

Ch 10 A

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Ch 10 B

## CHAPTER 10

# NERVOUS SYSTEM 1

**BASIC STRUCTURE and FUNCTION**

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*Some illustrations are courtesy of McGraw-Hill.*



## Overview of the Nervous System

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### A. *Subdivisions of the Nervous System:*

1. The **two major subdivisions** of the nervous system:

- a. **Central Nervous System (CNS)**,  
which *includes the brain and spinal cord.*
- b. **Peripheral Nervous System (PNS)**,  
which *includes the nerves leading to  
and from the CNS.*

2. **Forty-three nerve pairs (43) make up the PNS:**

**12 pairs of cranial nerves**  
**31 pairs of spinal nerves**

### B. *General Functions of the Nervous System:*

<b>SENSORY</b>	<b>detection</b> of internal or external changes
<b>INTEGRATIVE</b>	to " <b>decide</b> " on a course of action
<b>RESPONSIVE</b>	<u>motor neurons</u> ----> <b>adjustments</b>

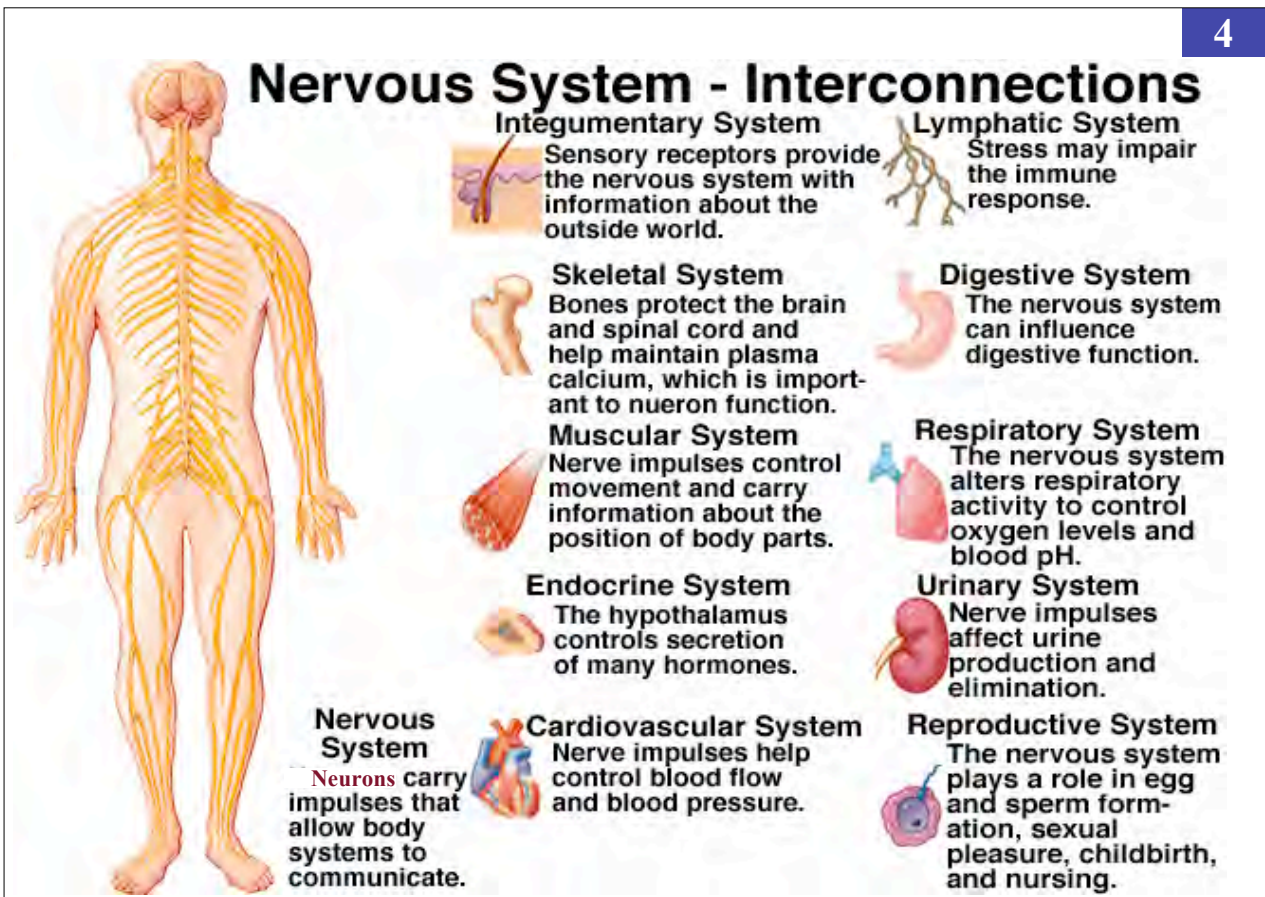
C. *Properties of Nerve Cells*

Excitability, conductivity, and secretion of neurotransmitters and other chemical messengers.

D. *Comparison of Nervous and Endocrine Systems*

1. a. The **NERVOUS** system transmits messages at **great speed** (1-10 msec), using **both electrical impulses** and **neurotransmitters**.
  - b. Its effects are **relatively local**, and the **response stops when the stimulus ceases**.
  - c. *Prolonged* stimulation results in **adaptation**.
2. a. The **ENDOCRINE** system, by contrast, sends chemical messages (**hormones**) into the **bloodstream** that are generally **much slower to act**.
  - b. Responses can be **systemic**, are **slow to adapt** and **last long after the stimulation ceases**.

## Nervous System - Interconnections



The diagram illustrates the human nervous system and its interconnections with other body systems. A central figure shows a human body with the nervous system highlighted in yellow. Surrounding this figure are ten boxes, each containing an icon of a system and a brief description of its interaction with the nervous system.

- Integumentary System**: Sensory receptors provide the nervous system with information about the outside world.
- Lymphatic System**: Stress may impair the immune response.
- Skeletal System**: Bones protect the brain and spinal cord and help maintain plasma calcium, which is important to neuron function.
- Digestive System**: The nervous system can influence digestive function.
- Muscular System**: Nerve impulses control movement and carry information about the position of body parts.
- Respiratory System**: The nervous system alters respiratory activity to control oxygen levels and blood pH.
- Endocrine System**: The hypothalamus controls secretion of many hormones.
- Urinary System**: Nerve impulses affect urine production and elimination.
- Nervous System**: Neurons carry impulses that allow body systems to communicate.
- Cardiovascular System**: Nerve impulses help control blood flow and blood pressure.
- Reproductive System**: The nervous system plays a role in egg and sperm formation, sexual pleasure, childbirth, and nursing.

