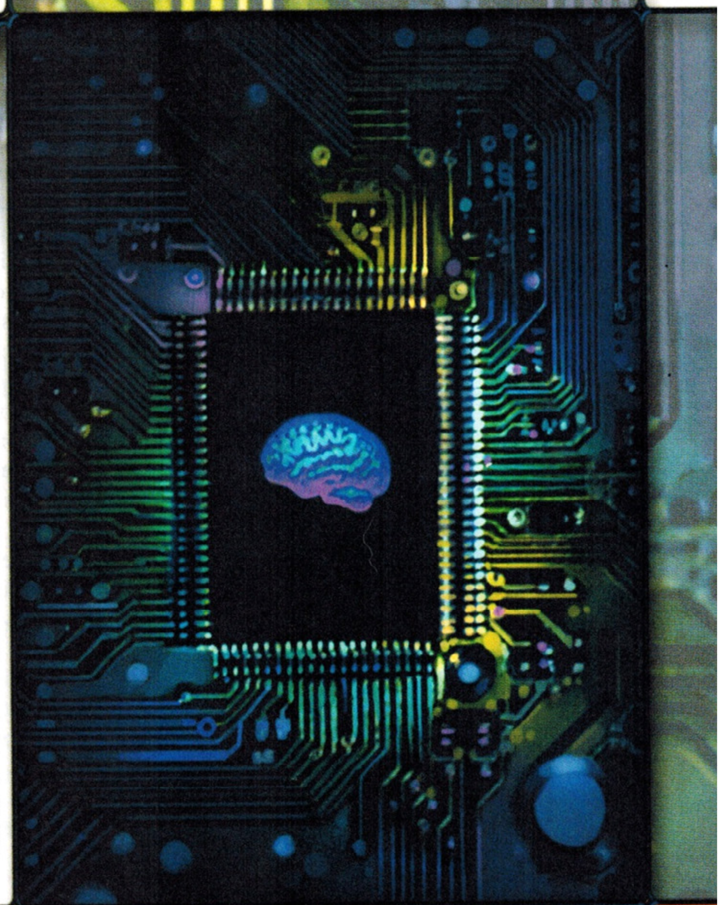
The Nervous System

Control Part I



Facets

23A—The Structure of the Nervous System

One of the great marvels of the human body is that it all works together. When something hot is touched, the response of withdrawing the hand is immediate. If a person consciously had to feel, see, recognize, and think before drawing away his hand, he could be seriously burned.

The body's internal workings, so often taken for granted, offer interesting examples of carefully designed control. As bodily activity increases, the heart automatically increases its pace; the respiratory system responds with deeper, more rapid breathing; but the digestive system slows down, while hundreds of other adjustments are made so that homeostasis can be maintained. When the activity stops, the systems automatically readjust.

Even a simple movement like taking a step involves thousands of cells, all of which must work with great precision. The intricate control mechanisms that are so vital to one's well-being were programmed by the Creator. How else could they be adequately explained?

Two main systems control the body: the *nervous system* and the *endocrine system.* The brain, spinal cord, sensory organs (eyes, ears, taste buds, touch receptors, and others), and the nerves that supply them compose the nervous system. The endocrine system is discussed in the next chapter.

All voluntary activities, such as speaking and running, and many involuntary activities, such as heartbeat and digestion, are controlled by the nervous system. The nervous system receives stimulation (possibly from the environment or an internal source such as the level of a blood chemical), interprets it, and responds to it. Scientists understand, at least in part, how the nerve cells are able to perform some of these simple functions.

But the human nervous system also performs activities that scientists cannot explain. How does a cell or group of cells in the brain remember a beautiful mountain landscape seen two years ago? Or, for that matter, how does it "store" the concept and the word *mountain*? How does one think? What is a dream? What is an emotion? The brain controls all of these. But what are these things, and how does a mass of cells inside the skull cause them? These questions continue to be the subjects of scientific studies, and many are not yet fully answered. However, many things about the nervous system are known, and a basic grasp of those concepts will help in understanding and using the body's controls wisely. The study begins with the neuron—the basic cell of the nervous system—and how nerve impulses are transmitted.

23A-1
Objectives

- Describe a typical neuron's structures and discuss their functions
- Distinguish between the three functional types of neurons
- Summarize the initiation and transmission of an action potential

23A-1 Neurons

Neurons* (N*OO*R AHNZ) are cells that serve as the functional units of the nervous system. Once mature, neurons are capable of living as long as the body does, although many do not. A typical neuron is designed to receive and distribute a *nerve impulse*. The number of impulses and whether or not a particular neuron is stimulated is the essence of the control of the body by the nervous system.

