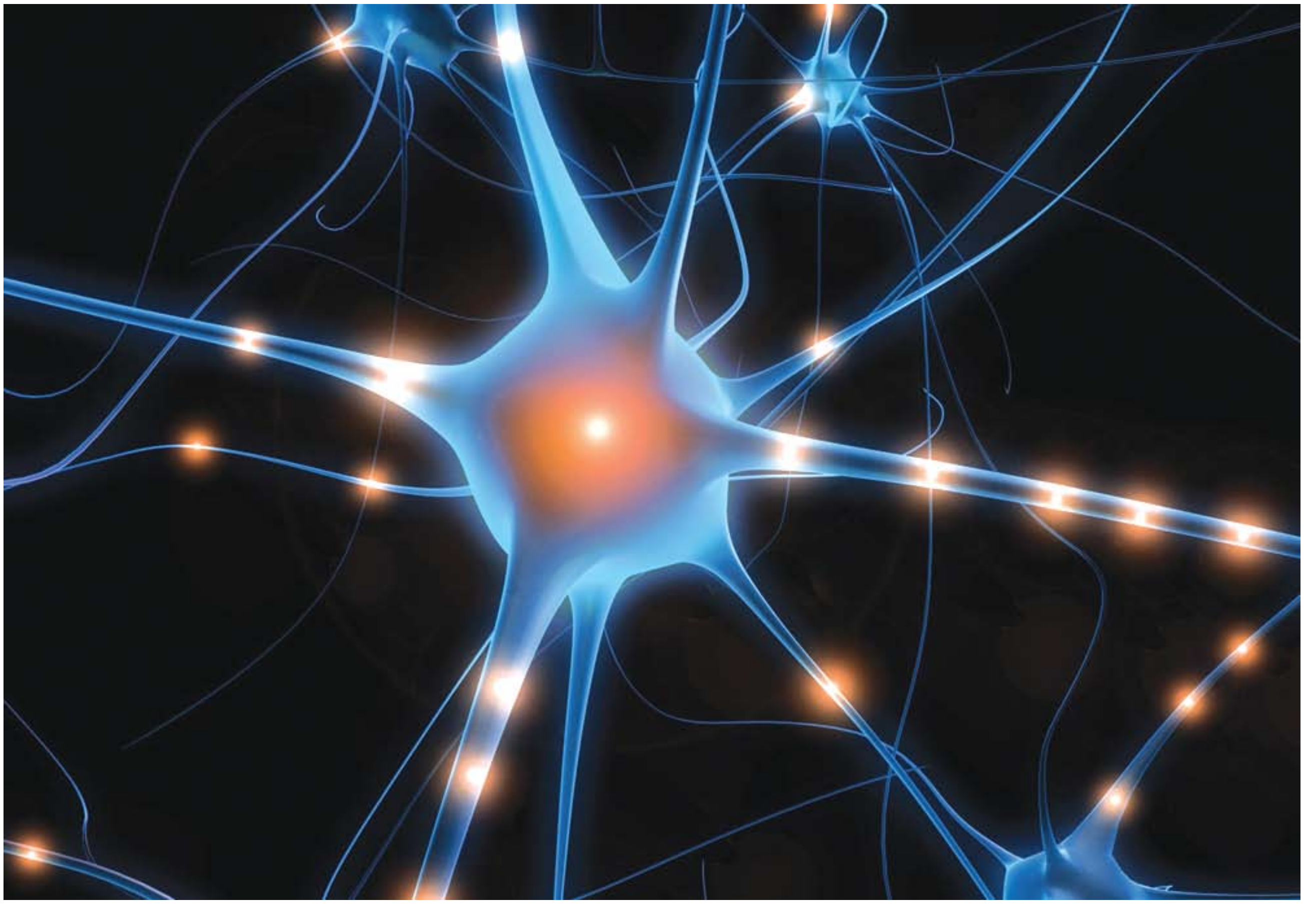


# In This Chapter:

# CHAPTER 9



# Information Processing in Human Movement

## After completing this chapter you should be able to:

- describe the structure and function of the human nervous system as it relates to information processing;
- explain the ways humans perceive and process information;
- demonstrate an understanding of the role of feedback in motor control;
- explain the advantages and disadvantages of closed- and open-loop control systems in motor control.