A. **Neuroglia** (HOLE; p. 343)

**Neuroglia outnumber neurons** 50 to 1.

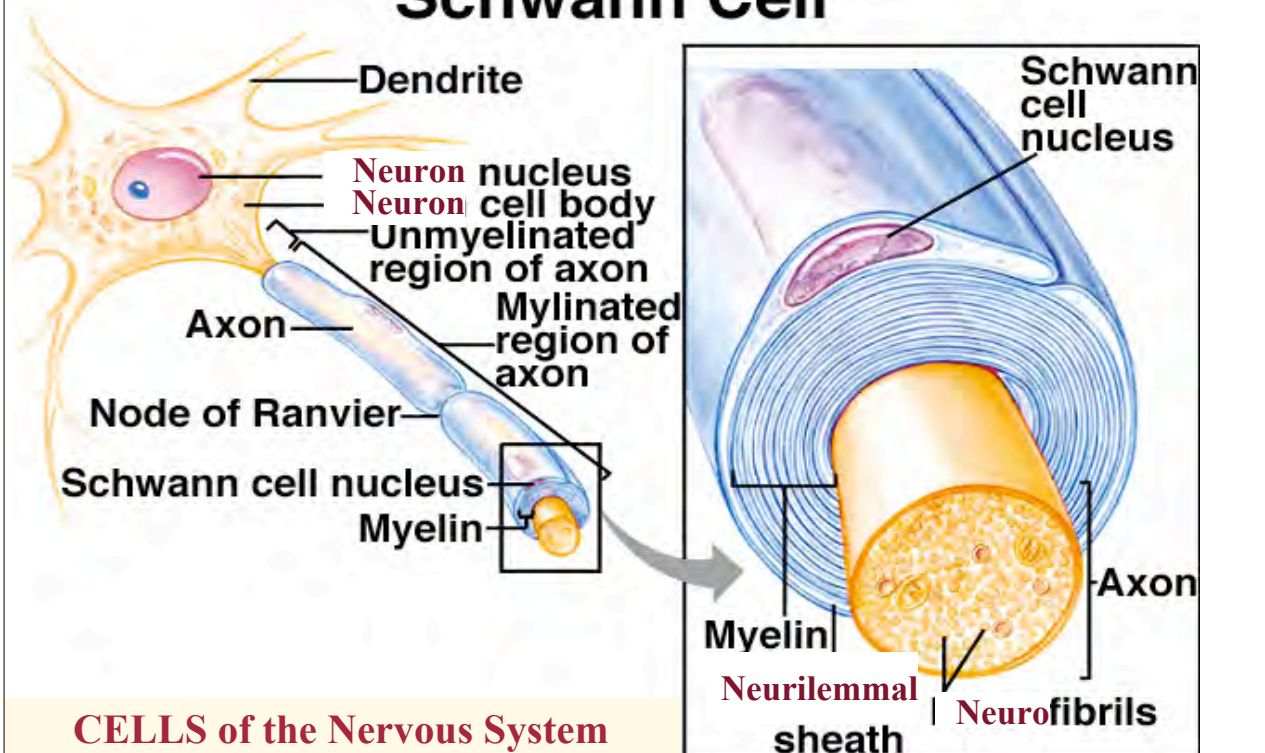
These are the *helper cells* of nervous tissue; they bind neurons together and provide a supportive framework, among other functions.

There are *six types of neuroglia*: first 2 in the PNS.

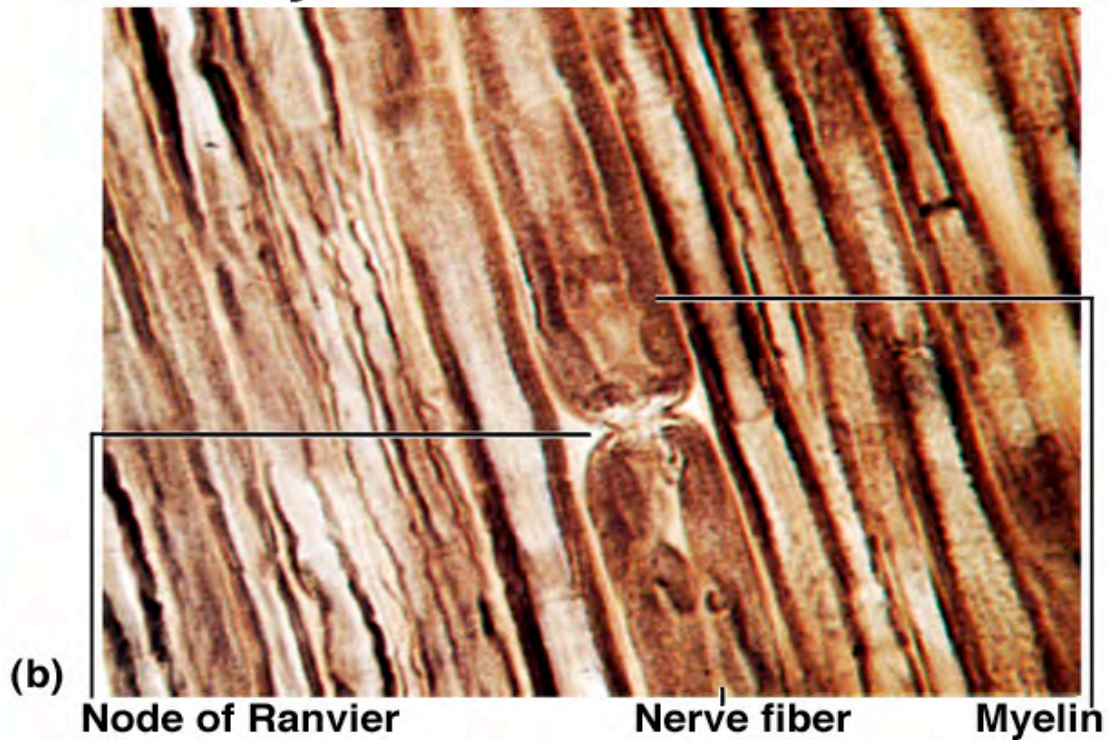
1. **Schwann cells** (in the **PNS**) (HOLE: p. 342), form a **neurilemma** around all cells they cover and *OFTEN* a **myelin sheath** around neuron fibers they cover in *successive wrappings*.  
Gaps = **nodes of Ranvier**; covered sections = **internodes**.  
Schwann cells are necessary for the regeneration of cut neurons.
2. **Satellite cells** surround cell bodies in the **PNS**, but little is known of their function. *No need to know*.

