

Chapter 1: Neurons, Glia, and the Nervous System

Summary

Your nervous system is built from two families of cells. **Neurons** carry messages as electrical and chemical signals, and **glial cells** keep those neurons fed, insulated, protected, and clean. This chapter tours the parts of a neuron, the three jobs neurons do, the glial cells that support them, and the blood-brain barrier that guards the brain. It ends at the bedside with multiple sclerosis, a disease in which the immune system attacks myelin, the insulation that lets signals travel fast.

Concepts Covered

1. Cell Membrane
2. Ion
3. Protein
4. Concentration Gradient
5. Nervous System
6. Central Nervous System
7. Peripheral Nervous System
8. Neuron
9. Dendrite
10. Cell Body (Soma)
11. Axon
12. Axon Terminal
13. Myelin Sheath
14. Node of Ranvier

15. Glial Cell
16. Astrocyte
17. Oligodendrocyte
18. Schwann Cell
19. Microglia
20. Sensory Neuron
21. Motor Neuron
22. Interneuron
23. Blood-Brain Barrier
24. Multiple Sclerosis

Prerequisites

- None beyond one year of high school biology.

Hi, I'm Ply!



I'm Ply, a California sea slug (*Aplysia californica*), and scientists learned how memories form by studying nerve cells just like mine. I only have about 20,000 neurons and you have billions, so I'm counting on you to put yours to good use! In this chapter you'll meet the cells that make every thought possible, and by the end you'll be able to explain why one patient's blurry vision traces back to a missing layer of fat. Every big idea starts at a single synapse!

Here's how I'll show up in every chapter:

1. **Welcome:** I tell you why the chapter matters.
2. **Thinking:** I flag a big idea worth pausing on.
3. **Tip:** I share a shortcut for remembering or checking something.
4. **Warning:** I point out a common mistake and how to avoid it.
5. **Encourage:** I cheer you through the hard parts.
6. **Celebrate:** I sum up what you just mastered.

If I'm not doing one of those six things, I'm not in the chapter.

1.1 Maya's Alarm Clock

It's 6:30 on a Tuesday morning. Maya, a 16-year-old soccer player who is studying for the Brain Bee, is fast asleep when her phone alarm starts to buzz. Before she is even fully awake, a chain of events has already begun. Tiny sensors in her ears turn the sound into electrical signals. Those signals race along nerve fibers into her brain. Her brain recognizes the sound ("ugh, the alarm"), decides what to do ("snooze it"), and sends a command down her spinal cord and out to the muscles of her arm. Her hand slaps the phone. All of this happens in well under a second, and Maya barely notices.

How can a lump of soft tissue do something so fast and so precise? The answer lives in its cells. Your brain contains about **86 billion** neurons, the cells that carry messages, plus a roughly equal number of other cells, mostly helper cells called glia ([Azevedo et al., 2009](#)). In this chapter you'll learn what these cells look like, what each part does, and what goes wrong when one small part, a fatty wrapping called myelin, is damaged.

1.2 A Quick Chemistry Refresher

Before we meet neurons, we need four ideas from basic biology and chemistry. Neurons use all four, all the time.

Think about a crowded school hallway between classes, with a classroom door. If the hallway is packed and the classroom is nearly empty, people naturally drift into the classroom when the door opens. Nobody has to push them. They spread out because there's more room on the other side. Hold on to that picture.

The cell membrane. Every cell, including a neuron, is wrapped in a **cell membrane**: a thin, flexible barrier made mostly of fat molecules (lipids). It acts like the wall of the hallway. It keeps the inside of the cell separate from the outside, and most charged particles can't slip through it on their own.

Ions. An **ion** is an atom (or small molecule) that carries an electric charge because it has gained or lost electrons. Your body fluids are full of ions. The ones neurons care most about are sodium (Na^+), potassium (K^+), chloride (Cl^-), and calcium (Ca^{2+}). Because ions are charged, moving them around moves electric charge. That is the key to how neurons make electrical signals.

Proteins. A **protein** is a large molecule built from a chain of amino acids that folds into a specific shape. The shape decides the job. Some proteins in the cell membrane act as doors (channels) that let only certain ions through. Others act as pumps that use energy to push ions across the membrane.

Concentration gradients. A **concentration gradient** is a difference in how crowded a substance is in two places, like the packed hallway next to the empty classroom. Substances tend to move "down" their gradient, from crowded to less crowded, whenever a path opens. Neurons keep a steady gradient across their membranes. There is much more sodium outside the cell than inside, and much more potassium inside than outside.

The table below pulls these four ideas together and shows why each one matters for a neuron.