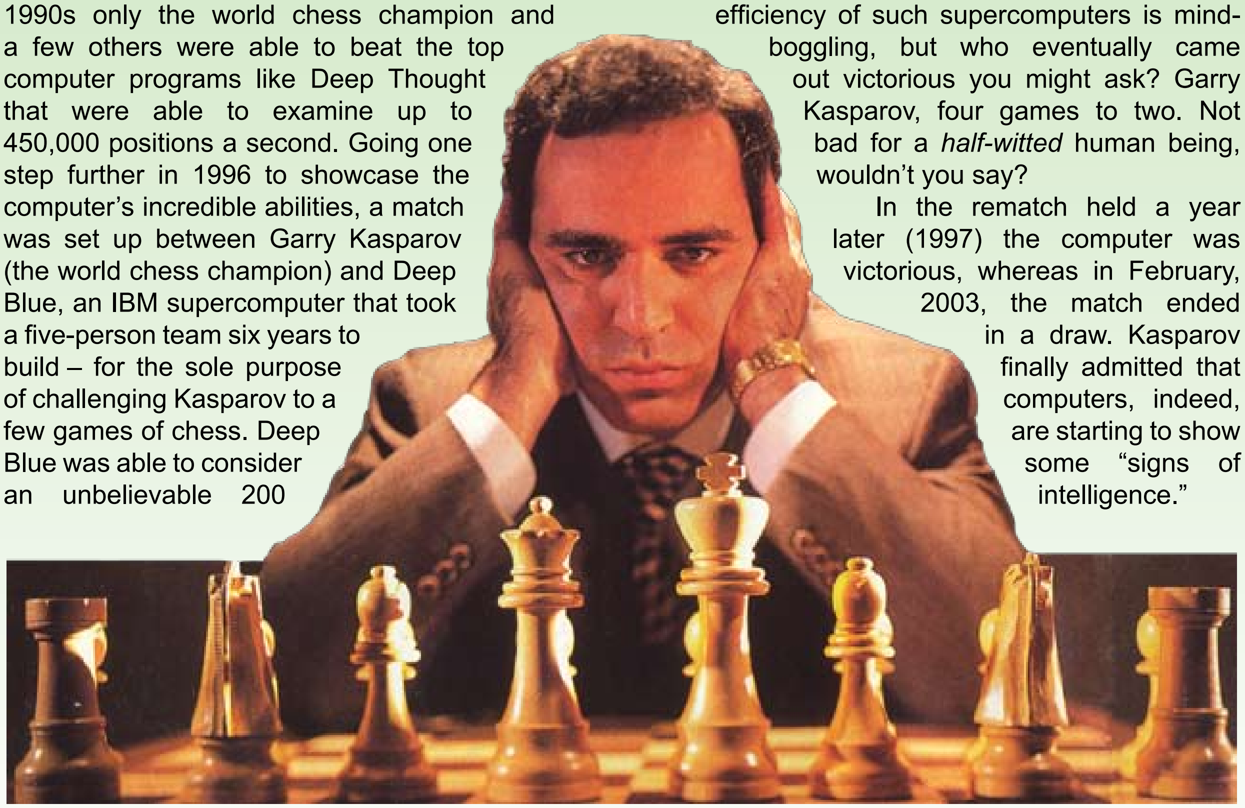
When we view the ease with which people move and execute most skills, it is difficult to appreciate the true complexities of human movement. At a glance, human actions appear simple and perhaps even trivial, but the intricate network and processes underlying motor skills are nothing short of extraordinary. The brain and spinal cord, comprising the **central nervous system (CNS)**, are accepted as the control center for our powerful and far-reaching abilities, whereas the nerve cells and fibers that lie outside the CNS, the **peripheral nervous system (PNS)**, connect the CNS with the rest of the body. The organization and vast capacity of the two systems are often oversimplified to the point that we rarely question how we are able to accomplish a range of movements with the precision we do. We are able to perform not only relatively simple skills such as walking and jumping without much thought but also more complex skills such as those involved in gymnastics and advanced dance steps. Whatever the activity, the colossal network of neurons sending messages to one another from one part of the body to another is responsible in no small part for our ability to sense, respond, and react to the world around us (Figure 9.1).