Neuron Anatomy

Neurons are composed of three basic parts.

✦ The **cell body** is the part of the neuron with the greatest diameter, and it contains the nucleus and cytoplasmic organelles. The cell body may also receive impulses from other neurons.

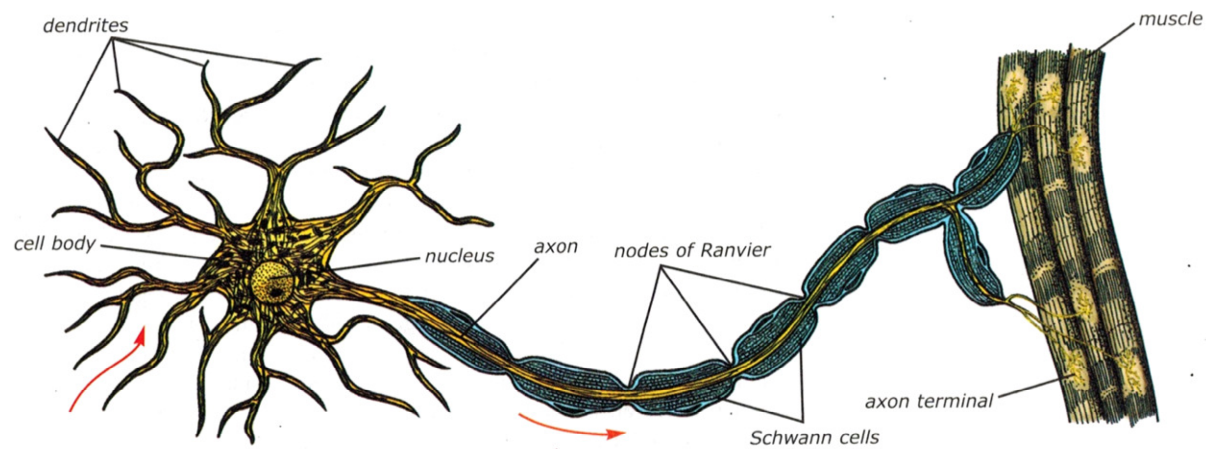
✦ The **dendrites*** are multibranched fibers that project from a neuron. They receive and relay nerve impulses *toward* the cell body of the neuron.

✦ The **axons** are fibers that carry impulses *away* from the cell body. They are usually the longest portion of a neuron. The axons of most neurons are covered by an additional lipid layer called the **myelin** (MYE uh lin) **sheath**. The myelin sheath functions to insulate the axon as well as increase the rate of transmission of nerve impulses. Special cells that surround the axon called **Schwann cells** produce the myelin sheath. The myelin sheath has many gaps along its length called **nodes of Ranvier** (RAHN vyay). A special structure called the **axon terminal** is located at the end of the axon. Axons terminate at another neuron, a muscle fiber, or a gland cell. It is important to note that neurons do not touch each other. The junction between two neurons is called a **synapse**, and the space between the axon terminal and a neuron is called the **synaptic cleft**.

Although neurons have many different functions, they may be grouped into three functional types.

✦ **Sensory neurons** carry impulses toward the central nervous system and respond to only particular stimuli. For example, the sensations everyone experi-

neuron: (nerve)
dendrite: (Gk. DENDRON, tree)



23A.1
A typical neuron. Arrows show the direction of nerve impulses.

ences (seeing, hearing, tasting, temperature changes, and such) result from stimulated sensory neurons that transmit impulses to other neurons in the central nervous system. Usually, the cell body of a sensory neuron is part of the central nervous system, but the dendrites are part of the peripheral nervous system.

✦ **Interneurons** are located within the central nervous system and receive impulses from sensory neurons. Interneurons distribute the impulse to other neurons.

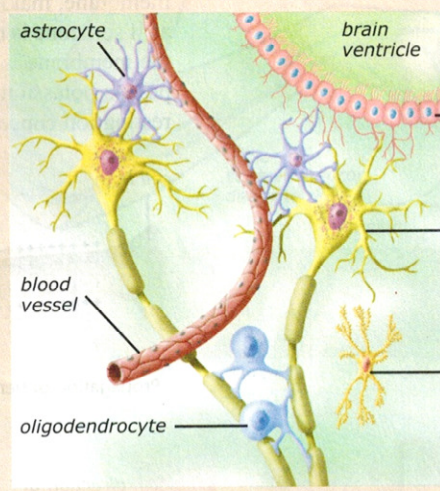
✦ **Motor neurons** have dendrites and a cell body located in the central nervous system but axons in the peripheral nervous system. The ends of the motor neuron axon usually stimulate muscles or glands to cause a response.