**MYELINATION IN the PNS:**  
**Both Neurilemma and myelin around ONE axon !**

**Schwann Cell**



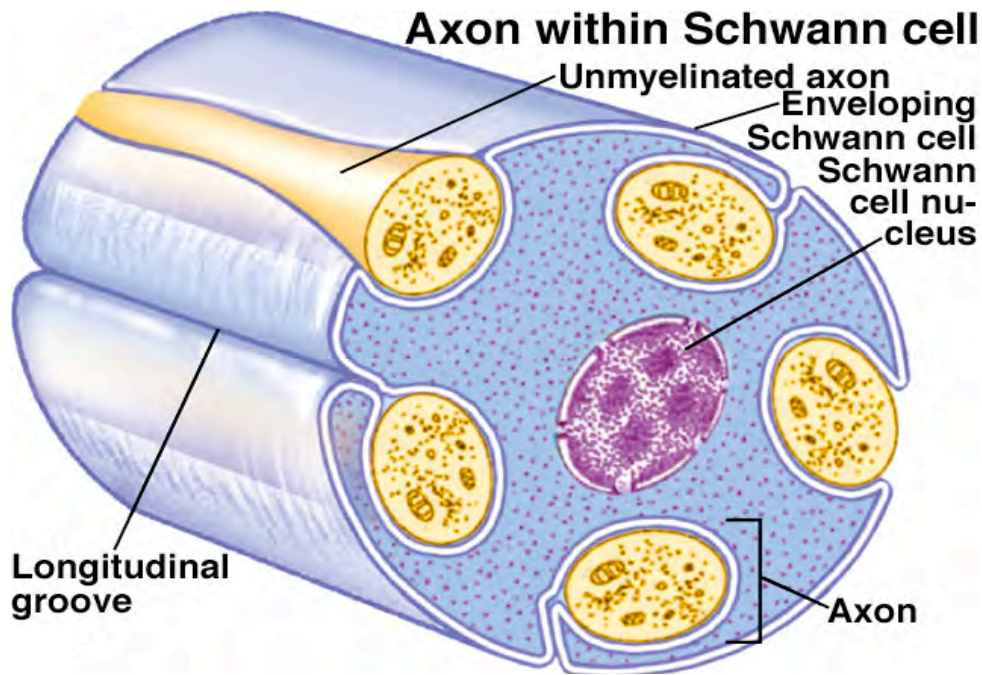
## Myelinated Nerve Fiber



## CELLS of the Nervous System

### Myelinated and Unmyelinated Axons





### NON - MYELINATION in the PNS:

Loose association of ONE Schwann cell and SEVERAL AXONS !

#### A. **Neuroglia** (HOLE; p. 345)

There are *six types of neuroglia*: **Last 4** (3 - 6) **in the CNS !**

#### 3. **Oligodendrocytes**

(name actually means few branches)

form **discontinuous myelin sheaths** in the **CNS** and **wrap several cells**.

#### 4. **Astrocytes**

abundant, *star-shaped* cells found in the **CNS**.

##### **Protoplasmic astrocytes:**

help form the *blood-brain barrier*.

##### **Fibrous astrocytes:**

supportive framework for the **CNS**.

Note: Recent research hints at more complex roles.

A. **Neuroglia** (HOLE; p. 347)

There are *six types of neuroglia*: **Last 4** (3 - 6) **in the CNS!**

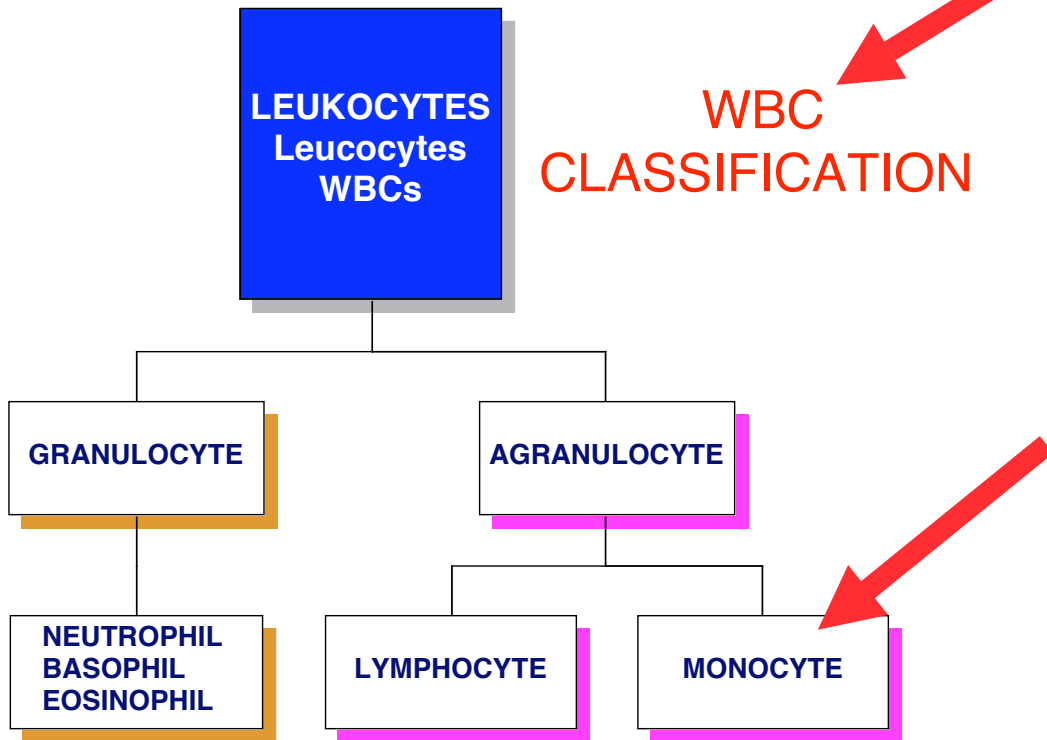
5. **Ependymal cells**

produce and circulate *cerebrospinal fluid (CSF)*  
line cavities on the brain & SC  
may be ciliated

