UNIT 3

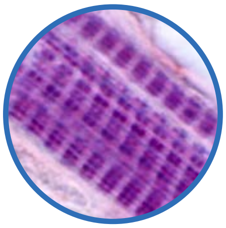
THE NERVOUS SYSTEM

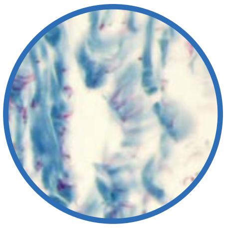
wonders of the HUMAN BODY

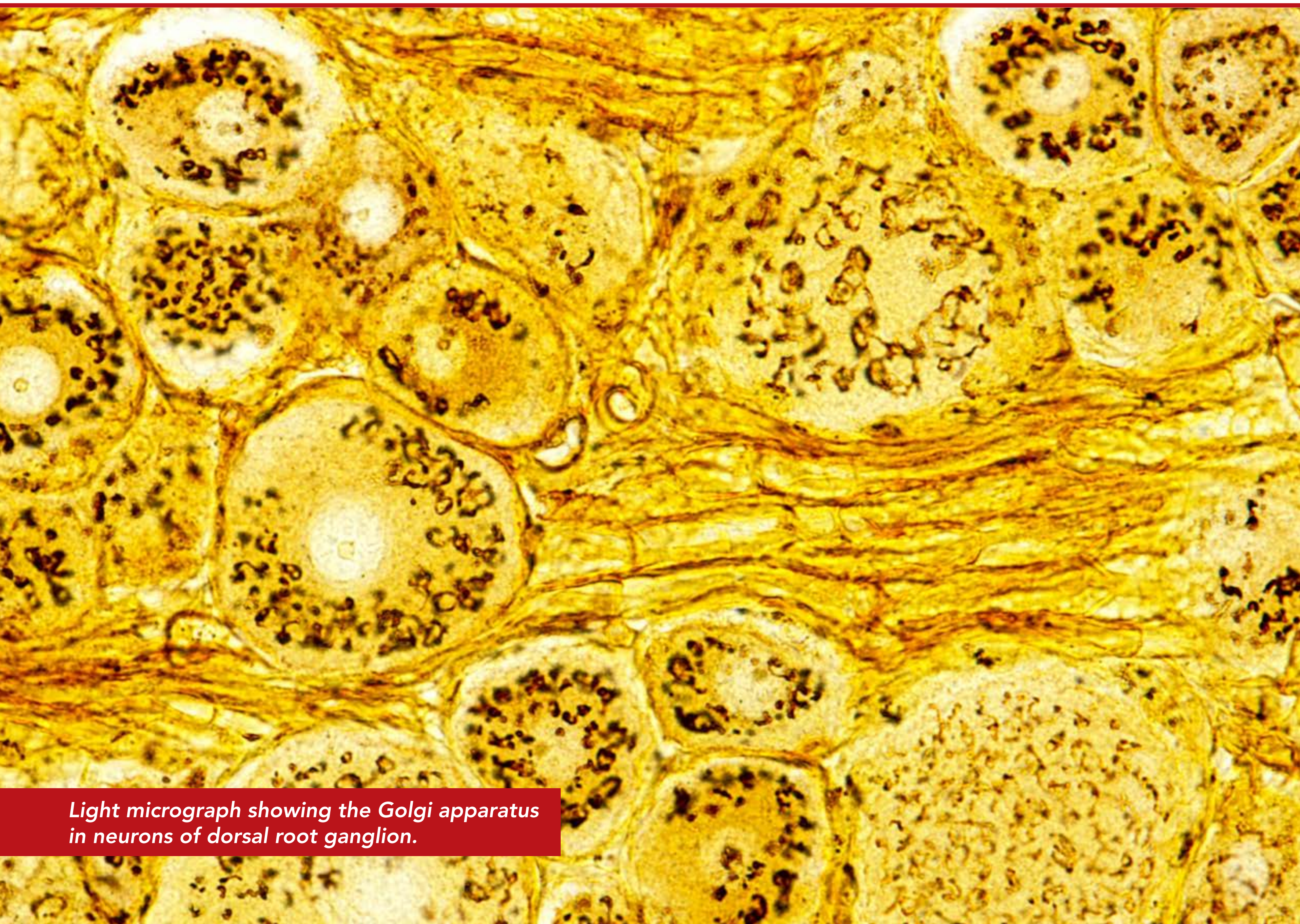
STRUCTURE OF NERVOUS TISSUE

The nervous system is composed primarily of nervous tissue. Nervous tissue is one of the four basic tissue types that we examined previously in Volume 1 of *Wonders of the Human Body*.

Nervous tissue consists of two primary types of cells: neurons and neuroglia.

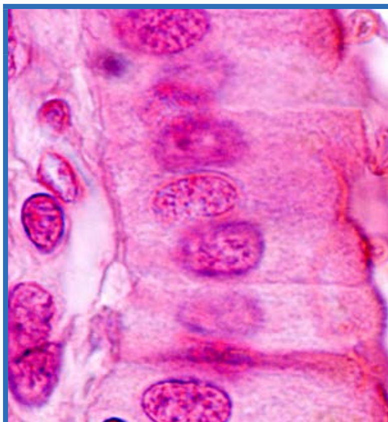






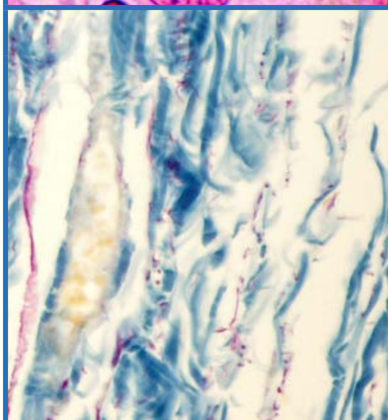
Light micrograph showing the Golgi apparatus in neurons of dorsal root ganglion.