Idea	Everyday picture	Why neurons need it
Cell membrane	The wall of a hallway	Keeps ions separated, so charge can build up
Ion	A charged particle	Moving ions moves charge, which creates electrical signals
Protein	Doors and pumps in the wall	Channels let specific ions through; pumps rebuild the gradients
Concentration gradient	A crowded hallway next to an empty room	Stored "push" that drives ions through open channels

Chapter 2 shows how a neuron opens and closes its ion channels to fire a signal. For now, remember the big idea: a neuron controls the flow of charged particles across its membrane, and that flow is the language of the nervous system.

1.3 The Big Picture: Your Nervous System

Imagine a city. It has a downtown headquarters where decisions are made, and a huge web of roads and cables that reach every house. Messages travel in from the houses ("there's a fire on Elm Street") and out from headquarters ("send a fire truck"). Your body works the same way.

The **nervous system** is the body's communication network. It is the set of all the cells, tissues, and organs that sense the world, process information, and control the body. It has two main divisions:

- The **central nervous system (CNS)** is the headquarters. It is made of the brain and the spinal cord. The CNS receives information, makes sense of it, and decides what to do.
- The **peripheral nervous system (PNS)** is the road network. It includes all the nerves that branch out from the brain and spinal cord to the rest of the body: your skin, muscles, eyes, ears, heart, and gut. The PNS carries information into the CNS and carries commands back out.

A **nerve** is a bundle of many axons (long fibers from neurons, which you'll meet in the next section) wrapped together like wires in a cable. There are twelve pairs of cranial nerves that connect directly to the brain, and many more spinal nerves that branch from the spinal cord.

Here is how the two divisions compare.

	Central nervous system (CNS)	Peripheral nervous system (PNS)
What it includes	Brain and spinal cord	Nerves outside the brain and spinal cord, and clusters of nerve cells along them
City analogy	Headquarters	Roads and cables to every house
Main job	Process information and make decisions	Carry information in and commands out
Protected by	Skull, spine, and the blood-brain barrier	Mostly by surrounding tissue
Glial cell that makes myelin	Oligodendrocyte	Schwann cell

In Maya's alarm story, the sound sensors in her ears and the nerves to her arm belong to the PNS. Recognizing the alarm and deciding to hit snooze happen in the CNS. Keep the last row of the table in mind; it matters later.

1.4 The Neuron: A Cell Built to Send Messages

Picture an uprooted tree lying on its side: spreading branches at one end, a thick base, a long trunk, and a tangle of roots at the far end. Now imagine messages flowing through it one way: in through the branches, down the trunk, and out through the roots to touch the next tree. That is a surprisingly good picture of a neuron.

A **neuron** (nerve cell) is a cell specialized to receive, process, and send information using electrical and chemical signals. Neurons come in many shapes, but most have four main parts.

1. **Dendrites** are the "branches." A **dendrite** is a short, branching extension that receives messages from other neurons and passes them toward the cell body. A single neuron can have many dendrites, which lets it listen to many other neurons at once.
2. The **cell body**, or **soma**, is the "base of the trunk." The **cell body (soma)** contains the nucleus (with the cell's DNA) and the machinery that builds most of the neuron's proteins. It also adds up all the incoming messages from the dendrites.
3. The **axon** is the "trunk." An **axon** is a single long, thin fiber that carries the neuron's own signal away from the cell body. A neuron usually has just one axon, though it may branch near its end. Axons can be extremely long. Some, such as those that run from the lower end of the spinal cord to the muscles of the foot, are about a meter long. The spot where the axon leaves the cell body is a cone-shaped region called the axon hillock. Here and at the start of the axon, the neuron "decides" whether the incoming messages add up to enough to fire.
4. **Axon terminals** are the "roots." An **axon terminal** is one of the small, swollen tips at the end of the axon's branches. This is where the neuron hands its message to the next cell, usually by releasing chemical messengers across a tiny gap. That gap, the synapse, is the star of Chapter 3.

Information in a typical neuron flows one way, in this order:

1. Dendrites receive messages from other cells.
2. The cell body adds up those messages.
3. If the total is strong enough at the axon hillock and the start of the axon, the neuron fires a signal.
4. The signal travels down the axon.
5. The axon terminals pass the message on to the next neuron, a muscle, or a gland.

Don't mix up neuron and nerve



again.

A common trap is using "neuron" and "nerve" as if they mean the same thing. A neuron is one single cell, while a nerve is a cable made of the axons of hundreds or thousands of neurons bundled together. If you can picture one wire versus a whole power cord, you'll never mix them up

Where the "neuron" idea came from

It wasn't always obvious that the brain is made of separate cells. In the late 1800s, scientists argued about whether the nervous system was one giant connected web or a collection of individual cells. The Spanish scientist Santiago Ramón y Cajal stained brain tissue, studied it under the microscope, and drew detailed pictures of neurons by hand. His work showed that neurons are separate cells that communicate at contact points. He shared the 1906 Nobel Prize in Physiology or Medicine with the Italian scientist Camillo Golgi, whose staining method Cajal used and improved ([Nobel Prize, 1906](#)). Ironically, Golgi himself favored the "one giant web" idea ([Wikipedia: Neuron doctrine](#)).