6. **Microglia**

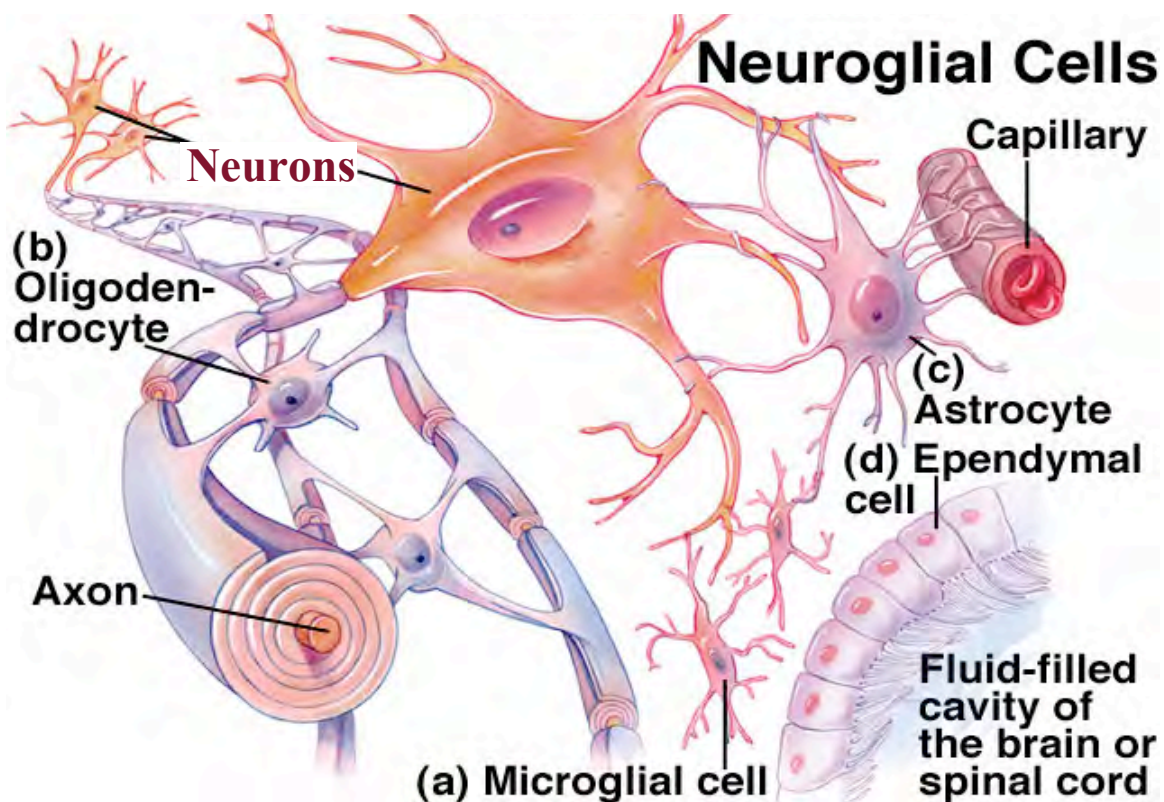
small *mobile macrophages*  
develop from **monocytes**  
**wander freely** through the **CNS**.

**What's a Monocyte ???**  
**Next plate --->>>>>**



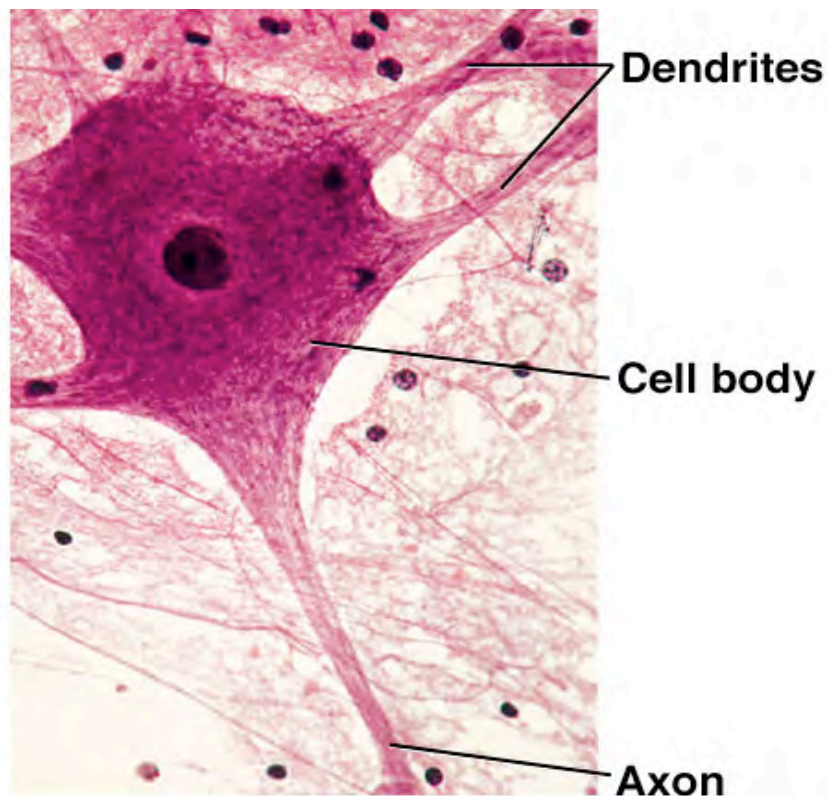
**TABLE 10.2 Neuroglial Cells of the CNS**

Type	Characteristics	Functions
Astrocytes	Star-shaped cells between neurons and blood vessels	Structural support, formation of scar tissue, transport of substances between blood vessels and neurons, communicate with one another and with neurons, mop up excess ions and neurotransmitters
Oligodendrocytes	Shaped like astrocytes, but with fewer cellular processes, occur in rows along nerve fibers	Form myelin sheaths within the brain and spinal cord; produce nerve growth factors
Microglia	Small cells with few cellular processes and found throughout the CNS	Structural support and phagocytosis (immune protection)
Ependyma	Cuboidal and columnar cells in the inner lining of the ventricles of the brain and the central canal of the spinal cord	Form a porous layer through which substances diffuse between the interstitial fluid of the brain and spinal cord and the cerebrospinal fluid