Tissue Types



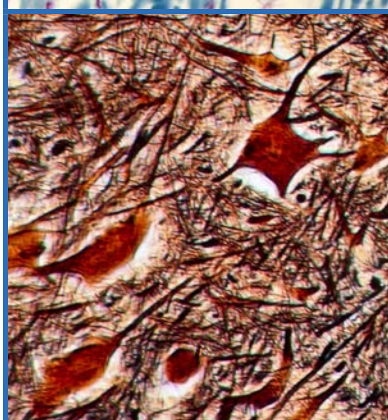
Epithelial Tissue

Epithelial tissue (or epithelium) lines body cavities or covers surfaces. For example, the outer layer of skin is epithelium. The sheet of cells that line the stomach and intestines, as well as the cells that line the heart, blood vessels, and the lungs, is epithelial tissue.



Connective Tissue

Connective tissue helps provide a framework for the body. It also helps connect and support other organs in the body. Further, it helps insulate the body, and it even helps transport substances throughout the body. This tissue can be hard or soft. Some connective tissue stretches. One type is even fluid. Connective tissue is comprised of three parts: cells, fibers, and ground substance.



Nervous Tissue

Nervous tissue is the primary component of the nervous system. The nervous system regulates and controls bodily functions.

Nerve cells are incredible. They are able to receive signals or input from other cells, generate a nerve impulse, and transmit a signal to other nerve cells or organs.

Muscle Tissue

Muscle tissue is responsible for movement. There are three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle.

Neurons are the excitable nerve cells that transmit electrical signals.

What starts such an electrical signal? Some type of change in the environment acts as the stimulus that excites a neuron, triggering an electrical signal called an action potential. The electrical signal transmitted by a neuron is also called an impulse. An impulse travels like a wave along the nerve cell membrane from one end of the neuron to another. We will soon study this in depth.

The other cells in nervous tissue are called neuroglia. There are several types of neuroglia cells. They help protect and support the neurons.

Let's examine the neuron in greater detail.

Neurons

The neuron is often called a nerve cell because it is the cell type that does the primary work of the nervous system. You have neurons in your brain, in your spinal cord, in your peripheral nervous system, and even in specialized sensory organs like your eye, nose, and ear.

A neuron doesn't look like a typical cell. If you have seen sketches of "typical" cells before, you will notice that, while the neuron still has a cell membrane, cytoplasm, and a nucleus, it has an unusual shape. The neuron is a very specialized type of cell that is designed to transmit electrical impulses (nerve impulses) rapidly to various parts of the body.

The neuron is composed of three parts: the cell body, dendrites, and the axon.

The cell body contains the typical organelles we discussed at length in Volume 1 of *Wonders of the Human Body*. The cell body contains a nucleus surrounded by cytoplasm. The cytoplasm contains plenty of protein-building organelles like rough endoplasmic reticulum dotted with ribosomes and free ribosomes. An extensive Golgi apparatus processes the proteins made by these ribosomes. Neurons require a lot of energy to build the substances they require, so lots of energy-generating mitochondria are also found in the cell body. Energy provided by these mitochondria fuels the building of the substances neurons need to do their job. Some of the most important substances synthesized in the neuron's cell body are neurotransmitters. As we will soon see, neurotransmitters are the chemicals that transmit an electrical impulse from one neuron to the next.

Extending from the cell body are numerous projections, or processes. Neuron cell bodies have two kinds of processes protruding from them, dendrites and axons. Dendrites are designed to receive signals. Axons are designed to carry signals away.

Some dendrites resemble the branches of a tree. Others have more thread-like branches, and some have branches covered with tiny spines. The reason for this branching design is simple. Remember, dendrites are the parts of neurons that receive inputs (signals). The branching pattern covers an extensive area, allowing the neuron to receive an enormous number of inputs. When an input is received by a dendrite, an electrical signal is generated and transmitted toward the cell body.

The axon is the portion of the neuron that carries a nerve impulse away from the cell body. The axon begins at a cone-shaped axon hillock on the cell body. The hillock narrows to form the more thread-like axon. The axon can be very short or up to several feet long. The axon of a motor nerve to the muscle that enables you to curl your big toe has to travel a long way, all the way from your spinal cord to your foot.

A neuron can have multiple dendrites

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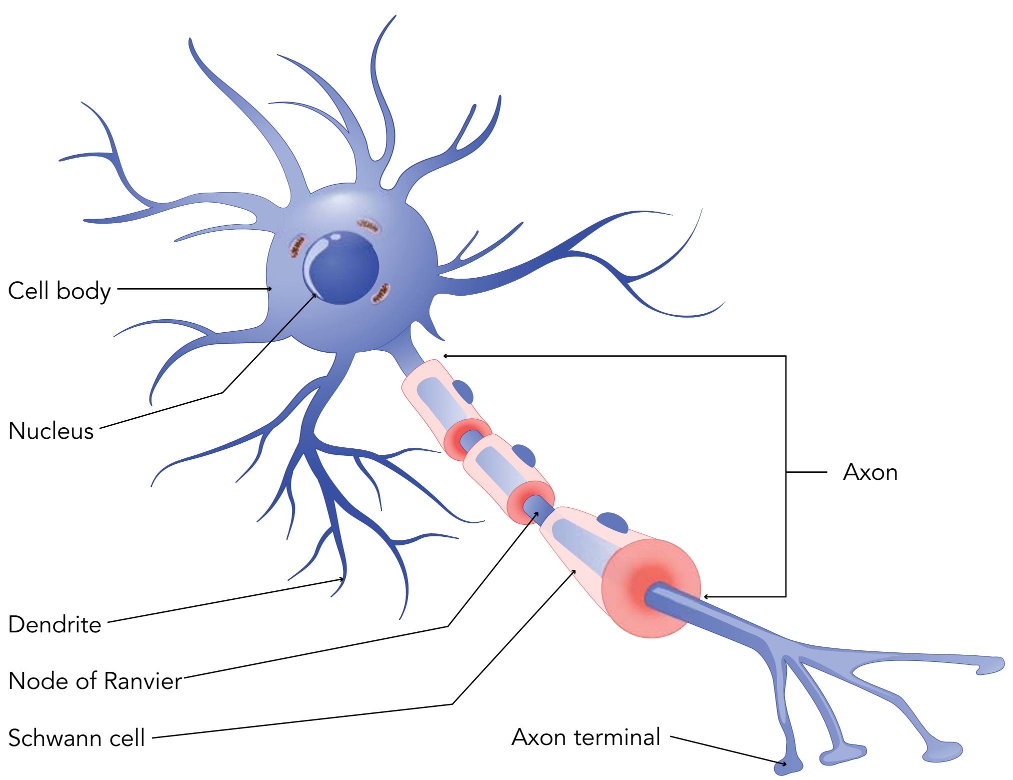
Neuron



but only one axon. Axons end in small branches called axon terminals. At the axon terminal, neurotransmitters are released to carry the neuron's signal on to the next cell in line. You will learn more about this shortly.