Scientists also learn from animals with simpler nervous systems. The sea slug *Aplysia* (Ply's species) has relatively few neurons, and many are large and easy to identify. Eric Kandel used *Aplysia* to show how connections between neurons change during learning, work that earned him a share of the 2000 Nobel Prize in Physiology or Medicine ([Nobel Prize, 2000](#)). You'll come back to Ply's neurons in Chapter 9.

1.5 Three Jobs for Neurons

It's afternoon, and Maya is at soccer practice. A ball flies toward her, she sees it, and she traps it with her foot. Three kinds of neurons make that happen, each defined by the direction its messages travel.

- A **sensory neuron** carries information *from* the body and the outside world *toward* the CNS. Sensory neurons start at receptors that detect light, sound, touch, temperature, stretch, or chemicals. When light from the ball hits Maya's eyes, sensory neurons carry the news inward. (Sensory neurons are also called afferent neurons. "Afferent" means "carrying toward.")
- A **motor neuron** carries commands *from* the CNS *out* to muscles (and glands). Motor neurons in Maya's spinal cord send long axons down her leg to the muscles that move her foot. (Motor neurons are also called efferent neurons. "Efferent" means "carrying away.")
- An **interneuron** connects other neurons to each other inside the CNS. Interneurons sit between sensory input and motor output. They compare, combine, and route information. Much of the work of judging where the ball will land and choosing how to move happens in circuits of interneurons in Maya's brain and spinal cord.

Here is a side-by-side comparison of the three types you just met.

Neuron type	Direction of message	Where the cell body usually sits	Maya example
Sensory neuron	Body → CNS	Outside the spinal cord, in clusters along nerves, or in sense organs	Light from the ball reaches her eyes
Interneuron	Neuron → neuron, within the CNS	Brain and spinal cord	Her brain predicts where the ball will land
Motor neuron	CNS → muscle or gland	Brainstem and spinal cord (taking orders from motor areas of the brain)	Her leg muscles contract to trap the ball

A memory trick for direction



Here's a shortcut: **S**ensory starts at the **S**urface and heads in; **M**otor moves **M**uscles and heads out. Interneurons are the "in-between" cells that link the two.

1.6 Myelin and Nodes of Ranvier: Insulation for Speed

Think about your phone's charging cable. Inside is a copper wire, and around it is a plastic coating that keeps the electricity from leaking out. Now imagine sending a signal down a wire that leaks along its whole length. The signal would fade and slow down.

Axons face the same problem. An axon's membrane is a little "leaky": as a signal travels, some electric charge escapes. Many axons solve this problem with insulation.

The **myelin sheath** is a fatty, insulating layer wrapped many times around an axon. It is made of lipids and proteins, and it isn't made by the neuron itself. Glial cells (Section 1.7) wrap it around the axon, like electrical tape wound around a wire. Myelin is what makes the brain's "white matter" look white.

Myelin is not one continuous tube. It comes in segments, with tiny gaps between them. Each bare gap is called a **node of Ranvier**, named after the French scientist Louis-Antoine Ranvier, who described them in the 1800s. Nodes are packed with ion channels. This is where the speed comes from: the signal is renewed at full strength at each node, and the insulated stretches in between let it race ahead without leaking. The signal seems to jump from node to node. (Chapter 2 gives this jumping its official name and explains the ion channels behind it.)

Myelin makes a big difference in speed.

Kind of axon	Typical speed	Comparison
Thin, unmyelinated (for example, some pain and temperature fibers)	About 1 meter per second	Walking speed
Thick, myelinated (for example, many motor neurons)	More than 100 meters per second	Race car speed

These figures come from an open university textbook on sensation and perception ([University of Minnesota, *Introduction to Sensation and Perception*](#)). The fastest myelinated axons carry signals more than a hundred times faster than the slowest bare ones. That's why the axons that control Maya's leg muscles are myelinated.

Why insulation means speed



Notice the shortcut: the neuron only has to renew its signal at the nodes, not at every point along the axon. Think of it like a relay race where runners only need to stand at a few checkpoints instead of every few steps. If the insulation between two checkpoints is lost, the baton has to be carried slowly the whole way, and it might be dropped.

This hints at what happens when myelin is damaged. Charge leaks out of the bare stretch, so the signal slows and weakens. If the damaged stretch is long enough, the signal fades out before it reaches the next healthy node, and the message is never delivered. That idea is the key to the disease at the end of this chapter.

1.7 Glia: The Nervous System's Support Crew

A soccer team isn't only the players on the field. Coaches, trainers, medical staff, and groundskeepers never score a goal, but without them the team falls apart. Your nervous system has a support crew too.

