Unit 1
THE NERVOUS SYSTEM

→ Structure and Functioning of the Neuron

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Nervous System

- We will explore a complex system of cells, chemicals, and organs that work together to produce behavior, thoughts, and actions.
- The first part of this complex arrangement is the **nervous system,** a network of cells that carries information to and from all parts of the body.
- The field of **neuroscience** is a branch of the life sciences that deals with the structure and functioning of the brain and the neurons, nerves, and nervous tissue that form the nervous system.
- **Biological psychology, or behavioral neuroscience,** is the branch of neuroscience that focuses on the biological bases of psychological processes, behavior, and learning, and it is the primary area associated with the biological perspective in psychology.

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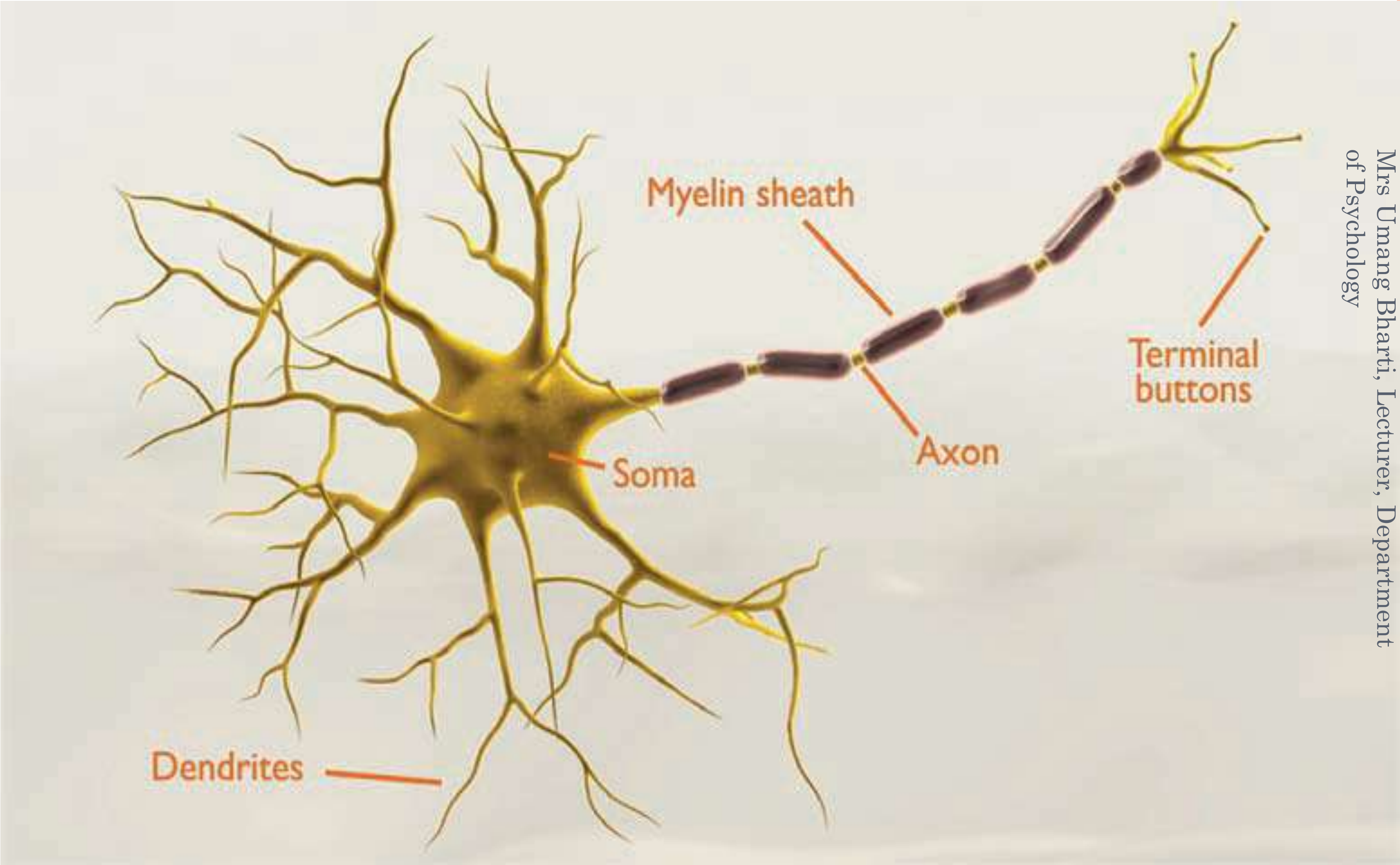
Structure of the Neuron: The Nervous System's Building Block