Neurons — The Lowdown

There are hundreds of millions of neurons in the human body. And that's a really good thing. Why? Unlike most cell types in your body, neurons cannot be routinely replaced. Once neurons mature, with only rare exceptions, they are no longer able to divide. The neurons you have, once your nervous system matures, are all the neurons you will ever have.

So…when neurons are damaged by drugs, disease, or injury, the loss of function is often permanent. Neurons are designed to last a lifetime, but we need to take care of them. For instance, we must be vigilant about what we put into our bodies, as many illicit drugs destroy these precious messengers. A lifetime of poor eating habits and lack of exercise can increase the risk of a stroke in later life, which can destroy many neurons in the brain. Riding your bicycle without a helmet puts the irreplaceable neurons in your brain at risk right now. Following the rules for safety in contact sports may prevent a tragic accident that could leave you paralyzed. Operating power tools unsafely may lead to permanent loss of peripheral nerve function in an injured body part, even if you do not lose the body part itself. Habitually exposing your ears to loud music or explosive noise without ear protection may destroy the specialized neural structures in your ears and impair your hearing. Looking directly at the sun can permanently damage your retina, the very specialized extension of your brain that enables you to see.

God only gave you one body, and there are no do-overs when it comes to neuron damage. While many diseases and conditions that damage neurons in this sin-cursed world are not preventable, you should take care to avoid those that are.

Further, neurons require lots of oxygen and glucose to function properly. Neuron cells can be quickly damaged by lack of these essentials. Loss of oxygen for as little as four minutes can permanently damage neurons. For this reason, many people take courses in basic CPR and water safety, so that they will be able to help others avoid permanent damage or loss of life.

Performing CPR (cardiopulmonary resuscitation) on someone who has stopped breathing.

Types of Neurons

There are several types of neurons. We can classify them according to how they look or according to how they work. Each type of classification can help us understand how the nervous system works.

One method of classifying neurons is based on the number of processes they have. Remember, processes are dendrites and axons, the projections sticking out from the cell body.

Most neurons have one axon and multiple dendrites. These are called multipolar neurons. This is by far the most common type of neuron in the body.

Bipolar neurons have only two processes: one axon and one dendrite. These are only found in special sensory organs, such as the eye, ear, and nose.

Unipolar neurons have a more unusual configuration. They have only one process extending from the cell body. This process looks like a "T." The dendrite and the axon form the arms of this "T."

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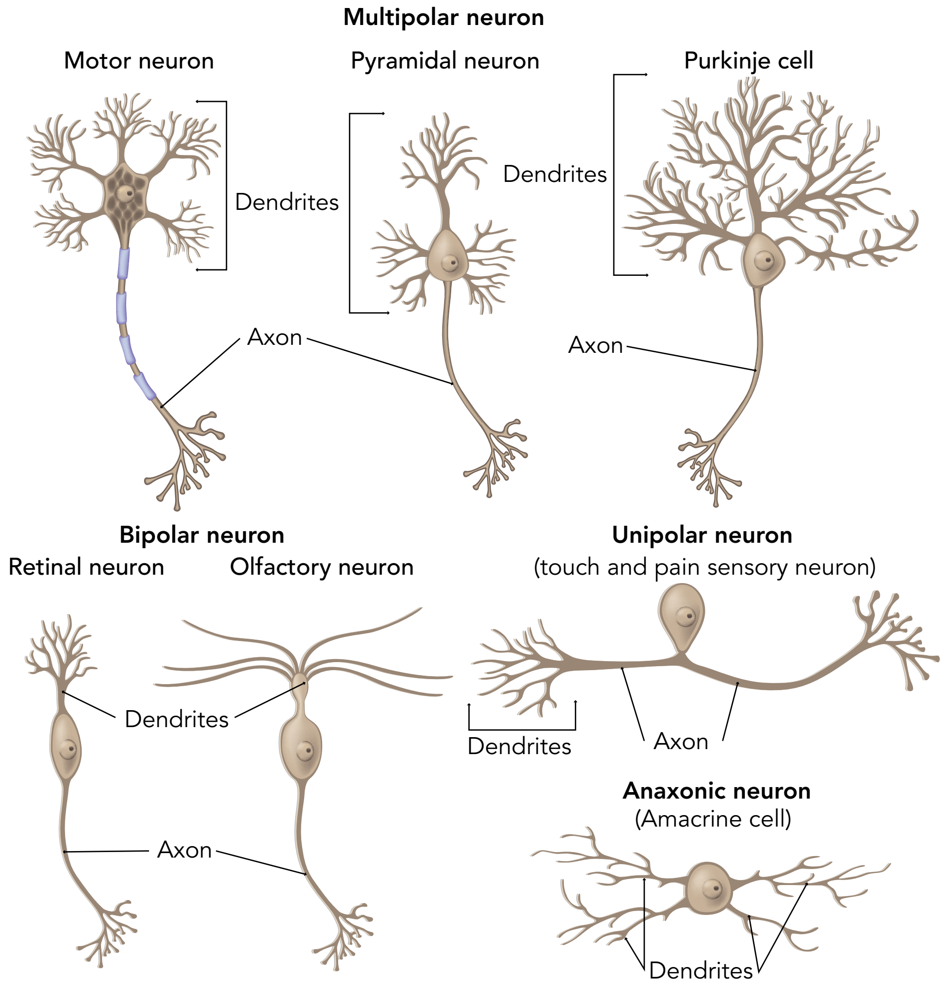
Types of Neurons



Neurons are also classified according to the direction they carry nerve impulses. Some neurons carry instructions from the central nervous system, and others bring information to the central nervous system.