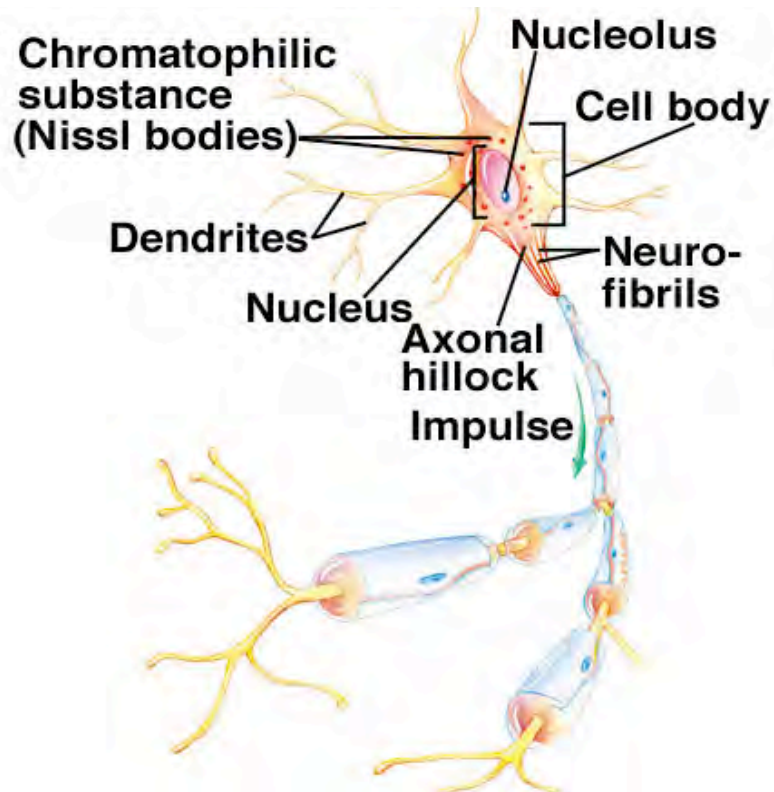
**B. NEURON STRUCTURE** (HOLE; p. 341)

1. The control center of the **neuron** is its **soma** (or **perikaryon: cell body**).  
contains the nucleus and nucleolus  
**Nissl bodies** (rough ER)  
supportive **neurofibrils**  
pigment (**lipofuscin** or "**aging bodies**"---  
a harmless by - product of lysosomal breakdown)
2. **Mature neurons lack centrioles** and do not undergo mitosis past adolescence.
3. Major **cytoplasmic inclusions**: (not membrane - bound)  
**glycogen granules**  
**lipid droplets**  
**melanin**  
**lipofuchsin.**

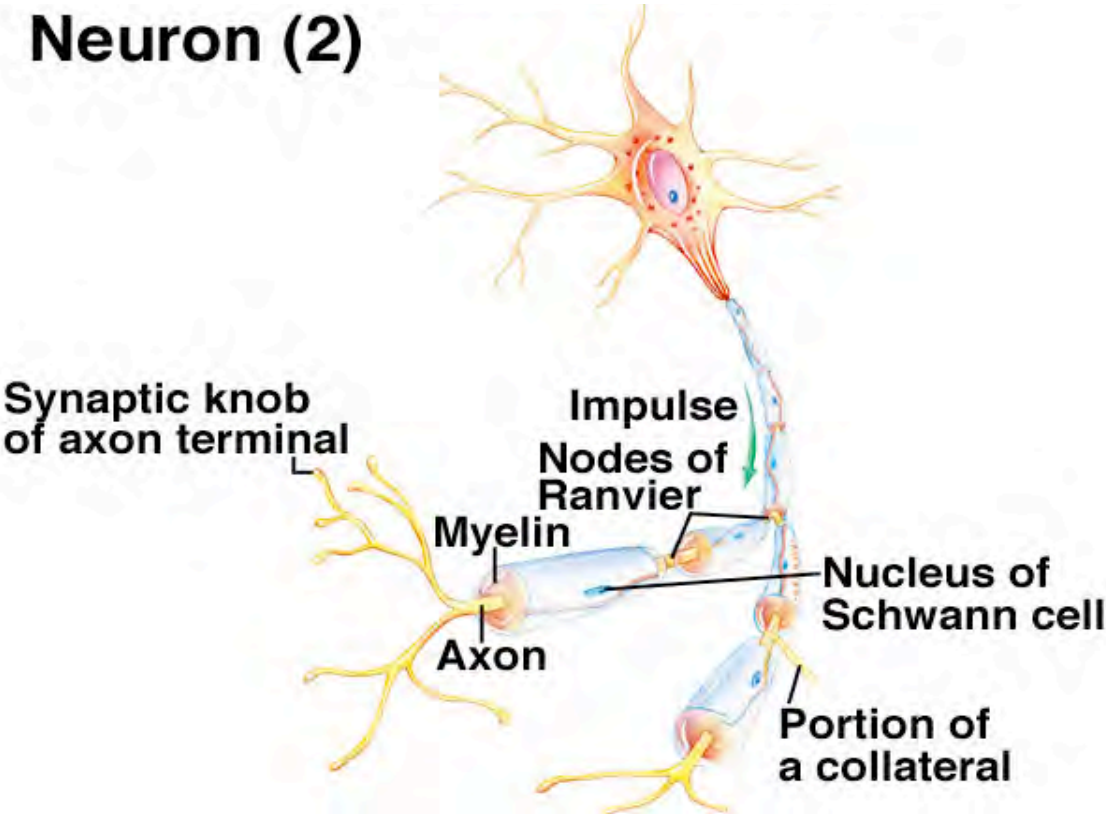
**Neuron**

**B. NEURON STRUCTURE** (HOLE; p. 341)

4. **Dendrites**  
cellular **extensions from the cell body**  
have **receptors for neurotransmitters** and  
***receive signals*** from other neurons.
5. On one side of the soma is the **axon hillock** which gives rise to the axon.  
Axons vary greatly in length and end in a **synaptic end bulb** through which **neurotransmitters** are passed to the next neuron.
6. **Large fibers** conduct impulses **more rapidly** than small ones  
**myelinated fibers** (whitish color) are **faster** than those that are non-myelinated.