In today's world of advanced technology, many people marvel at the considerable capabilities of the modern-day computers. Indeed, they are improving so quickly that they often become obsolete within years or even months of their creation. The human brain has often been compared to a computer, with its immense capacity, striking speed, and pinpoint precision. Yet, many consider the computer to be superior in many respects to the human nervous system.

### It's a Draw!

Computers have demonstrated extraordinary success in playing chess. In fact, by the early 1990s only the world chess champion and a few others were able to beat the top computer programs like Deep Thought that were able to examine up to 450,000 positions a second. Going one step further in 1996 to showcase the computer's incredible abilities, a match was set up between Garry Kasparov (the world chess champion) and Deep Blue, an IBM supercomputer that took a five-person team six years to build – for the sole purpose of challenging Kasparov to a few games of chess. Deep Blue was able to consider an unbelievable 200 million moves in one second, more than any of its predecessors. The processing speed and efficiency of such supercomputers is mind-boggling, but who eventually came out victorious you might ask? Garry Kasparov, four games to two. Not bad for a *half-witted* human being, wouldn't you say?

In the rematch held a year later (1997) the computer was victorious, whereas in February, 2003, the match ended in a draw. Kasparov finally admitted that computers, indeed, are starting to show some "signs of intelligence."



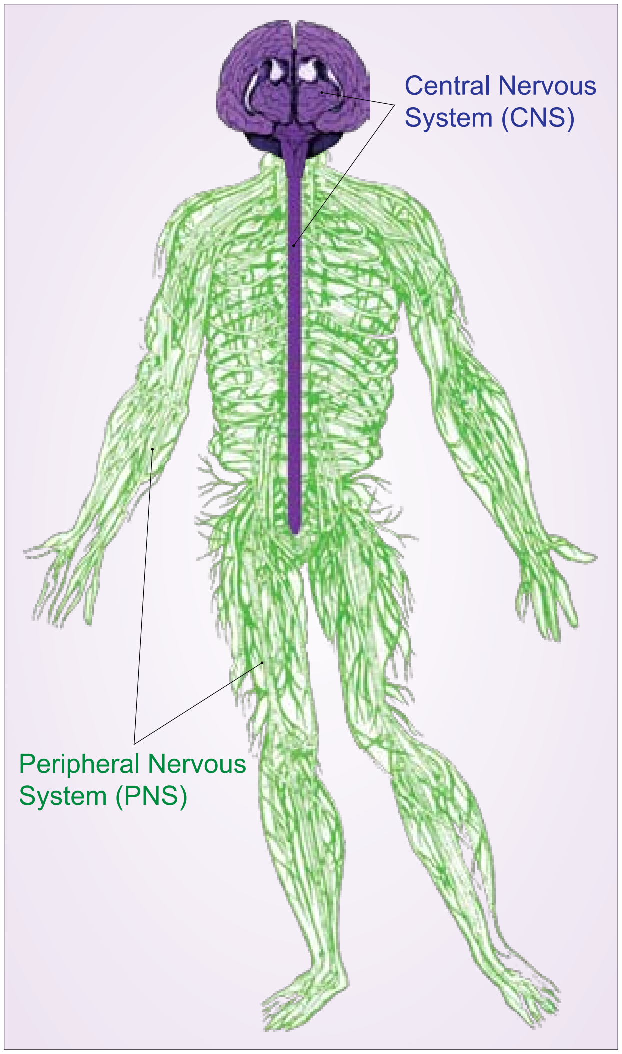



**Figure 9.1** The central and peripheral nervous systems.

While it is true that modern computers are capable of carrying out logical tasks (such as solving equations in higher mathematics) in a fraction of the time it would take most individuals to do so, we must not forget that it was the brilliance of the human mind that allowed for the creation of this splendid technology. The fact that any individual is able to claim victory against a machine with such speed and capacity only solidifies the astonishing competency of the human brain itself (see box *It's a Draw!*). So the next time you find yourself driving along the information superhighway, remind yourself how it came to be.

The human body and its nervous system have many parts that cohesively work together to maintain control by sending messages to one another. What are the mechanisms that keep these messages flowing? How do humans process information? What effects do attention and memory have on human processing and performance? The answers to these and other questions to follow should shed light on the marvel of the human body, its capabilities, and its numerous abilities to perform an almost limitless number of motor skills.