Neurons that transmit impulses away from the central nervous system are called motor or efferent (remember "carrying away" or "carrying outward") neurons. These impulses contain instructions to muscles or to glands in the body. Most motor neurons are multipolar.

Sensory or afferent (remember "bringing toward") neurons carry impulses triggered by sensory receptors toward the central nervous system. Most sensory neurons are unipolar.

Yet one other class of neurons carries impulses from one neuron to another within the central nervous system. These connectors are called interneurons, a word that obviously means "between neurons." Interneurons make up the vast majority of the neurons in the body. Some estimates are as high as 99 percent. Interneurons are located in the brain and spinal cord, forming connections between sensory and motor neurons. Signals from sensory neurons are delivered to the interneurons. The interneurons pass the impulse on to the appropriate motor neurons. If you recall the basic functions of the nervous system, this is the integration step we discussed, a step in which inputs are processed and passed on to generate suitable output.

Neuroglia

Neurons are not usually alone. They are generally surrounded by several types of smaller cells in the nervous system. These other cells are known as neuroglia, or glial cells. Neuroglia are found both in the central nervous system and the peripheral nervous system. Neuroglia have various functions depending on their cell type and location.

We will first examine the neuroglia in the CNS.

Astrocytes are the most numerous of the neuroglial cells in the CNS. Astro means "star," and cytes means "cells." Astrocytes are therefore glial cells with

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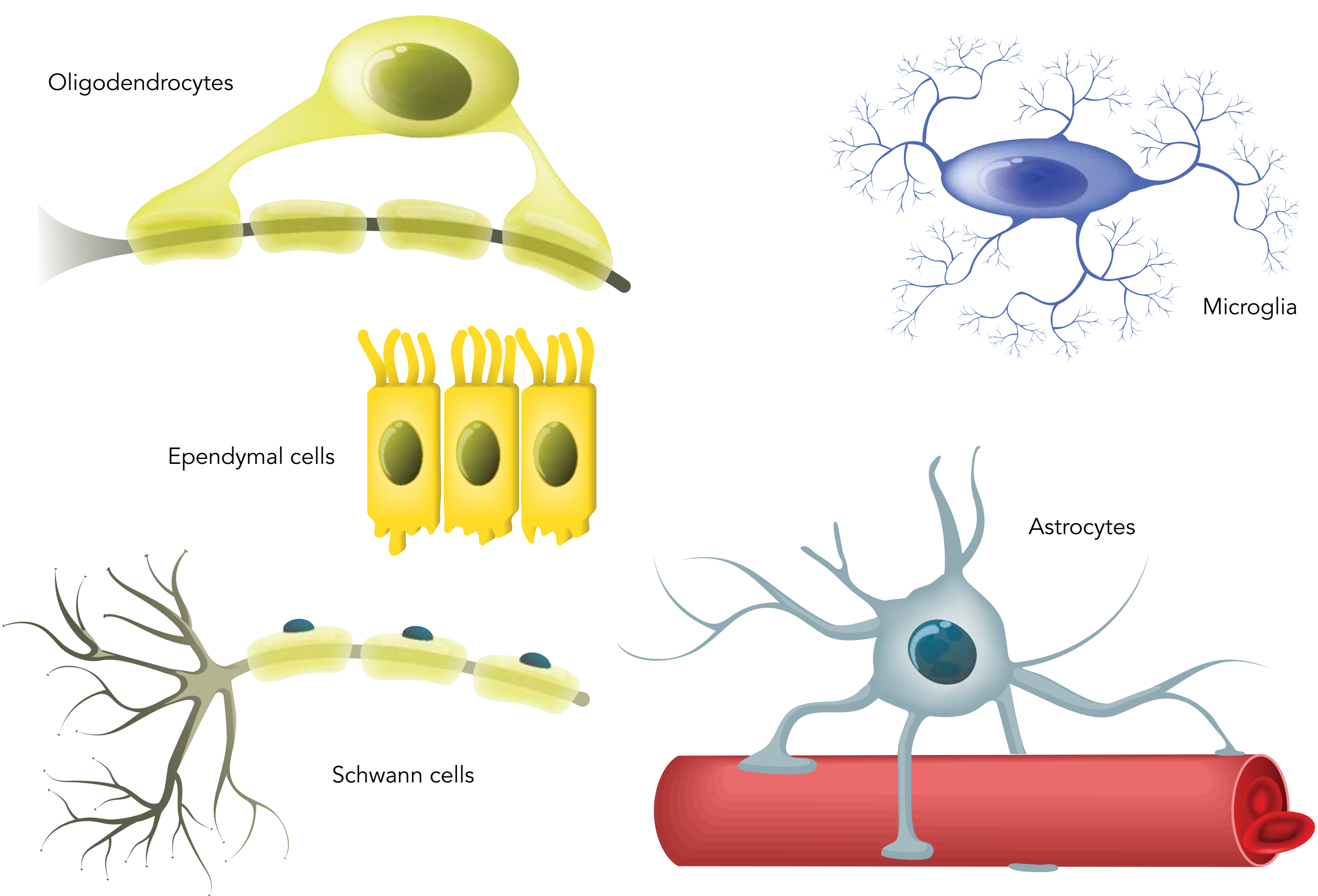
Types of Neuroglia



many star-shaped processes. These cells anchor and support the neurons associated with them. They help the neurons pass on impulses efficiently. Astrocytes also protect their neurons. They monitor nearby capillaries, ensuring that harmful substances in the blood do not reach the neuron. Astrocytes help maintain the correct level of ions, such as potassium (K^+), and other nutrients around the neurons. They contain a readily available supply of glucose that they supply to neurons when lots of energy is needed. They even help recycle neurotransmitters released from their neurons.