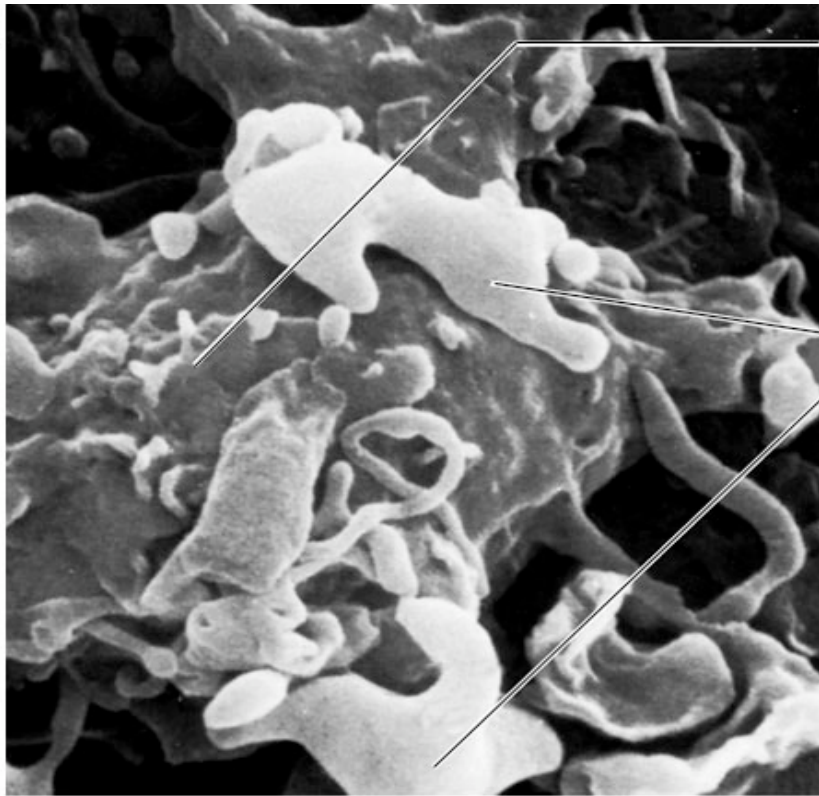
**Neuron (1)**

# Neuron (2)



- Mitochondrion
- Synaptic Knob**
- Synaptic vesicle
- Synaptic cleft
- Postsynaptic membrane

Neuron Cell Body

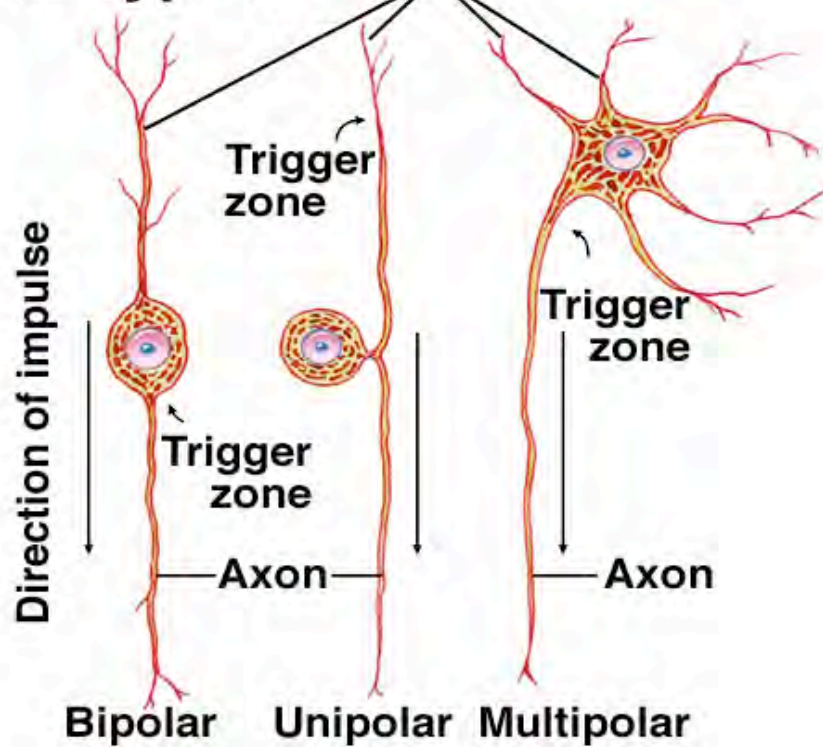


Neuron cell body

Neuroglial cells

# Neuron Types

Dendrites



Bipolar Unipolar Multipolar

TABLE

## 10.1

## Types of Neurons

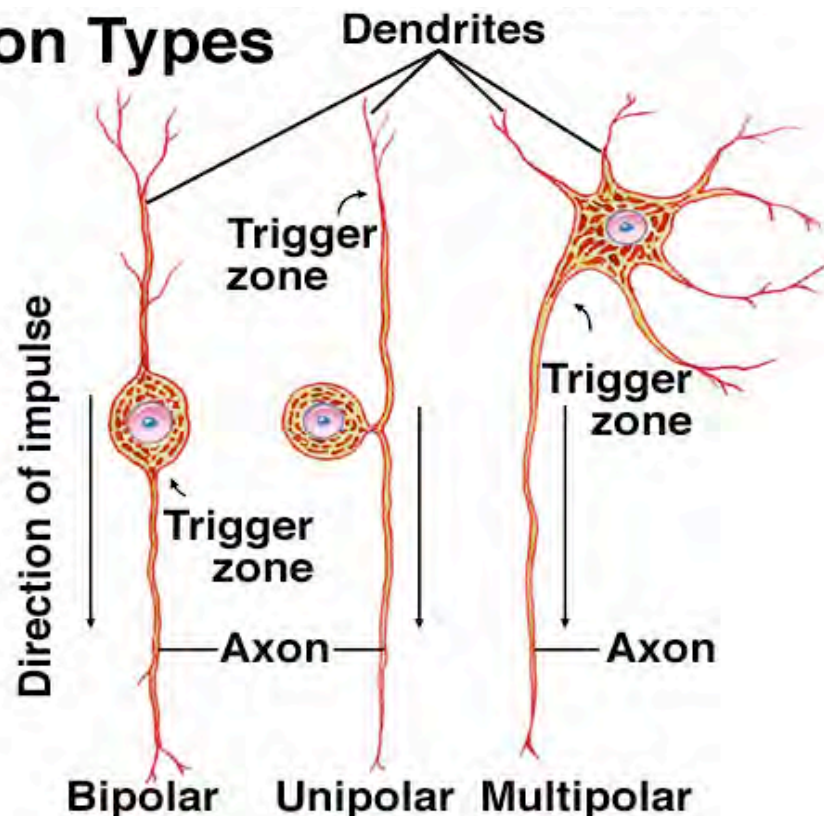
## A. Classified by Structure

Type	Structural Characteristics	Location
1. Bipolar neuron	Cell body with a process, arising from each end, one axon and one dendrite	In specialized parts of the eyes, nose, and ears
2. Unipolar neuron	Cell body with a single process that divides into two branches and functions as an axon	In ganglia outside the brain or spinal cord
3. Multipolar neuron	Cell body with many processes, one of which is an axon, the rest dendrites	Most common type of neuron in the brain and spinal cord

## B. Classified by Function

Type	Functional Characteristics	Structural Characteristics
1. Sensory neuron	Conducts nerve impulses from receptors in peripheral body parts into the brain or spinal cord	Most unipolar; some bipolar
2. Inter-neuron	Transmits nerve impulses between neurons within the brain and spinal cord	Multipolar
3. Motor neuron	Conducts nerve impulses from the brain or spinal cord out to effectors-muscles or glands	Multipolar

## Neuron Types



C. **STRUCTURAL DIVERSITY in NEURONS** (HOLE; p. 344)

Neurons are classified according to the *number of extensions arising from the soma*. *All one-way conduction.*

1. **Multipolar**

Neurons with **one axon** and **several dendrites** are **multipolar** (the *most common type*).