Neuron Function

The primary function of neurons is to transmit nerve impulses from one area to another. Neurons are *at rest* when they are neither receiving nor transmitting impulses. A **nerve impulse** is an electrochemical pulse that moves along the membrane of a neuron. To understand how a nerve impulse occurs, one must examine the chemical and electrical changes that occur on both sides of a neuron's membrane.

Neuroglia—Another Type of Neuron

Dispersed throughout the nervous system are small cells called **neuroglia*** (NOOR uh GLEE uh) or *glial cells*. Some have very irregular shapes while others are more symmetrical. These cells were once thought to be only a sort of passive "glue" that provided a matrix for the other neurons. Neuroglia outnumber neurons about ten to one. Unlike neurons, they are able to divide as long as they live; therefore, many brain tumors are composed of glial cells rather than neurons.



Although neuroglia do not conduct nerve impulses, they do perform major functions. There are four main types in the central nervous system—astrocytes, microglia, ependymal cells, and oligodendrocytes. The functions of the glial cells are summarized in the following table.

Types of Neuroglia

Cell type	Function
Astrocytes	Provide structural support for neurons; guide embryonic neural cells to proper position; form neural scar tissue; regulate movement of substances between blood vessels and neurons
Microglia	Phagocytize bacterial cells and cellular debris
Ependymal cells	Form the inner lining of the brain ventricles and spinal cord central canal; regulate movement of substances between cerebrospinal fluid and central nervous system tissues
Oligodendrocytes	Form myelin sheaths on axons of central nervous system neurons

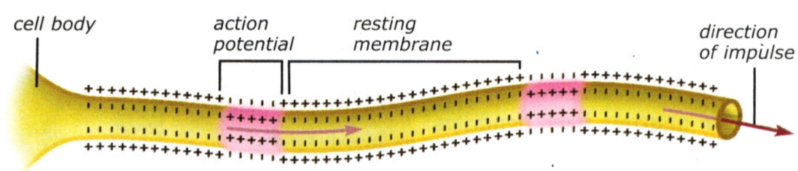
* **neuroglia:** neuro- (nerve) + -glia (glue)

A resting neuron is said to be *polarized*. This means that positive and negative charges are concentrated in different areas in relation to the neuron membrane. The difference in electrical charge between two areas is called a **potential**. Since the neuron is at rest, this relative charge differential between the inside and the outside of the neuron is called the **resting potential**.

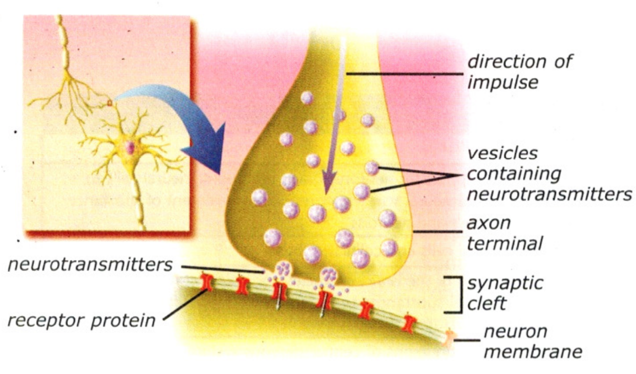
Inside the neuron, there is a high concentration of positively charged potassium ions and negatively charged proteins. Outside the membrane there is a higher concentration of positive sodium ions. The negatively charged proteins cannot cross the membrane; however, the potassium ions can freely cross the membrane. As potassium ions leave the neuron, there is a net negative charge inside the neuron and a positive charge outside. Cellular processes maintain this imbalance of various ions. The membrane is not very permeable to sodium ions; therefore, they remain concentrated outside the membrane.

When a neuron is stimulated, its membrane becomes more permeable to sodium ions and they rush into the cytoplasm. That area of the cytoplasm now has a net positive charge—it is *depolarized*. The increased positive charge causes adjacent areas of the membrane to become depolarized, and an **action potential** is created. This is a chain reaction, very similar to the falling of a row of dominoes. The action potential continues along the membrane until it reaches the axon terminal.

As the action potential travels along the membrane, the sodium ions stop moving into the cytoplasm and potassium ions rush out. This *repolarizes* the membrane, making the outside more positive than the cytoplasm. It is almost as if someone is repositioning the dominoes as quickly as they fall down. Once the membrane is repolarized, the action potential is over. The membrane then pumps potassium back into the cell and pumps sodium out to reestablish the resting ion concentrations.