Microglia are small cells with long slender processes. (Micro means "small," so this is a good name.) Microglial cells "keep watch" over neurons in their vicinity. If they detect damage to a neuron or invading bacteria, they transform into a cell that can remove damaged nerve tissue or engulf and destroy the bacteria.

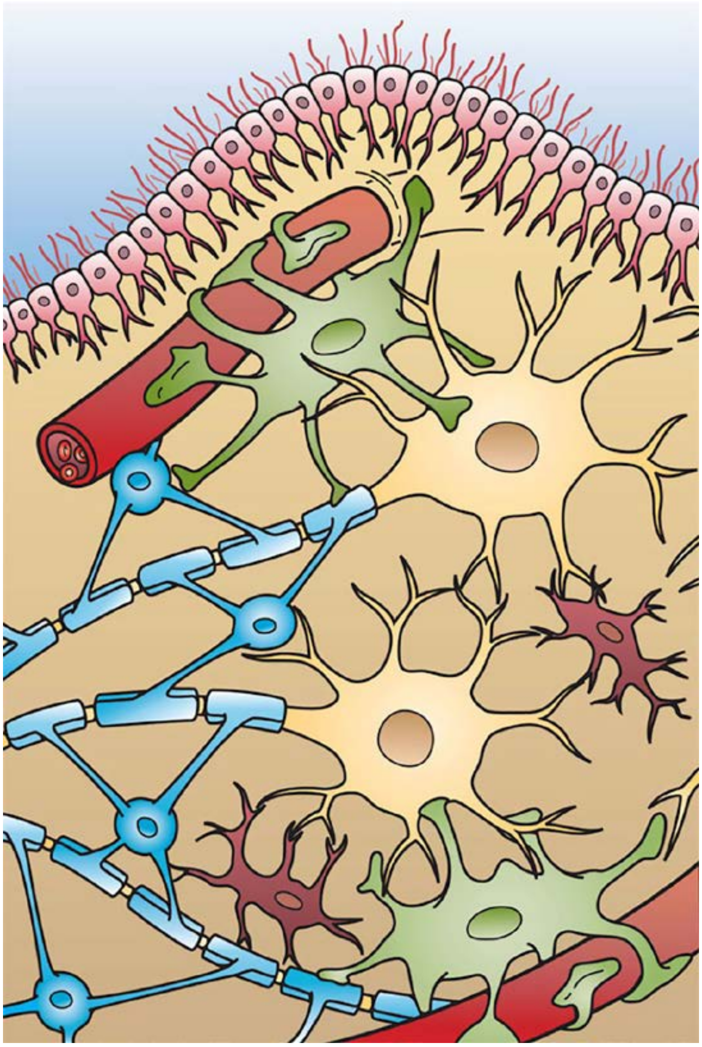
Ependymal cells line the ventricles of the brain and the spinal canal. The ventricles in the brain, like the canal surrounding the spinal cord, are filled with cerebrospinal fluid. Ependymal cells produce much of the cerebrospinal fluid that fills these cavities. Cerebrospinal fluid doesn't just sit still; it circulates through these fluid-filled spaces in the CNS. Cilia on the ependymal cells help move this fluid around.

Oligodendrocytes resemble astrocytes, but they are smaller. Oligodendrocytes produce and maintain a special covering (called a myelin sheath) around neuronal axons. This myelin sheath is made of lipids and protein. We will be learning much more about myelinated axons shortly.

Okay, now you know there are four types of glial cells in the central nervous system—astrocytes, microglial cells, ependymal cells, and oligodendrocytes. There are two types of neuroglial cells in the peripheral nervous system, satellite cells and Schwann cells.

Satellite cells surround the cell bodies of neurons in the PNS. They provide structural support and also control the extracellular environment around the cell bodies. Thus, the satellite cells function in the PNS much in the way astrocytes do in the CNS.

Schwann cells form the myelin sheaths around axons in the PNS. Therefore, Schwann cells function in the PNS the way oligodendrocytes do in the CNS. Let's explore myelination in more detail next.



This image shows the four different types of glial cells found in the central nervous system: Ependymal cells (light pink), Astrocytes (green), Microglial cells (red), and Oligodendrocytes (functionally similar to Schwann cells in the PNS) (light blue).

Myelination

Myelination is a process in which long axons are covered by a myelin sheath. The myelin sheath is a spiral wrapping of the modified cell membranes of the Schwann cells or oligodendrocytes responsible for forming the myelin. Axons having this myelin covering are said to be myelinated. Axons not having this covering are called nonmyelinated.

The myelin sheath provides electrical insulation for the axon. It also increases the speed a nerve signal can travel.

In the PNS, myelination is carried out by Schwann cells. These cells initially indent to receive the axon, and then wrap themselves repeatedly around the axon. Ultimately, this wrapping has the appearance of tape wrapped around a wire or gauze wrapped around a finger. At the end of the wrapping process, there may be several dozen layers of wrapping to the sheath.

Each of the Schwann cells wraps only a small length of a single axon. Other Schwann cells wrap the remaining length of the axon, like so many hot dogs in buns laid end to end. However, Schwann cells do not touch each other. There are small gaps between adjacent Schwann cells. These gaps are called nodes of Ranvier. (They were discovered by—you guessed it!—French anatomist Louis-Antoine Ranvier in the 19th century, and his name is pronounced ron'- vee-ay.)