A **glial cell** (or glia) is any cell of the nervous system that is not a neuron. Glia don't send fast electrical signals the way neurons do. Instead, they build myelin, support and protect neurons, clean up, and fight infection. The German scientist Rudolf Virchow described them in 1856 while looking for the brain's "connective tissue," and the name glia comes from the Greek word for "glue." For a long time, glia were treated as packing material. We now know they are active partners.

How many glia are there? You may have read that glia outnumber neurons ten to one. A careful review of 150 years of cell counting found that the real ratio in the whole human brain is about one to one or a little less, with fewer than 100 billion glia in total ([von Bartheld, Bahney, and Herculano-Houzel, 2016](#)). The ratio varies by brain region, but "ten to one" was never backed by good data.

This chapter covers four kinds of glia.

Astrocytes. An **astrocyte** is a star-shaped glial cell of the CNS. ("Astro" means star.) Astrocytes are multitaskers. They give neurons structural and metabolic support, and recycle chemical messengers around synapses so signals stay crisp ([OpenStax](#)). Their long arms end in "end-feet" that wrap around the brain's tiny blood vessels. Those end-feet come up again in Section 1.9.

Oligodendrocytes. An **oligodendrocyte** is a glial cell of the CNS that makes myelin. ("Oligo" means few and "dendro" means branch.) Each oligodendrocyte sends out several arms, and each arm wraps one segment of myelin around a nearby axon. One oligodendrocyte can myelinate segments of many different axons, by some counts up to about 40.

Schwann cells. A **Schwann cell** is a glial cell of the PNS that makes myelin. Unlike an oligodendrocyte, each Schwann cell wraps just one segment of one axon. So a long peripheral axon needs a whole row of Schwann cells along its length. Schwann cells are named after the German scientist Theodor Schwann.

Microglia. **Microglia** are small immune cells that live in the CNS. Microglia constantly patrol the brain, find and swallow invaders and dead or damaged cells, and help trim away

unnneeded connections between neurons as the brain develops. You can think of them as the brain's security guards and cleanup crew rolled into one.

So many new words!



If the glia names feel like a vocabulary avalanche, that's normal; most people need a couple of passes. Try sorting them by just two questions: "Brain and spinal cord, or body?" and "What's its one main job?" The table below does exactly that, so use it as your cheat sheet.

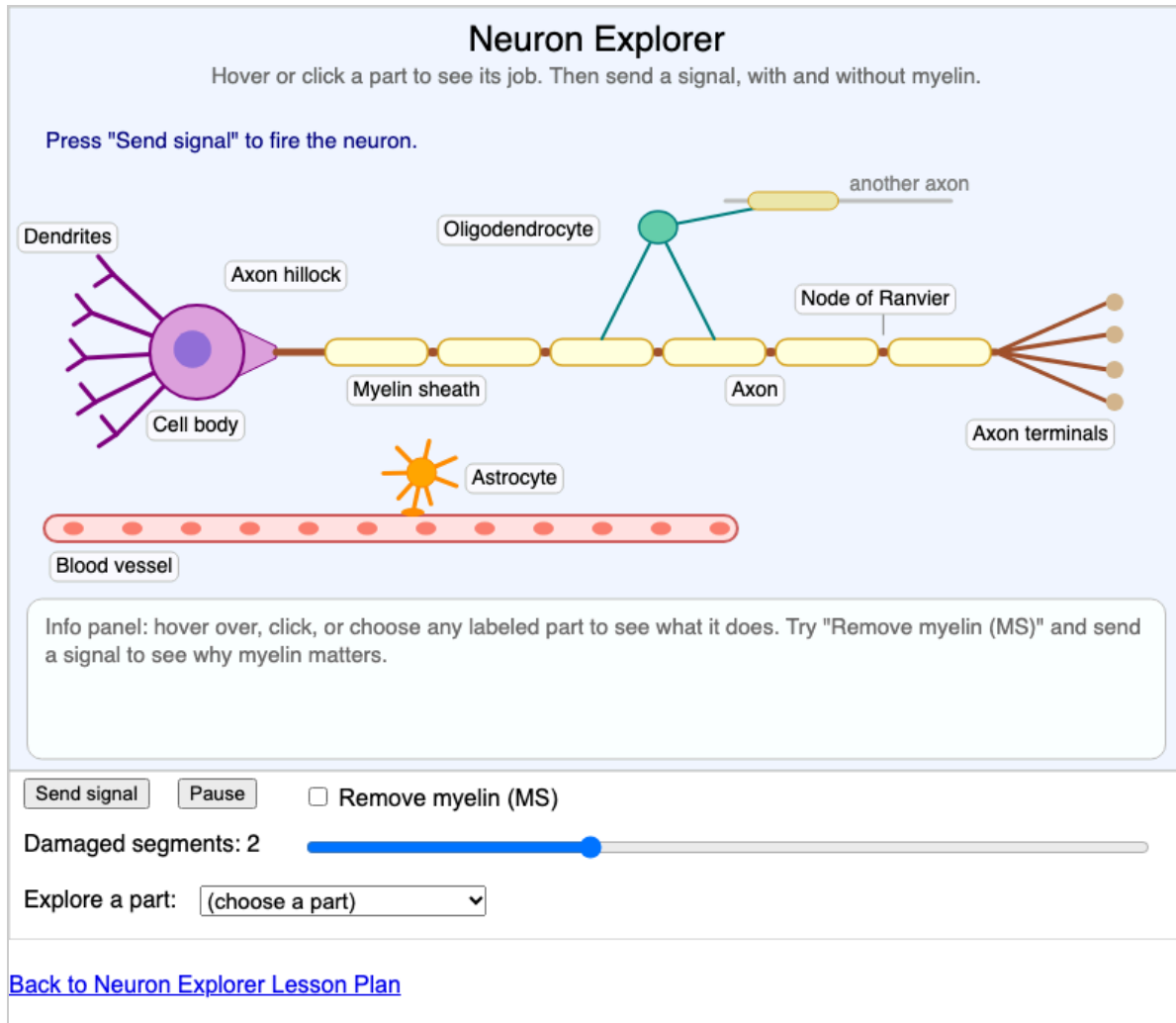
Here are the four glial cells, sorted by where they live and what they do.