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Neuron

- Most cells have three things in common: a **nucleus**, a **cell body**, and a **cell membrane** holding it all together.
- The **neuron** is the specialized cell in the nervous system that receives and sends messages within that system.
- Neurons are one of the messengers of the body, and that means that they have a very special structure.

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PARTS OF THE NEURON

Dendrites

- *"Tree-like," or "branch,"* and this structure does indeed look like the branches of a tree
- Receive messages from other cells.

Soma

- The dendrites are attached to the cell body, or soma.
- The word *soma means "body."*
- The part of the cell that contains the nucleus and keeps the entire cell alive and functioning.

Axon

- *A fiber* attached to the soma, and its job is to carry messages out to other cells.

Axon Terminals

- The end of the axon branches out into several shorter fibers that have swellings or little knobs on the ends.
- May also be called presynaptic terminals, terminal buttons, or synaptic knobs
- Responsible for communicating with other nerve cells.

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GLIAL CELLS

Neurons make up a large part of the brain but they are not the only cells that affect our thinking, learning, memory, perception, and all of the other facets of life that make us who we are.

The other primary cells are called glia, or **glial cells**, which serve a variety of functions.

Some glia serve as a sort of structure on which the neurons develop and work and that hold the neurons in place.

Other glia are involved in getting nutrients to the neurons, cleaning up the remains of neurons that have died, communicating with neurons and other glial cells, and providing insulation for neurons.

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Two special types of glial cells

Oligodendrocytes

(produce myelin for the neurons in the brain and spinal cord - the central nervous system)

Schwann cells

(produce myelin for the neurons of the body - the peripheral nervous system)

Generate a layer of fatty substances called **myelin**

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MYELIN SHEATH

Myelin wraps around the shaft of the axons, forming an insulating and protective sheath.

Bundles of myelin-coated axons travel together as “cables” in the central nervous system called *tracts*, and in the peripheral nervous system bundles of axons are called **nerves.**

Myelin from Schwann cells has a unique feature that can serve as a tunnel through which damaged nerve fibers can reconnect and repair themselves.

Unfortunately, myelin from oligodendrocytes covering axons in the brain and spinal cord does not have this feature, and these axons are more likely to be permanently damaged.

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Nodes and electrical impulse

- Myelin sheath not only insulates and protects the neuron, it also speeds up the neural message traveling down the axon.
- The places where the myelin seems to bump are actually small spaces on the axon called **nodes**, which are not covered in myelin.
- Myelinated and unmyelinated sections of axons have slightly different electrical properties. There are also far more ion channels at each node.
- Both of these features affect the speed the electrical signal is conducted down the axon.
- When the electrical impulse that is the neural message travels down an axon coated with myelin, the electrical impulse is regenerated at each node and appears to "jump" or skip rapidly from node to node down the axon. That makes the message go much faster down the coated axon than it would down an uncoated axon of a neuron in the brain.

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Generating the Message Within the Neuron: The Neural Impulse

Neuron at Rest

- Not currently firing a neural impulse or message—is actually **electrically charged**.
- Inside and outside of the cell is a **semiliquid** (jelly-like) solution in which there are charged particles, or ions.

Diffusion and Electrostatic Pressure

- **Diffusion**, the process of ions moving from areas of high concentration to areas of low concentration, and
- **Electrostatic pressure**, the relative electrical charges when the ions are at rest.

Cell Membrane

- The cell membrane itself is **semipermeable**.
- This means some substances that are outside the cell can enter through tiny protein openings, or channels, in the membrane, while other substances in the cell can go outside.

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Inside and outside the cell

Many of these channels are gated—they open or close based on the electrical potential of the membrane—more about that in a minute.

Inside the cell

- A concentration of both smaller positively charged potassium ions and larger negatively charged protein ions.
- The negatively charged protein ions, however, are so big that they can't get out, which leaves the inside of the cell primarily negative when at rest.