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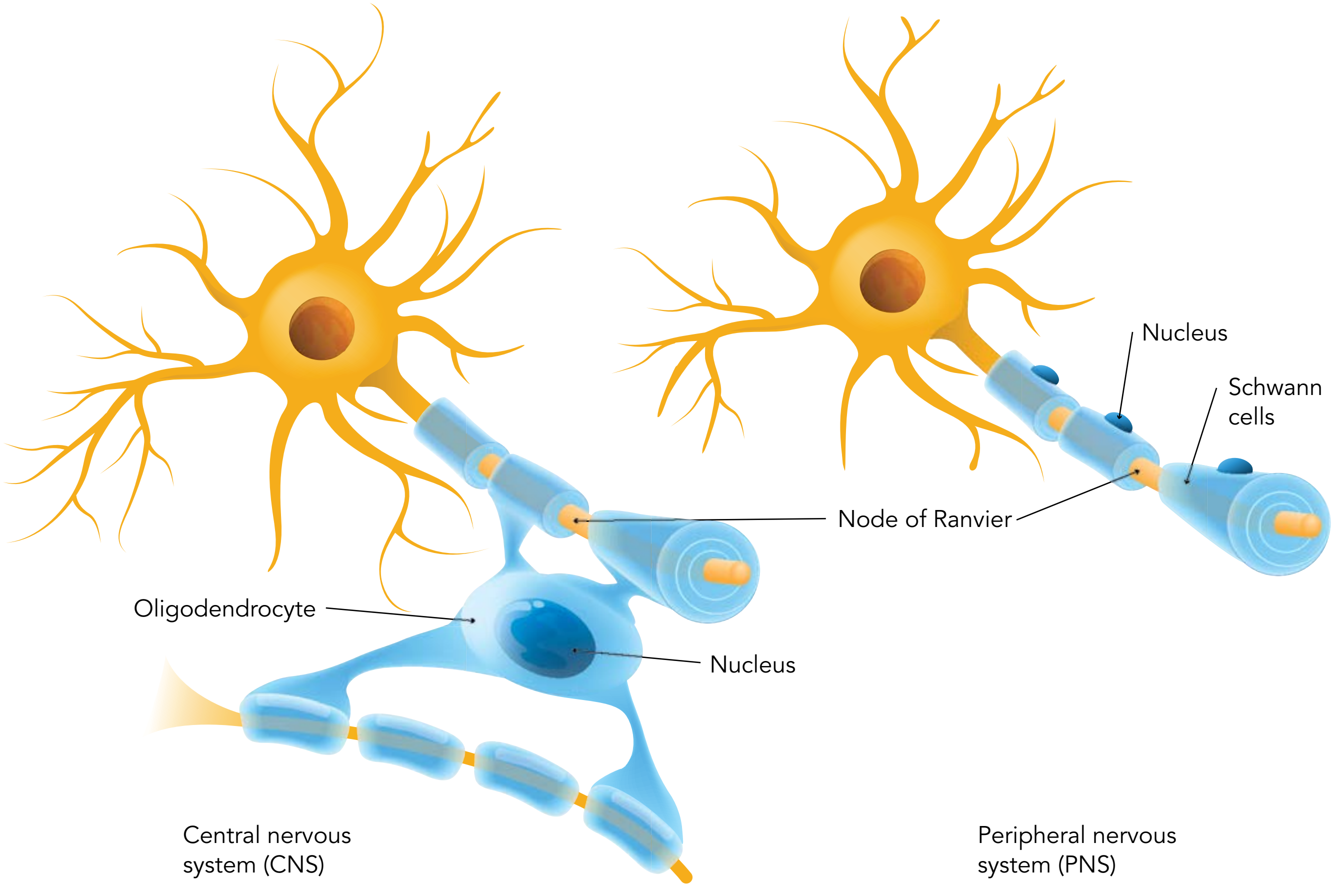
Myelination



It should be pointed out here that a Schwann cell can enclose a dozen or more axons without wrapping them. These axons are nonmyelinated even though they are in contact with a Schwann cell.

In the CNS, it is the oligodendrocyte that is responsible for myelination. Because an oligodendrocyte has many processes, it can wrap around numerous axons rather that only one, as in the case of the Schwann cell.

The amount of myelin in the body is very low at birth and increases as the body develops and matures. Thus the number of myelinated axons increases from birth throughout childhood until adulthood. Myelination increases the speed of nerve impulse conduction through the axon. Faster conduction

Multiple Sclerosis

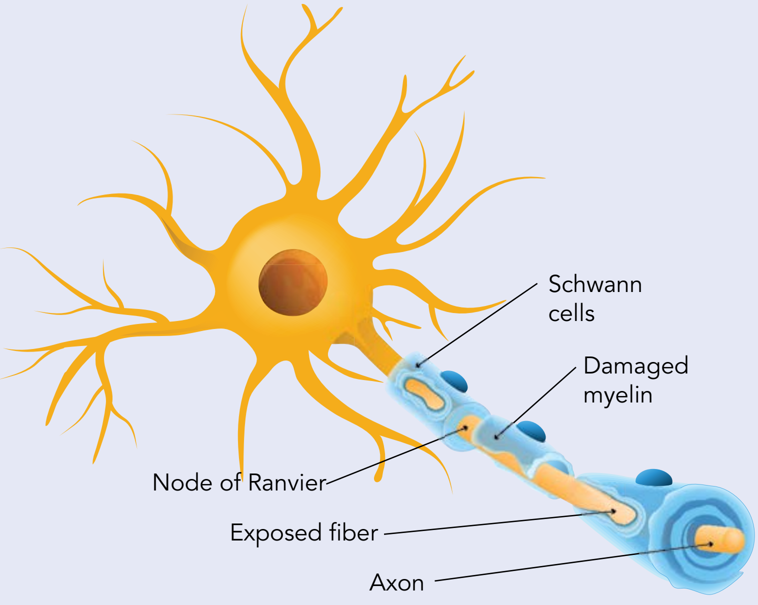
Multiple Sclerosis (MS) is an autoimmune disease that results in the destruction of myelin sheaths in the central nervous system. (In autoimmune diseases, the body's immune system turns against its owner's own tissues.) In multiple sclerosis, the body's immune system attacks myelin proteins, creating hardened lesions called scleroses. These lesions commonly occur in the optic nerve, the brain stem, and the spinal cord.

As the myelin loss increases, conduction of nerve impulses becomes progressively slower. Short circuits develop and interfere with the proper functioning of the neurons. That this disease is so debilitating shows the importance of the myelination of nerve fibers to proper functioning of the nervous system.

MS primarily occurs in people under 50 years of age. Symptoms include double vision, weakness, loss of coordination, and paralysis.