Glial cell	Where it lives	Main job	Easy picture
Astrocyte	CNS	Supports and feeds neurons, cleans up around synapses, wraps blood vessels	Star-shaped caretaker
Oligodendrocyte	CNS	Makes myelin for segments of many axons	One octopus wrapping many wires
Schwann cell	PNS	Makes myelin for one segment of one axon	One roll of tape per segment
Microglia	CNS	Immune defense and cleanup	Security guard and janitor

1.8 Putting It Together: Explore a Neuron

You now know every part in the simulation below. It shows a neuron with its dendrites, cell body, axon hillock, axon, myelin sheath, nodes of Ranvier, and axon terminals. Nearby are an oligodendrocyte, whose arms wrap myelin around the axon (and around a second axon), and an astrocyte, whose end-foot touches a blood vessel.

Diagram: Neuron Explorer



Screenshot of the interactive simulation. Try it online: <https://aaryavvatts-lab.github.io/neuroscience-textbook/sims/ch01-neuron-explorer/>

[Open the Neuron Explorer fullscreen](#)



MicroSim specification: Neuron Explorer



Type: microsim **sim-id:** ch01-neuron-explorer

Library: p5.js

Status: Implemented

Bloom Level: Understand

Bloom Verb: explain

Learning Objective: The learner will explain the job of each part of a neuron and two nearby glial cells, and explain why losing myelin slows a signal or blocks it.

Parts with info-panel text (hover, click, or menu): dendrites, cell body (soma), axon hillock, axon, myelin sheath, node of Ranvier, axon terminals, oligodendrocyte, astrocyte, blood vessel (capillary).

Controls: Send signal (button); Pause/Resume (button); Remove myelin (MS) (checkbox, default off); Damaged segments (slider, min 1, max 4, step 1, default 2); Explore a part (menu).

Behavior (simplified, illustrative model): The axon has 6 myelinated segments. A signal crosses a healthy segment in 8 frames and is renewed to 100% at each healthy node. With Remove myelin (MS) checked, the chosen number of segments (starting under the oligodendrocyte) lose myelin. A bare segment takes 40 frames to cross, and the signal's strength falls by a factor of 0.55 per bare segment. If it reaches a healthy node with strength $\geq 25\%$, it is renewed to 100%; if strength drops below 25% first, the signal is blocked. Result: 1 or 2 damaged segments = arrives late; 3 or 4 damaged segments = blocked. The sim starts paused with no signal.

Chapter Anchors: 1 or 2 damaged segments slow the signal; 3 or 4 block it. Speeds and fading are illustrative, not measured.

First, hover over or click each labeled part and read its job in the info panel. Then press **Send signal** with healthy myelin and watch the signal flash at each node as it races to the axon terminals. Notice that the oligodendrocyte's arms reach two segments of this axon *and* a segment of another axon, so damage to one oligodendrocyte can affect more than one pathway.

Next, check **Remove myelin (MS)** and send the signal again with 2 damaged segments. The signal crawls through the bare stretch, weakens, and arrives late. Now slide to 3 or 4 damaged segments. This time the signal fades out before it reaches a healthy node, and the message never arrives. If this axon carried information from the eye, what would the person notice in each case?

1.9 The Blood-Brain Barrier: The Brain's Security Checkpoint

Think about airport security: travelers with tickets get through to the gates, and many other things are stopped. The brain has its own security checkpoint, built into the walls of its blood vessels.