2. **Bipolar**

Neurons with **one axon and one dendrite** are **bipolar**.

3. **Unipolar** (reference: **ganglia** outside CNS)

Neurons with **ONE extension from the soma**.

*Branches shortly, thereafter...*

Peripheral process: to dendrites near  
peripheral body part

Central process: enters brain or SC.

**Somatic sensory neurons** are *mostly* **unipolar**.

D. **AXONAL TRANSPORT in NEURONS**

Axonal Transport refers to the ways in which material within a neuron is moved:

1. **Anterograde**

movement *away from the soma* (perikaryon, cell body)

2. **Retrograde**

movement *towards the soma* (perikaryon, cell body)

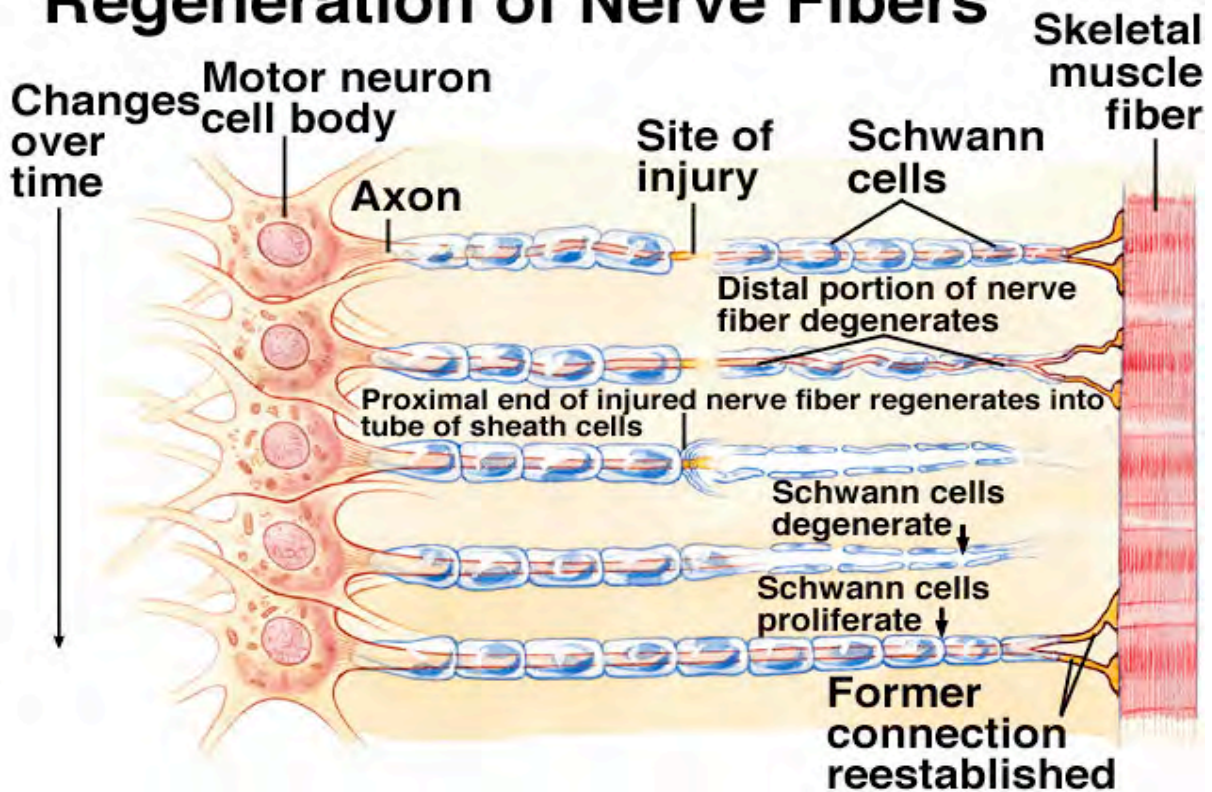
E. **REGENERATION of NERVE FIBERS** (HOLE; p. 348)

1. **Peripheral nerve fibers** can sometimes regenerate *if the soma is not damaged and some of the neurilemma remains intact*.

2. The **neurilemma** forms a **regeneration tube** through which the growing axon re-establishes its connection.

If the nerve originally led to a skeletal muscle, the muscle **atrophies in the absence of innervation** but may, under some circumstances, grow when the connection is re-established.

# Regeneration of Nerve Fibers



## Electrophysiology of Neurons

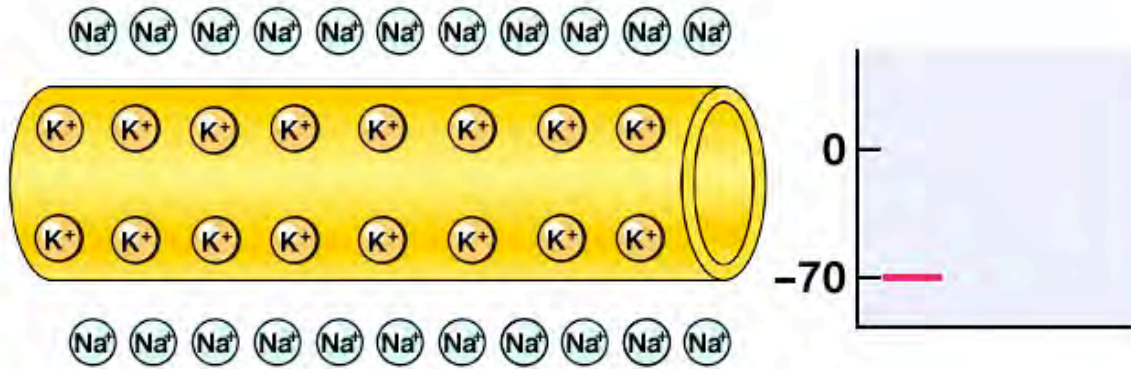
### A. *First, a Quick Review:* (HOLE; pp. 348)

1. At **resting potential** neurons are **polarized**, with a resting membrane potential (**RMP**) of **-70 mV**.
2. The **sodium-potassium pump** contributes some of the **RMP**; accounts for 70% of the energy requirements of the nervous system.
3. An **electrical charge** is called a **potential** because it has the potential *to make charged particles move*.