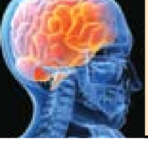
## Introduction to the Structure and Function of the Nervous System

How is it that a champion chess master is able to plan several moves ahead, or that a tennis player can plan many shots in advance during a point? What processes underlie an individual's ability to perceive, respond to, and execute certain movements and actions? The answer lies in the human brain. But nervous activity is not solely achieved by the brain; rather, in conjunction with the spinal cord and nerves, a complex system is set up whereby vast interconnecting pathways integrate and control the actions of the entire body from head to toe. How the nervous system accomplishes such a remarkable feat is the subject of the brief overview that follows.

### The Neuron and Its Function

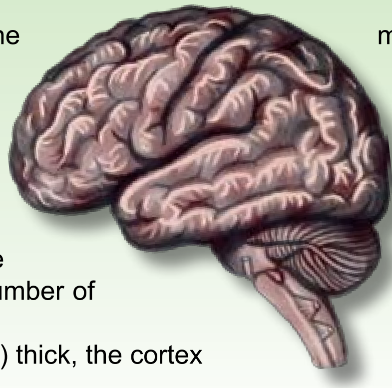
#### *Types of Neurons*

**Neurons** (nerve cells) are the fundamental functional and structural units of the nervous system that allow information to travel throughout the body to various destinations. There are three general categories of neurons that carry neural information between the brain, spinal cord, and muscles. **Afferent neurons** carry signals *to* the brain or spinal cord and are also referred to as **sensory neurons**. **Efferent neurons**, or **motor neurons**, carry signals *from* the brain or spinal





### A Giant on Maximum and Minimum Scales



The external appearance of the human brain conceals its true complexity. Approximately 15 billion neurons are concentrated within the 85 cubic inches of the brain, the largest number located in the cortex numbering 10 billion (a value over two and a half times the number of inhabitants on the globe).

At only 1/8 of an inch (3 mm) thick, the cortex may seem insignificant in size, but if all of its numerous folds and clefts were spread out, it would approximate the dimensions of a newspaper page bustling with neurons. Another staggering fact is that all the nerve fibers link to form a network four times greater than the distance between the earth and the moon. Now that's maximum use of space!

cord (Figure 9.2). A third category of neurons, the **interneurons**, originate or terminate in the brain or spinal cord.

Every neuron is composed of many parts, each of which serves a particular purpose. The **dendrites** extend from the **cell body** (which houses the cell nucleus) as branch-like fibers and serve as the centers for stimuli by receiving messages. The **axon** exists as a single extension from the cell body and functions to transmit and carry messages to its **terminal endings**, numbering in the thousands, along to the dendrites of other neurons (Figure 9.3).