23A.2
Propagation of nerve impulse



23A.3
A synapse showing the transfer of a nerve impulse across a synaptic cleft

Once the action potential arrives at the axon terminal, it must be transmitted across the synaptic cleft to the next neuron. The impulse cannot "jump" this space. The change in membrane permeability of the action potential is believed to cause the end of the axon terminal to release chemicals called **neurotransmitters** into the synaptic cleft. The neurotransmitters stimulate receptor proteins in the membrane of the next neuron. An action potential is created, and the impulse is passed on.

Once the impulse has crossed the synaptic cleft, special enzymes in the cleft rapidly inactivate the neurotransmitters. Since neurotransmitters are produced only at the axon terminals, action potentials can be passed only from the axon terminal of one neuron to the dendrite or cell body of the next neuron.

The Reflex Arc

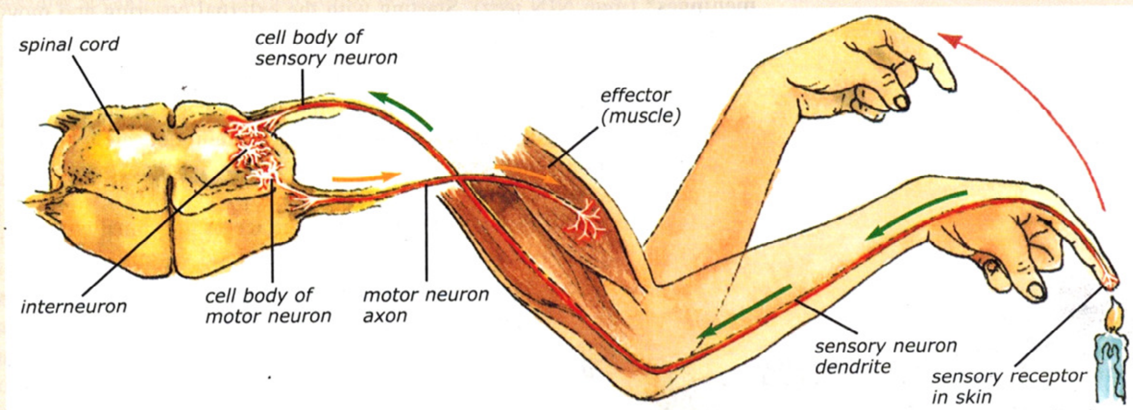
The **reflex arc** is a good example of various types of neurons working together. A *reflex* is an involuntary response to a stimulus. The automatic, immediate jerk of a person's body in response to a stimulus such as a wasp sting or a cut is a reflex. The nerve impulses travel so rapidly that the body moves before the person has time to think.

Skin contains an abundance of receptors, which are actually the dendrites of sensory neurons. Once the sensory neuron is stimulated, the impulse is carried to the central nervous system. There the sensory neuron may form a synapse with only one interneuron, or it may branch and pass the impulse to many interneurons. What happens depends on the particular stimulus and the part of the body involved.

The interneuron passes the impulse to a motor neuron (or motor neurons), which carries the impulse to a muscle; body movements result. At the same time, the interneurons may send impulses to the brain, telling of the stimulus it received. But the muscle action prompted by the motor neuron often happens before a person is conscious of the stimulus. Thus reflex arcs are involuntary.

The body part that responds to the stimulus is the **effector**.* Effectors may be muscles or glands, depending on the reflex arc. For example, the eyelid muscles are effectors when something gets in the eye. Sweat glands may be the effectors in a reflex arc when a person is in a warm room. Many bodily movements and most internal responses are controlled by reflex arcs.

There may be only one sensory and one motor neuron or dozens of each in a reflex arc. If only two or three neurons are involved, a person is usually unaware of the stimuli, as is the case with those that control internal organs. No matter how many neurons are involved, the central nervous system is the center of each reflex arc. Parts of the brain and spinal cord are *reflex centers* for such actions as eye movement, sneezing, coughing, and breathing.



* **effector:** (L. EFFECTUS, to bring about)

Unit 8: The Nervous System, Part 1

1. What are the two primary control systems of the body?
2. List the three main parts of a neuron and describe how they are different.
3. What are the three basic types of neurons? What does each one do?
4. Sketch a neuron (like the one on page 713) and label its parts. Indicate with arrows the direction of a nerve impulse.
5. When a neuron is resting, is it more positive or more negative on the outside?
6. What is a neurotransmitter?