Outside the cell

- Lots of positively charged sodium ions and negatively charged chloride ions.
- But they are unable to enter the cell membrane when the cell is at rest because the ion channels that would allow them in are closed.

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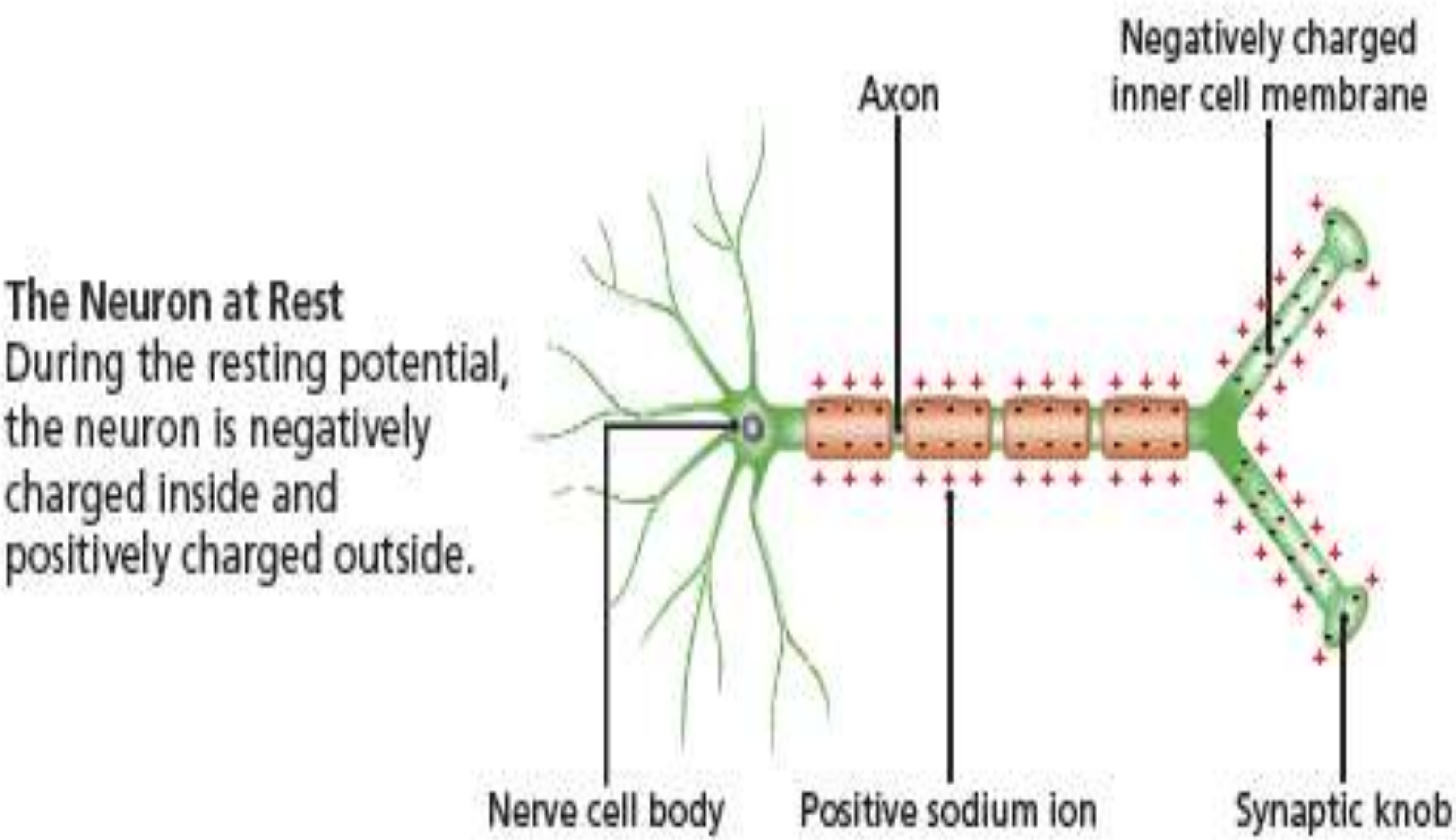
But because the outside sodium ions are positive and the inside ions are negative, and because opposite electrical charges attract each other, the sodium ions will cluster around the membrane. This difference in charges creates an electrical potential.