In most of the body, the walls of the smallest blood vessels (capillaries) have small gaps, so many substances leak out of the blood into the tissue. The brain and spinal cord are different. The **blood-brain barrier** is a protective filter between the blood and the fluid around the brain's cells. It is formed mainly by the cells lining the brain's capillaries, which are sealed tightly together, with support from astrocyte end-feet wrapped around the vessels and other support cells embedded in the vessel walls ([Wikipedia: Blood-brain barrier](#)).

The blood-brain barrier does two jobs at once:

- **It lets in what the brain needs.** Oxygen and some other small molecules pass through easily. Special transport proteins carry in glucose (the brain's main fuel) and amino acids.
- **It keeps out what could cause harm.** Most germs, many large molecules, and many substances that dissolve easily in water are blocked.

This protection matters, because the brain is a very hungry organ. It makes up only about 2 to 3 percent of body weight but uses roughly 20 to 25 percent of the body's energy ([OpenStax, Introduction to Behavioral Neuroscience](#); [Scientific American, 2008](#)). It needs a steady, carefully controlled supply.

The barrier has a downside for medicine: because it blocks so much, many drugs that might help brain diseases can't get in. And as you'll see next, in multiple sclerosis, immune cells that are normally kept out manage to cross into the brain and spinal cord, where they cause damage.

At the Bedside: Blurry Vision and Tingling Legs

Meet the patient

Jordan is a 28-year-old graphic designer. Over three days, the vision in her right eye has become blurry and "washed out," as if she's looking through frosted glass. It hurts a little when she moves that eye. When she mentions it to her doctor, she adds something she had brushed off: a year ago, both of her legs tingled and felt numb for about two weeks, and then the feeling went away on its own. She also says her symptoms seem worse after a hot shower.

What the doctor checks: The doctor tests Jordan's vision and finds that her right eye sees less sharply and that colors look faded in that eye. A full neurological exam checks strength, sensation, reflexes, coordination, and walking. The doctor orders an MRI scan of the brain and spinal cord, which shows several small spots of damage (lesions) in the white matter, in more than one place. Other tests that doctors may use include a lumbar puncture (a sample of the fluid around the spinal cord, to look for signs of inflammation) and evoked potential tests, which measure how quickly the nervous system responds to stimulation such as a flashing pattern ([NINDS, Multiple Sclerosis](#)).

Where is the problem? (localization): Painful, blurry vision in one eye points to the optic nerve, the cable of axons that carries signals from the eye to the brain. This is called optic neuritis (inflammation of the optic nerve). Despite its name, the optic nerve is technically a tract of the CNS, and its myelin is made by oligodendrocytes, not Schwann cells ([Wikipedia: Optic nerve](#)). The earlier tingling in *both* legs points somewhere else: the spinal cord, where sensory pathways from both legs travel close together. So Jordan has had problems in at least two parts of the CNS, at two different times, and both are made of myelinated axons wrapped by oligodendrocytes. "Different places, different times, white matter" is a classic pattern that makes doctors think of one disease.

Diagnosis: Multiple sclerosis (MS), relapsing-remitting type. **Multiple sclerosis** is a long-lasting autoimmune disease in which the immune system mistakenly attacks myelin in the central nervous system. It also damages the axons and nerve cell bodies themselves over time. "Sclerosis" refers to the scar-like patches (plaques or lesions) that form where myelin has been attacked, which are visible on MRI. Symptoms usually begin between ages 20 and 40, and women are affected more often than men ([NINDS](#)). One large study of health insurance records estimated that about 727,000 U.S. adults were living with MS in 2010, with women affected about 2.8 times as often as men. Extending their numbers forward, the same researchers estimated roughly 850,000 to 914,000 by 2017, and they warned that this extension should be read with caution ([Wallin et al., 2019](#)). A 2023 study using a similar

method found about 745,000 U.S. adults with MS ([Hittle et al., 2023](#)), but its records also date from 2008 to 2010, so these remain the most detailed national counts this book could find as of 2026. Most people with MS are first diagnosed with the relapsing-remitting form, in which attacks are followed by full or partial recovery.

Why it happens: This is the Neuron Explorer in real life. In MS, immune cells cross into the CNS and attack myelin and the oligodendrocytes that make it. Where myelin is stripped away, charge leaks out of the bare axon, and signals slow, weaken, or fail, just as in the sim. Slowed or blocked signals in the optic nerve cause blurry, washed-out vision. Blocked signals in the spinal cord's sensory pathways cause tingling and numbness. Symptoms can improve after an attack as inflammation calms down and the nervous system partly recovers. Many people with MS notice that heat temporarily makes symptoms worse ([NINDS](#)). Notice that the attack happens in the CNS, which is why the oligodendrocyte, not the Schwann cell, is the glial cell in trouble.