Some axons also have a fatty covering that wraps around the axon, called a **myelin sheath**, that is separated by gaps called **nodes of Ranvier**. This specialized structure of some neurons, such as the motor neurons that innervate muscle fibers, offers an advantage because neural messages travel much faster as the impulse skips from one node to the next (Figure 9.3). Myelin acts as an insulator, similar to the rubber that surrounds electrical wire to prevent leakage of current. This rapid and efficient system allows the body to react quickly whenever and wherever required. Whether you are trying to avoid a hit in football, reacting to a spike in volleyball, or contemplating your next move during a basketball game, the central mechanisms involving neurons are essentially the same.

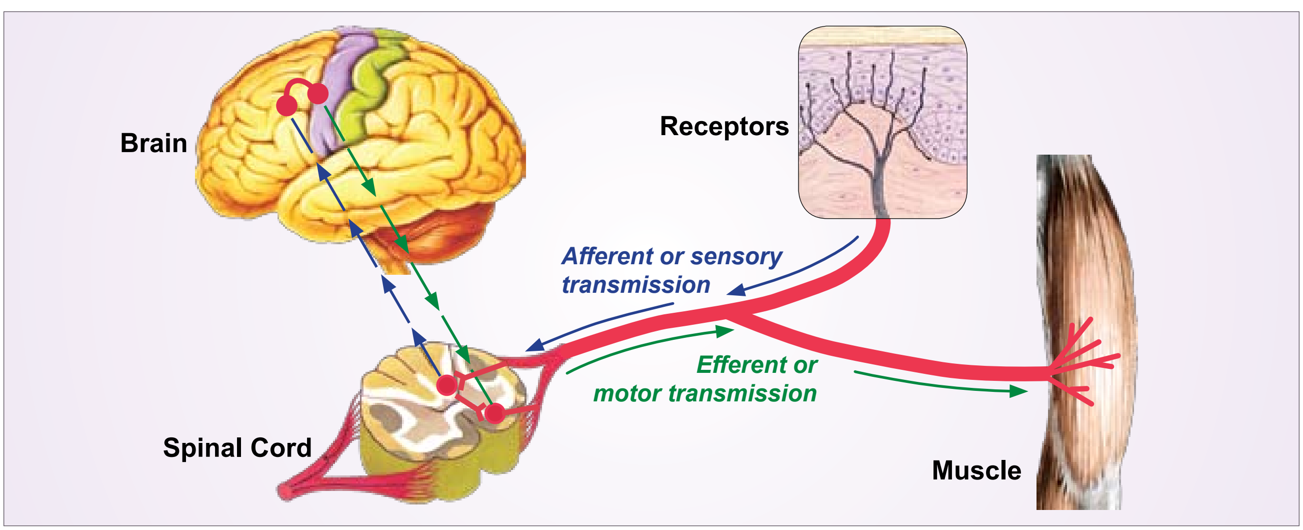



**Figure 9.2** The receptors guide the stimulus across a sensory pathway (afferent) network to a specific sensory region of the cortex. Decisions are sent via a motor pathway (efferent) network to muscles and joints for execution.