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RESTING POTENTIAL

Think of the ions inside the cell as a baseball game inside a stadium (the cell walls). The sodium ions outside the cell are all the fans in the area, and they want to get inside to see the game.

When the cell is resting (the electrical potential is in a state called the **resting potential,** because the cell is at rest), the fans are stuck outside.

The sodium ions cannot enter when the cell is at rest, because even though the cell membrane has all these channels, the particular channels for the big sodium ions aren't open yet.

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ACTION POTENTIAL

But when the cell receives a strong enough stimulation from another cell (meaning that the dendrites are activated), the cell membrane opens up those particular channels, one after the other, all down its surface, allowing the sodium ions (the "fans") to rush into the cell.

That causes the inside of the cell to become mostly positive and the outside of the cell to become mostly negative, because many of the positive sodium ions are now inside the cell—at the point where the first ion channel opened.

This electrical charge reversal will start at the part of the axon closest to the soma, the *axon hillock,* and then proceed down the axon in a kind of chain reaction.

This electrical charge reversal is known as the **action potential** because the electrical potential is now in action rather than at rest.

Each action potential sequence takes about one thousandth of a second, so the neural message travels very fast—from 2 miles per hour in the slowest, shortest neurons to 270 miles per hour in other neurons.

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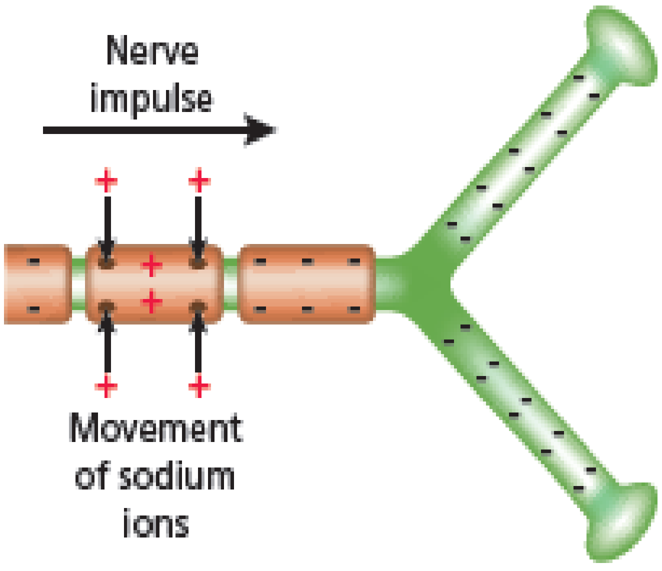

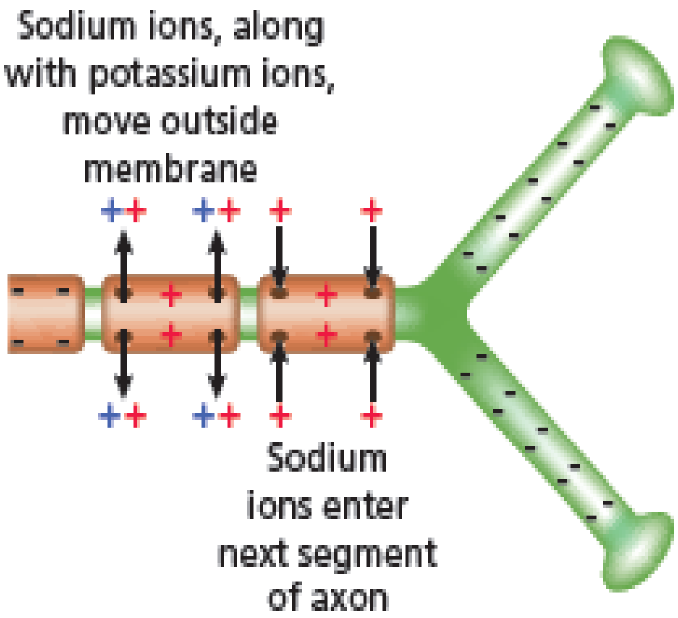

The Neural Impulse
The action potential occurs when positive sodium ions enter into the cell, causing a reversal of the electrical charge from negative to positive.