Treatment today: There is no cure yet, but treatment has improved a lot. For a sudden attack, doctors may give corticosteroids (strong anti-inflammatory medicines) for a few days to speed recovery, although these don't change the long-term course. To prevent future attacks and slow the disease, neurologists prescribe disease-modifying therapies, which calm or redirect the immune system. Some are pills, some are injections, and some are infusions. Physical and occupational therapy, treatment of symptoms like fatigue and stiffness, and staying active also help ([NINDS](#)). Most people with MS have a normal life expectancy.

What's new in research: One of the biggest advances has been B-cell depletion. B cells are a type of white blood cell, and drugs that remove many of them from the blood reduce MS attacks. In March 2017, the FDA approved ocrelizumab, a B-cell-depleting antibody, for relapsing MS and for primary progressive MS, making it the first approved disease-modifying therapy for the primary progressive form ([Genentech, 2017](#)). Other B-cell-depleting drugs have followed for relapsing MS, including ofatumumab (FDA approval, August 2020; [Novartis, 2020](#)) and ublituximab (FDA approval, December 2022; [Pharmacy Times, 2023](#)).

A newer kind of pill, called a BTK inhibitor (it blocks BTK, an enzyme that some immune cells use to pass signals inside the cell), crosses the blood-brain barrier and calms immune signaling inside the CNS, including in microglia. Its approval status differs by country, so dates matter. In December 2025, the FDA declined to approve tolebrutinib for secondary progressive MS without relapses ([Pharmacy Times, 2025](#)). In 2026 the European Union

approved it for that form of MS, with liver injury listed as a known risk that needs close monitoring ([NeurologyLive, 2026](#)). As of 2026, it is not approved in the United States.

Researchers are also asking what triggers MS. A 2022 study that followed more than 10 million young adults in the U.S. military found that the risk of MS rose 32-fold after infection with Epstein-Barr virus (the virus that causes mononucleosis), but not after other viruses. That makes the virus a leading suspected cause ([Bjornevik et al., 2022, Science](#)). Most people who catch the virus never get MS, so other factors, such as genes and vitamin D, are also involved.

Your turn: diagnose a variation

A 45-year-old man had a stomach bug two weeks ago. Now, over a few days, his feet and hands tingle and his legs have become weak, climbing up toward his arms. His reflexes are gone. An MRI of his brain and spinal cord is normal, but tests of the nerves in his arms and legs show that signals travel very slowly along them. Like MS, this is an immune attack on myelin. Which part of the nervous system is affected, and which glial cell's myelin is under attack?

Answer: The peripheral nervous system. The normal brain and spinal cord MRI and the slowed signals in the limb nerves point to the PNS, so the myelin under attack is made by Schwann cells. This pattern fits Guillain-Barré syndrome, a rare disorder in which the immune system attacks the peripheral nerves, most commonly their myelin ([NINDS, Guillain-Barré Syndrome](#)). It is a medical emergency because weakness can spread to the breathing muscles. MS and Guillain-Barré both strip myelin, but they strike opposite sides of the CNS/PNS border.

This is a fictional teaching case. It is not medical advice. If you or someone you know has symptoms like these, talk to a doctor.

Common Misconceptions

Myth: The brain is made only of neurons.

Reality: The brain contains about as many non-neuron cells as neurons. Most of these are glia, and the rest include the cells that make up blood vessels ([Azevedo et al., 2009](#)). A brain made only of neurons would have no myelin, no immune defense, and no blood-brain barrier.

Myth: Glia are just "glue" that holds neurons in place.

Reality: The name is a leftover from the 1800s. Glia make myelin, feed neurons, clean up

chemical messengers at synapses, help form the blood-brain barrier, and fight infection. When glia fail, as oligodendrocytes do in MS, the nervous system stops working properly.

Myth: Glia outnumber neurons ten to one.

Reality: A review of 150 years of cell counting found that the ratio of glia to neurons in the whole human brain is about one to one or a little less, and the "ten to one" claim was never supported by solid data ([von Bartheld et al., 2016](#)).

Myth: We only use 10 percent of our brain.

Reality: Brain imaging shows that over the course of a day, most regions of the brain are active, and some stay active even during sleep. The brain is only about 3 percent of body weight but uses about 20 percent of the body's energy, and an organ that expensive would not be mostly idle ([Scientific American, 2008](#)).

Brain Bee Practice

? 1. Name the four main parts of a typical neuron, in the order a message travels through them. ✓

Dendrites, cell body (soma), axon, and axon terminals. Messages come in through the dendrites, are added up in the cell body, travel down the axon, and leave through the axon terminals.

? 2. Which glial cell makes myelin in the central nervous system, and which makes it in the peripheral nervous system? ✓

Oligodendrocytes make myelin in the CNS, and one oligodendrocyte can myelinate segments of many axons. Schwann cells make myelin in the PNS, and each Schwann cell wraps one segment of one axon.

? 3. What are nodes of Ranvier, and why do they matter? ✓

They are the small, bare gaps between segments of myelin along an axon. They are packed with ion channels, so the signal is renewed at each node, which lets it seem to jump from node to node and travel much faster than along an unmyelinated axon.