One form of MS is characterized by periods of active disease alternating with periods of minimal symptoms. Another form of MS is slowly progressive, without the symptom-free periods.

Although in recent years much progress has been made in our understanding of multiple sclerosis, at present there is still no cure.



makes those nerves work better, more efficiently, as an individual matures.

Think of a newborn baby. It has very little control of its body in the beginning. It cannot hold its head up or sit up or walk. As more axons become myelinated, it has more and better control of its muscles. Compare this to a teenager. After years of development, the teenager has much better control and coordination of the body. Much of this improvement of due to increased myelination both in the central and peripheral nervous systems.

Nerves

What are nerves? They not the same thing as neurons.

A neuron is a nerve cell. Neurons have dendrites and axons. The neuron is the cell that transmits electrical impulses in the nervous system. Thus, the neuron, not the nerve, is the basic unit of nervous tissue.

So what is a nerve? Well remember that axons, even though they are part of nerve cell, can be very long. Some reach from your back to your foot. A nerve is made of bundles of axons located in the peripheral nervous system. These bundles of axons are not alone in the nerve. The nerve also contains the Schwann cells associated with the axons, as well as blood vessels, connective tissue, and lymphatic vessels. This cross section shows the various components.

Before we go further, let's see how some of these things fit together.

Individual axons and their associated Schwann cells are covered by a very thin layer of connective tissue known as the

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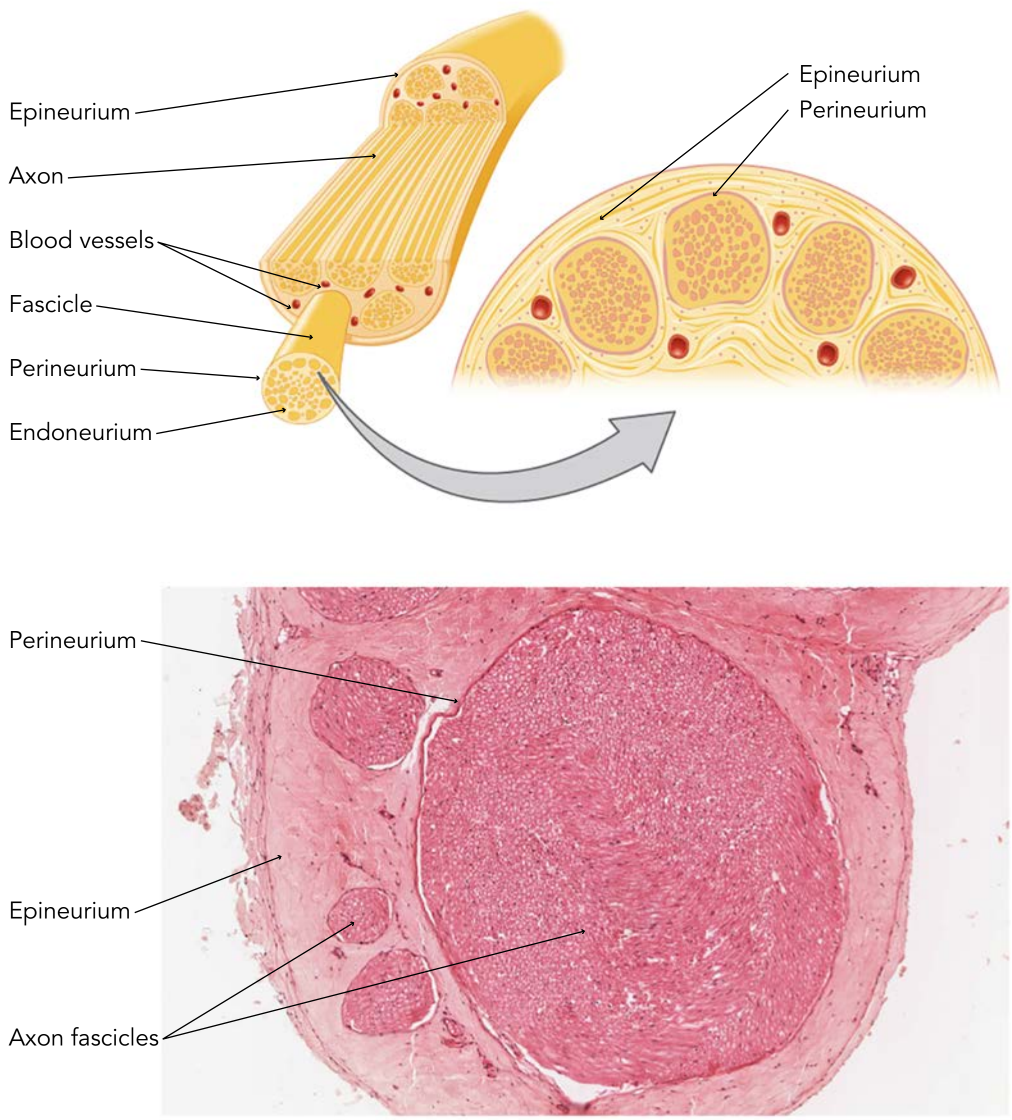
Anatomy of a Nerve



endoneurium (endo- meaning “inner,” and neurium meaning “nerve”). Next, many such endoneurium-covered axons running parallel to each other are grouped in bundles called fascicles. Each fascicle is then covered by another connective tissue layer known as the perineurium (peri- meaning “around”). Lastly, numerous fascicles, blood and lymphatic vessels are bound together by yet another connective tissue wrapping called the epineurium (epi- meaning “over”). This epineurium-wrapped bundle of bundles—containing axons, neuroglia, blood vessels, lymphatic vessels, and layers of connective tissue—is known as a “nerve.”

Remember that neurons can be classified by the direction they carry electrical impulses. Motor neurons carry impulses away from the central nervous system, and sensory neurons carry impulses toward the central nervous system. Nerves can be classified the same way.