The Neural Impulse Continues
As the action potential moves down the axon toward the axon terminals, the cell areas behind the action potential return to their resting state of a negative charge as the positive sodium ions are pumped to the outside of the cell, and the positive potassium ions rapidly leave.

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What is happening to the parts of the cell that the action potential has already left behind?

How does the cell get the "fans" back outside?

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Remember, the action potential means that the cell is now positive inside and negative outside at the point where the channel opened.

Several things happen to return the cell to its resting state.

First, the sodium ion channels close immediately after the action potential has passed, allowing no more "fans" (sodium ions) to enter.

The cell membrane also literally pumps the positive sodium ions back outside the cell, kicking the "fans" out until the next action potential opens the ion channels again. This pumping process is a little slow, so another type of ion gets into the act.

Small, positively charged potassium ions inside the neuron move rapidly out of the cell after the action potential passes, helping to more quickly restore the inside of the cell to a negative charge.

Now the cell becomes negative inside and positive outside, and the neuron is capable of "firing off " another message. Once the sodium pumps finish pumping out the sodium ions, the neuron can be said to have returned to its full resting potential, poised and ready to do it all again.

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THRESHOLD FOR FIRING

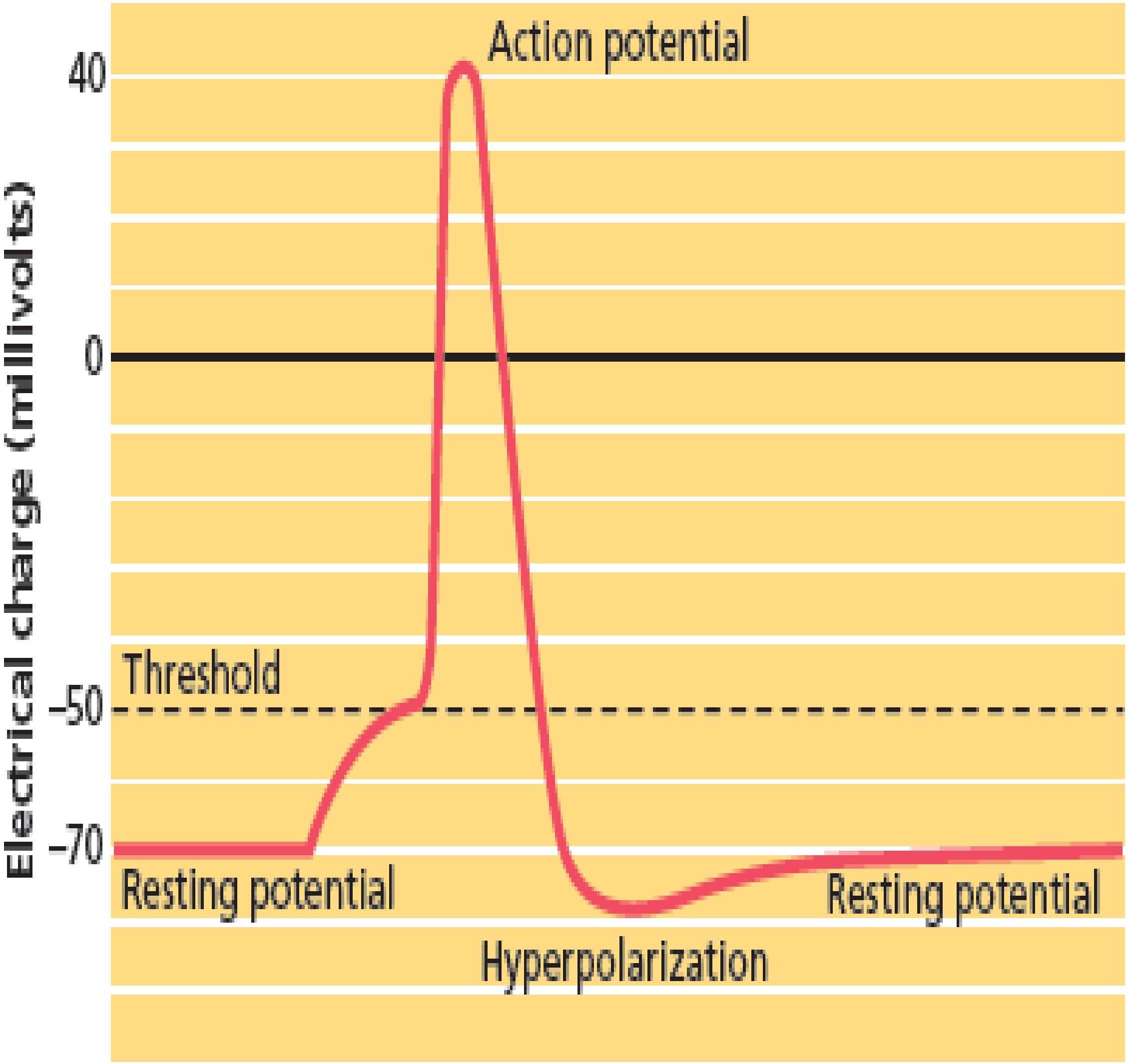
Each neuron is receiving many signals from other neurons.