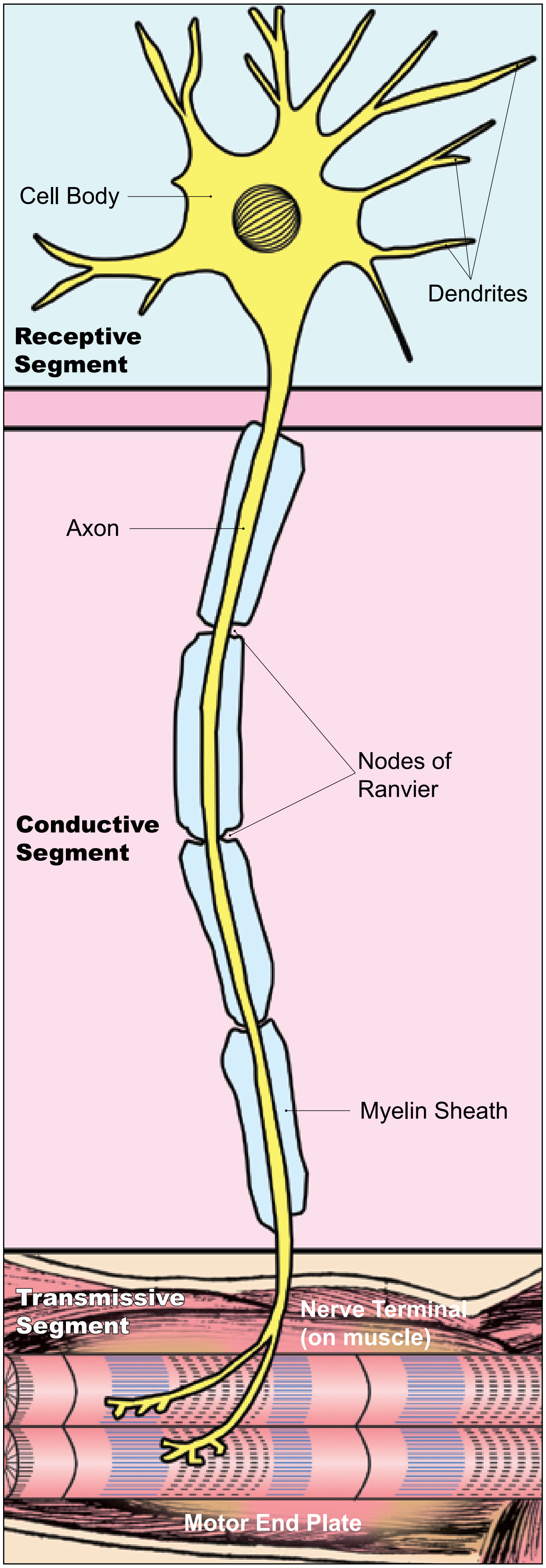



**Figure 9.3** Functional organization of a typical neuron.

## *The Neuron's Function*

Most neurons contain three functional regions (i.e., **receptive**, **conductive**, and **transmissive segments**), each responsible for a very specific information processing task (Figure 9.3).

**Receptive Segment** This segment receives a continuous bombardment of synaptic input from numerous other neurons on the receptor site. These inputs are processed and sent further to the conductive region of the neuron, the axon.

**Conductive Segment** The axon serves as the conductive segment of the neuron. It is specialized for the conduction of neural information in the form of nerve impulses.

**Transmissive Segment** The axon terminals convert the stimulation of the nerve impulse to release chemical neurotransmitters at its synapses. These chemicals give rise to effective reception of information by another neuron or muscle cell.

## *Neural Impulses*

Our nervous systems can be likened to a railway complex and our brains to a signal tower, although along our sensory pathways, traffic is the law. Neural impulses may be thought of as trains that transport the information necessary for all the activities and actions we carry out, including reading the words in this sentence. They are the language of the nervous system, continually relaying information to the appropriate sensory cells and musculature. But how do these messages find their way along the axons, one neuron to another, without being derailed?

The secret lies with the distribution of ions (charged particles, e.g., sodium and potassium) that are located on both sides of each neuron's cell membrane. The inside of the neuron tends to be negative relative to the outside, while the outside tends to be positive relative to the inside – this