Motor nerves carry signals away from the CNS. Sensory nerves carry impulses toward the CNS. But motor nerves and sensory nerves are very rare. The most common type of nerve by far is called a mixed nerve. Even though an individual neuron can only carry an impulse in one direction (remember, from dendrite to cell body to axon), mixed nerves possess both motor and sensory fibers. Mixed nerves have two-way traffic. They carry impulses both toward and away from the CNS.

Nerve Damage and Repair

With rare exceptions, mature neurons do not divide to reproduce themselves. The mature nervous system is not designed to replace damaged nerve cells. The neurons you have now are pretty much all you are going to get. Because of this, damage to the nervous system is serious.

However, there is a bright spot here. In the peripheral nervous system, there can be regeneration of a nerve after an injury. Recall that a nerve does not contain whole neurons, but instead consists of bundles of axons and their supporting tissues.

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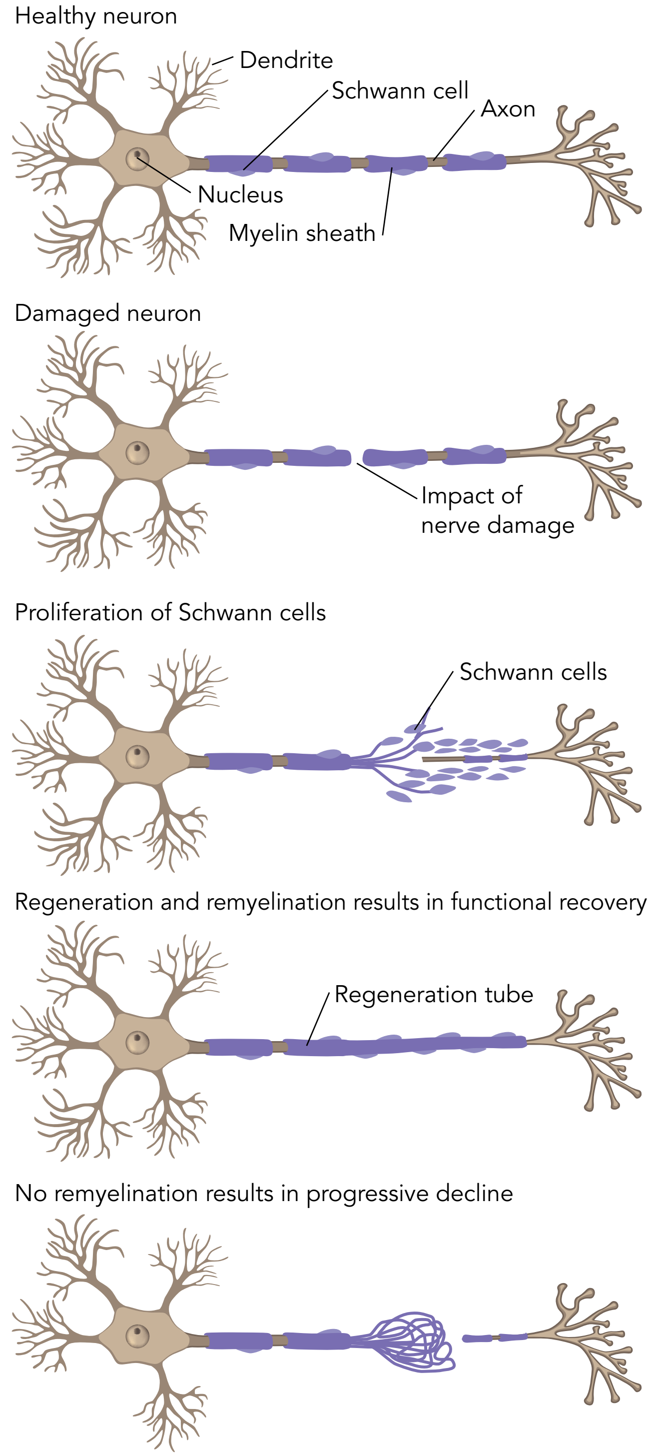
Neuron Damage and Repair



When a nerve is badly damaged, proteins and other vital substances produced in the neuron cell bodies cannot be transported all the way out to the ends of their axons. The distal (farther away) portions of the axons—the part beyond the injury—begin to break down without these nutrients. This is known as Wallerian degeneration. However, the Schwann cells near the injured area multiply and begin to form a protective tube. This "tube" helps align the damaged ends of the axons as they regenerate. Further, the Schwann cells secrete growth factors to promote axon regeneration. Therefore, nerve damage in the PNS does not always result in permanent loss of function.

It is a different story in the CNS. Recall that myelination in the CNS is due to the presence of oligodendrocytes. Unlike the Schwann cells in the PNS, oligodendrocytes do not have the capability of supporting regeneration of a damaged axon. For this reason, damage to the brain or spinal cord is more serious and more likely to be permanent than peripheral nerve injury.

The foundation of our thinking in every area of our lives should be the Word of God.

How we understand the world, how we approach our daily tasks, how we view and treat our fellow man — these things should be based on the principles we find in the Bible.

Unfortunately, too many people are so strongly influenced by the views of the world that they reject the direct teaching found in God's Word. These people view the world around them as just a chemical accident. Matter somehow just came into existence all on its own billions of years ago. Then everything in our world just created itself. Millions of years of chemicals banging together resulted in something as incredibly complex as the human body.

Even though we've only just begun our study of the nervous system, I'll bet you are already getting the idea of how complex just this one body system truly is. Do you really think it could have just created itself, all on its own? No, neither do I.

In the Book of Genesis, we are told

> In the beginning God created the heavens and the earth (Gen. 1:1).

There is an all-powerful God who indeed created all things. The earth, the living creatures, the sun and moon, the planets, the stars in the sky—these things did not come into being as the result of an accident. They are not the result of time and chance. They are the work of our wonderful Creator.

Even more, you and I are not the products of chance. We are special creations.

> Then God said, "Let Us make man in Our image, according to Our likeness" (Gen. 1:26a).

As we continue our study of the human body, we need to always remember that the complex systems we study bear the unmistakable mark of the Master Designer. The enormous complexity of the body should remind us constantly of God's wisdom and creativity. We should also be reminded of His boundless love for us that He should take such care in our creation.