Some of these signals are meant to cause the neuron to fire, whereas others are meant to prevent the neuron from firing.

The neuron constantly adds together the effects of the "fire" messages and subtracts the "don't fire" messages, and if the fire messages are great enough, the threshold is crossed and the neuron fires.

When a neuron does fire, it fires in an **all-or-none** fashion**.** That is, neurons are either firing at full strength or not firing at all—there's no such thing as "partial" firing of a neuron.

Example - turning on a light switch.



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Sending the Message to Other Cells: The Synapse

Synaptic Vesicles
- A number of little sac-like structures in the presynaptic terminal.

Neurotransmitters
- Inside the synaptic vesicles are chemicals suspended in fluid, which are molecules of substances.
- They are inside a neuron and they are going to transmit a message.

Synapse or the Synaptic Gap
- Between the axon terminal and the dendrite of another neuron is a fluid-filled space.

Receptor Sites
- The surface of the dendrite next to the axon contains ion channels that have receptor sites, proteins that allow only particular molecules of a certain shape to fit into it.

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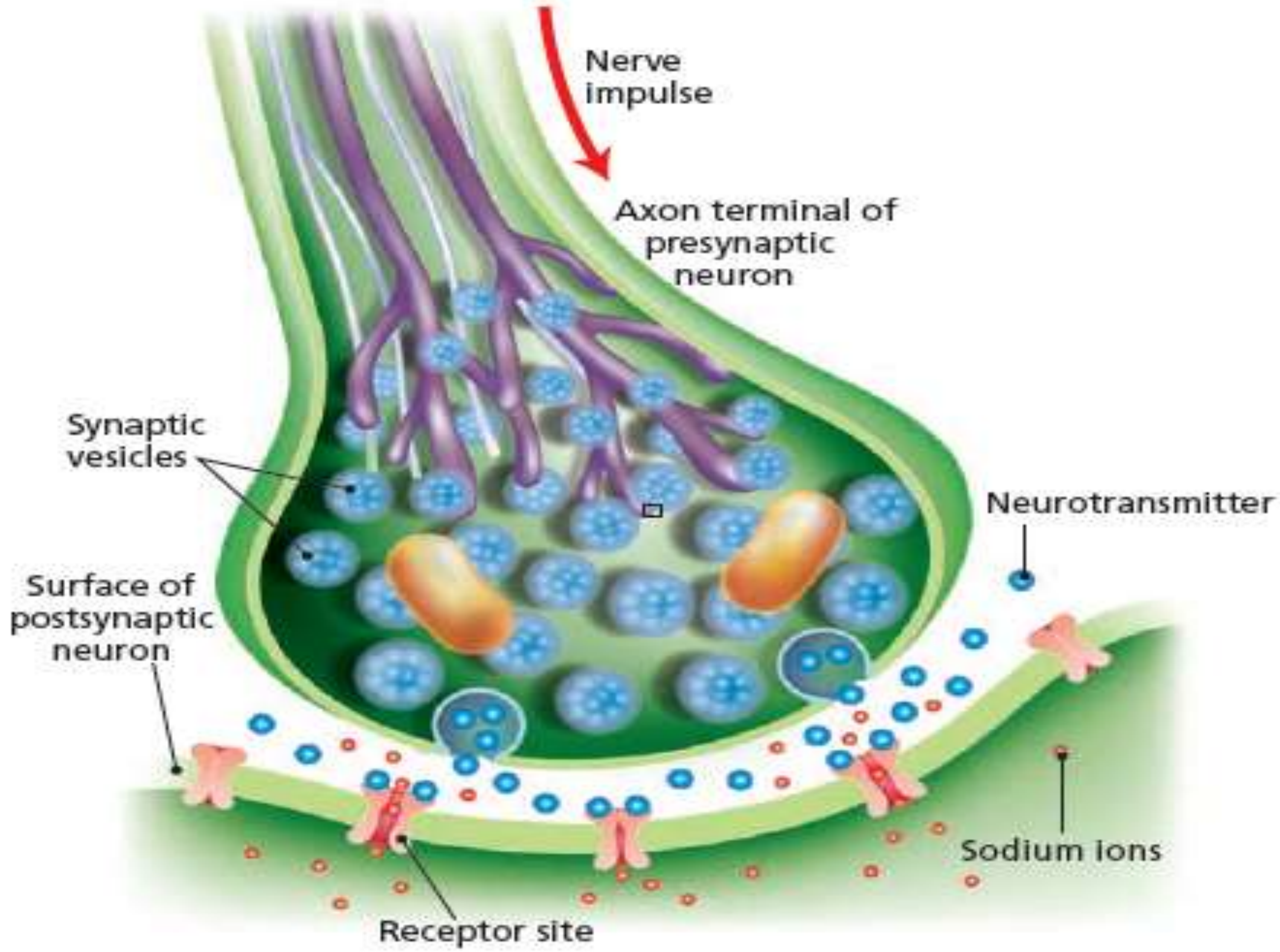
THE SYNAPSE