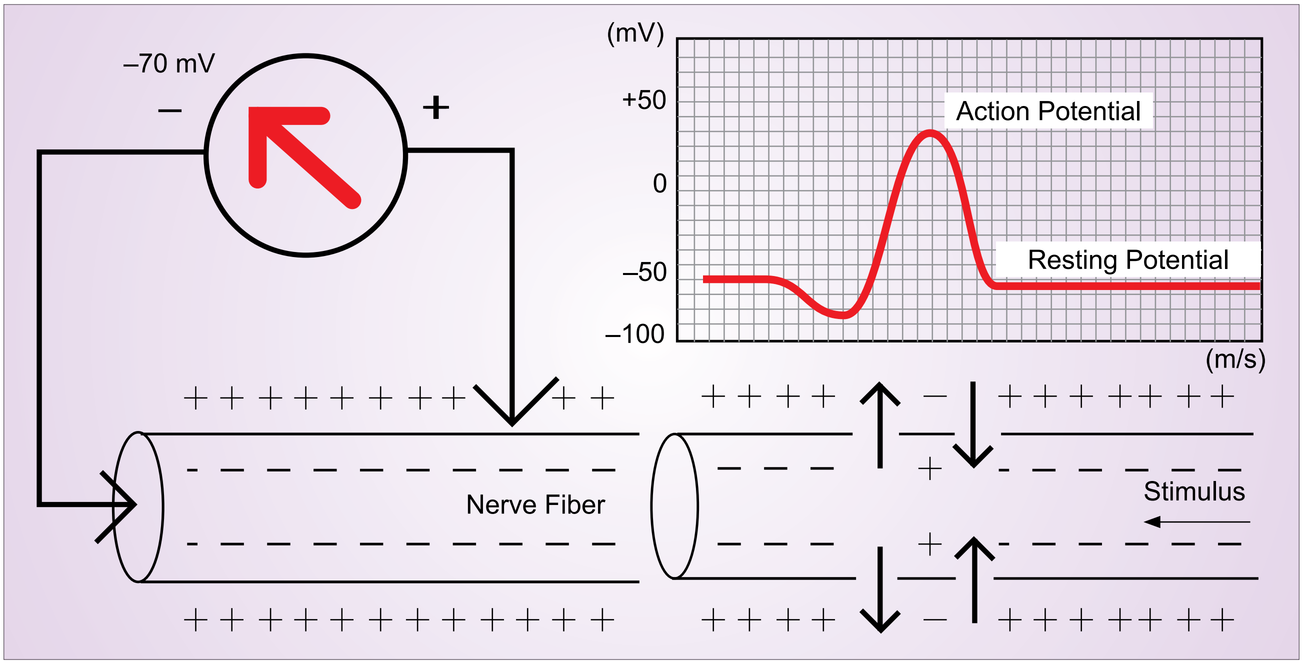



**Figure 9.4** Action potential of a neuron.

creates an imbalance of charges, or an electrical potential difference across the cell membrane called a **membrane potential**. This idea may be compared to a battery that has a positive terminal (outside cell) and negative terminal (inside cell).

The situation just described reflects the neuron's resting potential, or state of **polarization** at approximately –70 millivolts (mV). When a stimulus reaches the nerve fiber, positive ions rush into a particular region of the membrane and are then quickly pumped back out to return the neuron to its resting state. This is called an **action potential**, or state of **depolarization**, which reaches its peak at about 40 mV. In a domino effect, the same process is repeated in adjacent areas of the neural membrane until the action potential reaches the end of the cell membrane (Figure 9.4).

## *The Synapse and Synaptic Transmission*

Each axon branches into terminals and at its end forms a junction with another neuron called a **synapse**. Synapses are small – a few billion could fit into a thimble – but their small size says nothing about the very important role they play. Movement of a neural impulse across this junction is called **synaptic transmission**. Although several steps in synaptic transmission have been identified, much about the precise mechanics behind it remains shrouded in mystery.

**"All-or-none" Law** A synaptic transmission will cause an action potential in the postsynaptic cell as long as its strength is above a minimum threshold level. This characteristic is called the **"all-or-none" law**, and the intensity of the action potential remains constant along the nerve fiber's length. It follows that a stronger stimulus will not give rise to a stronger action potential.

It is useful to explain this phenomenon by making a comparison to the firing of a gun. In order for the gun to be fired successfully, there is a minimum degree to which the trigger must be pulled. Further, when the trigger is pulled past that critical point and the gun fires, it will fire at full force regardless of the force applied to the trigger.