? 4. A patient has optic neuritis now and had numbness in both legs a year ago. MRI shows white matter lesions in the brain and spinal cord. What disease is most likely, and what is being attacked? ✓

Multiple sclerosis. The immune system is attacking myelin (and the oligodendrocytes that make it) in the central nervous system, causing lesions in different places at different times.

? 5. What is the blood-brain barrier, and which glial cell helps support it? ✓

It is a protective filter formed mainly by tightly sealed cells lining the brain's capillaries, which lets in needed substances like glucose and oxygen but blocks most germs and many other molecules. Astrocytes support it by wrapping their end-feet around these blood vessels.

Exercises

Remember

1. Define *cell membrane*, *ion*, and *concentration gradient* in your own words.
2. List the four kinds of glial cells from this chapter and state where each one lives (CNS or PNS).

✎ Answer ✓

1. The cell membrane is the thin, fatty barrier that wraps a cell and separates inside from outside. An ion is an atom or small molecule with an electric charge. A concentration gradient is a difference in how crowded a substance is in two places; substances tend to move from crowded to less crowded.
2. Astrocytes (CNS), oligodendrocytes (CNS), microglia (CNS), and Schwann cells (PNS).

Understand

1. Explain the difference between the central nervous system and the peripheral nervous system, using the "city" analogy from Section 1.3.
2. Explain why a myelinated axon carries signals faster than an unmyelinated axon of similar size.

Answer



1. The CNS (brain and spinal cord) is like a city's headquarters, where information is processed and decisions are made. The PNS (nerves throughout the body) is like the road and cable network that carries messages in from the houses and commands back out.
2. Myelin insulates the axon so that electric charge does not leak out along the way. The signal only has to be renewed at the nodes of Ranvier, so it seems to jump from node to node instead of being rebuilt at every point along the axon.

Apply

1. Maya touches a hot pan and pulls her hand away. For each step, name the type of neuron involved (sensory, interneuron, or motor): (a) heat detected in the skin of her fingertip; (b) signal relayed inside her spinal cord; (c) her arm muscles contract.
2. A new medicine works well on brain cells in a lab dish but has no effect when given to patients as a pill. Using what you know about the blood-brain barrier, suggest one reason why, and one property the medicine would need to work better.

Analyze

1. In the Neuron Explorer, removing myelin from 2 segments slows the signal, but removing it from 3 segments blocks it. Analyze why the length of a damaged stretch matters, using the ideas of leaking charge and renewal at nodes.
2. A patient has muscle weakness. Compare how you would expect the problem to look if it came from damaged motor neurons in the spinal cord versus damaged Schwann cells along the nerves to the legs. What test results might help tell them apart?

Evaluate

1. A website claims that "glia are just filler cells, so brain health is all about neurons." Evaluate this claim using at least three pieces of evidence from this chapter.
2. Which do you think is the most important job of glia: making myelin, supporting the blood-brain barrier, or immune defense? Defend your choice using an example of what goes wrong when that job fails.

Create

1. Design a one-page infographic for middle school students explaining what myelin is and why MS affects signals. Use an analogy other than this chapter's phone cable.
2. Write a short fictional case (5 to 7 sentences) of a patient whose symptoms come from a problem in the PNS rather than the CNS. Include the symptoms, one exam finding, and the clue that lets a doctor localize the problem to the PNS.

Key Takeaways

- The nervous system has two divisions: the **central nervous system** (brain and spinal cord) processes information, and the **peripheral nervous system** (nerves throughout the body) carries information in and commands out.
- Neurons send messages by controlling the flow of **ions** across their **cell membrane**, using membrane **proteins** and **concentration gradients**.
- A typical neuron receives messages through **dendrites**, adds them up in the **cell body (soma)**, sends its signal down the **axon**, and passes it on at the **axon terminals**.
- **Sensory neurons** carry information toward the CNS, **motor neurons** carry commands out to muscles, and **interneurons** connect neurons within the CNS.
- The **myelin sheath** insulates axons, and the signal is renewed at **nodes of Ranvier**, so myelinated axons can carry signals more than a hundred times faster than thin unmyelinated ones.
- **Glial cells** are roughly as numerous as neurons (about one to one, or a little fewer): **astrocytes** support neurons and the **blood-brain barrier**, **oligodendrocytes** (CNS) and **Schwann cells** (PNS) make myelin, and **microglia** defend and clean the brain.
- In **multiple sclerosis**, the immune system attacks CNS myelin, so signals slow or fail, causing symptoms such as blurry vision and tingling that depend on where the damage is.

You've met the whole crew!



talk!

You can now name every part of a neuron, sort the glial cells by job and location, and explain why a patch of missing myelin can blur someone's vision. Next, in Chapter 2, we'll zoom in on the axon and watch ions rush through their channels to create the electrical spike every neuron uses to