Nerve
impulse
Axon terminal of
presynaptic
neuron
Synaptic
vesicles
Neurotransmitter
Surface of
postsynaptic
neuron
Sodium ions
Receptor site

EXCITATORY SYNAPSES AND INHIBITORY SYNAPSES

- The neurotransmitters found at various synapses around the nervous system can either turn cells on (called an *excitatory effect*) or turn cells off (called an *inhibitory effect),* depending on exactly what synapse is being affected.
- Note: It's not the neurotransmitter itself that is excitatory or inhibitory, but rather it is the effect of that neurotransmitter that is either excitatory or inhibitory at the receptor sites of a particular synapse.

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NEUROTRANSMITTERS: MESSENGERS OF THE NETWORK

Some Neurotransmitters and Their Functions

NEUROTRANSMITTERS	FUNCTIONS
Acetylcholine (ACh)	Excitatory or inhibitory; involved in arousal, attention, memory, and controls muscle contractions
Norepinephrine (NE)	Mainly excitatory; involved in arousal and mood
Dopamine (DA)	Excitatory or inhibitory; involved in control of movement and sensations of pleasure
Serotonin (5-HT)	Excitatory or inhibitory; involved in sleep, mood, anxiety, and appetite
Gaba-aminobutyric acid (GABA)	Major inhibitory neurotransmitter; involved in sleep and inhibits movement
Glutamate	Major excitatory neurotransmitter; involved in learning, memory formation, nervous system development, and synaptic plasticity
Endorphins	Inhibitory neural regulators; involved in pain relief

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Cleaning Up the Synapse: Reuptake and Enzymes

The neurotransmitters have to get out of the receptor sites before the next stimulation can occur.

Some just drift away through the process of diffusion, but most will end up back in the synaptic vesicles in a process called **reuptake.** (Think of a little suction tube, sucking the chemicals back into the vesicles.)

That way, the synapse is cleared for the next release of neurotransmitters.

Some drugs, like cocaine, affect the nervous system by blocking the reuptake process.

There is one neurotransmitter that is not taken back into the vesicles, however. Because ACh is responsible for muscle activity, and muscle activity needs to happen rapidly and continue happening, it's not possible to wait around for the "sucking up" process to occur.

Instead, an enzyme (a complex protein that is manufactured by cells) specifically designed to break apart ACh clears the synaptic gap very quickly (a process called **enzymatic degradation.)** There are enzymes that break down other neurotransmitters as well.

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THANK YOU ☺

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