In similar fashion, a neuron will either fire an action potential at full force or it will not fire at all. But while a stronger stimulus will not elicit a stronger action potential, it will cause it to fire at a faster rate. Thus, the rate at which neurons fire provides an indication of the strength of a stimulus.

For example, intense stimuli, those that might result from rapid, powerful movements in the muscles (e.g., golf swing, soccer ball kick, or football throw) or deep bending and stretching in the joints, trigger numerous simultaneous impulses; weaker stimuli, such as those during slow stretching movements, trigger fewer.

The firing rate of action potentials has a limit, just as a gun cannot be fired a second time until the first shot is complete. In other words, an **absolute refractory period** exists (about a millisecond) – a period in which a second action potential is not possible. After this period, neurons enter what is called a **relative refractory period** of several milliseconds, during which a neuron can be fired only by a very strong synaptic transmission (i.e., an elevated threshold level). Although this slight limit exists, rates remain amazingly fast, allowing a batter, for example, to swing at a pitch that seemed to be going outside but instead curved back over the plate.

All synaptic transmissions are not of the same strength, nor do they exert the same effects. In fact, they differ in terms of the chemical transmitter located at the synapse as well as the general function they serve at that synapse. Some transmitters, such as **acetylcholine (ACh)**, have a strong excitatory effect (usually to muscles) and result in a fast response. Others, however, respond more slowly, while still others exert an inhibitory effect. Depending on the particular location and intended function, a variety of transmitters exist, serving to keep the system under precise control.

The preceding discussion has only touched the surface of the complex network that forms the nervous system. If anything, this brief overview was intended to open your eyes to the involved processes that control our every move and guide our perceptions. Without them, you would not be able to turn the pages in this book or even read the words before you.

## Information Processing and Decision Making

The goalie starts out of his net, preparing for the oncoming breakaway. As the player draws nearer, the goalie slowly backs in toward the net, following his adversary's every move. The goalie knows that the charging player likes to go to his backhand shot, so he prepares to react to such a move. Indeed, the offensive forward begins the motions of a backhand, but stops halfway, pulls the puck back, and rifles a wrist shot that finds the corner of the net. What was going through the goalie's mind? How did he process the information used to make the decision to move the way he did? Similarly, how does the batter contend with pitches of varying speeds and spins? And what goes through the mind of the tennis player awaiting a powerful serve by her opponent? The ability to sense and respond quickly and with accuracy to such dynamic information in the environment is a crucial component of successful performances.

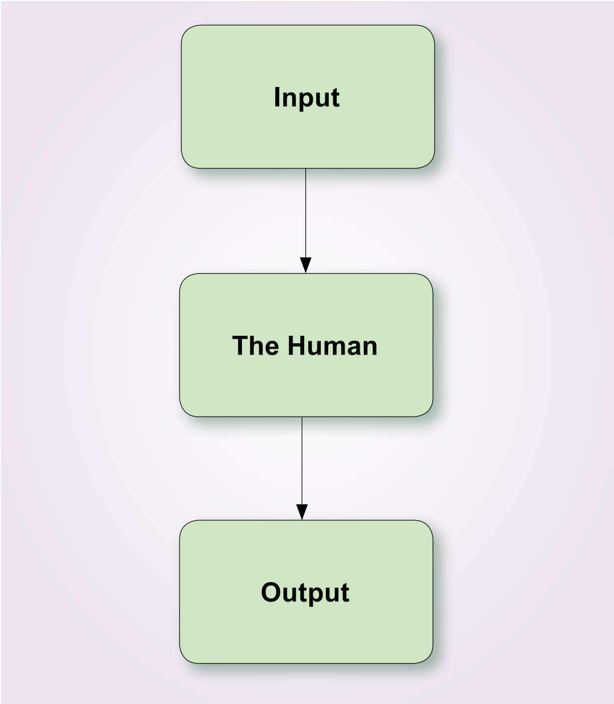



**Figure 9.5** The simplest information processing model.