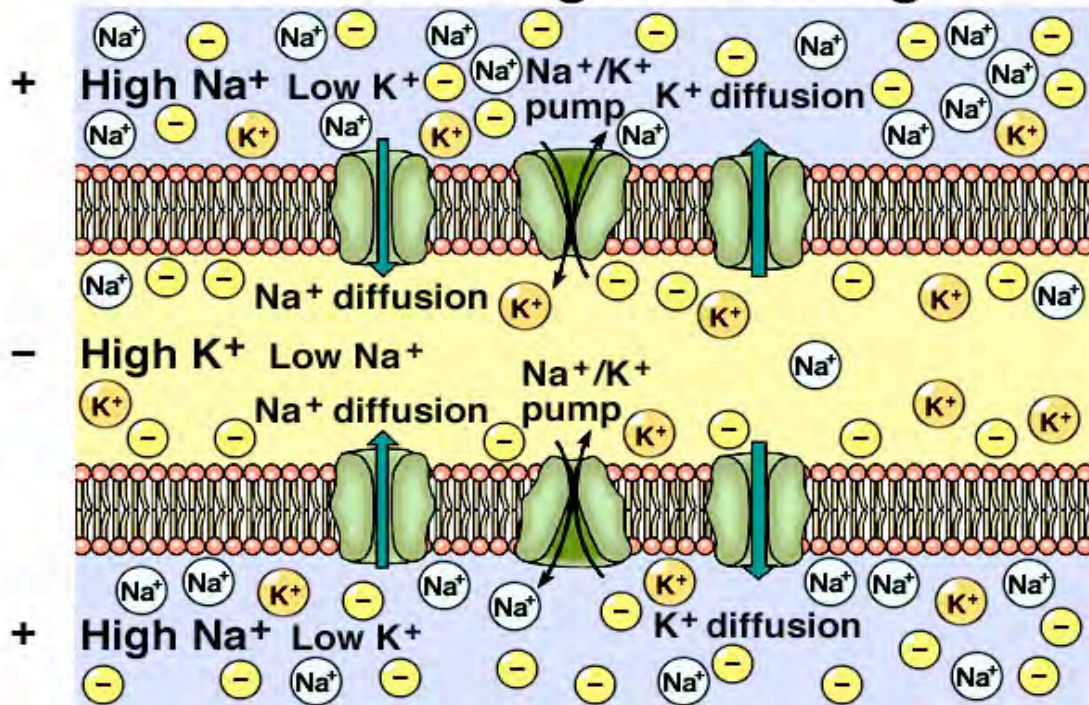
### B. **Local Potentials**

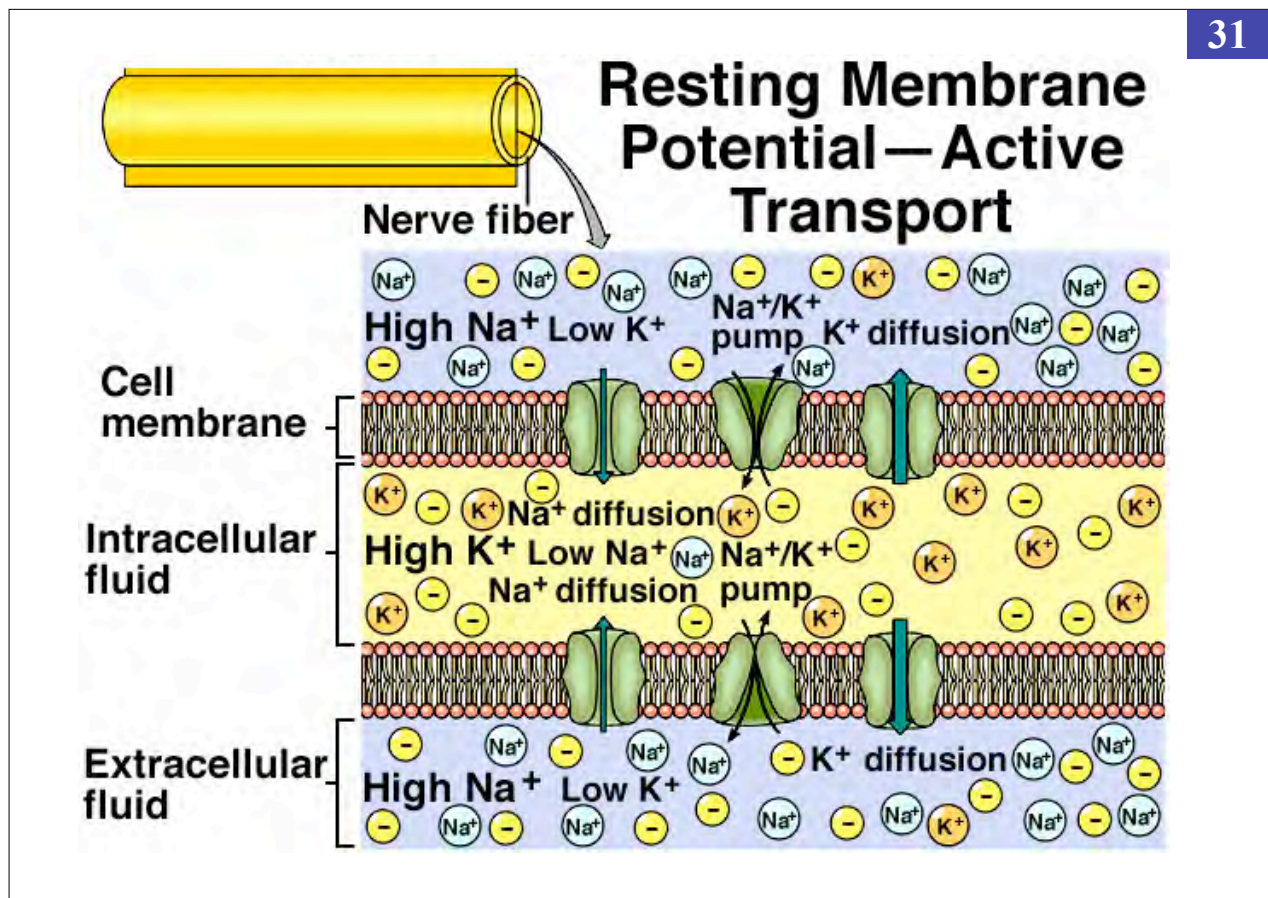
1. A **local potential** is a **small deviation in the RMP** caused by a stimulation.
2. **Local potentials** have the following attributes:  
**graded, decremental, ineffective beyond a short distance, irreversible.**  
 May be **either excitatory OR inhibitory**.

# Resting Membrane Potential



## Resting Membrane Potential – Negative Charge



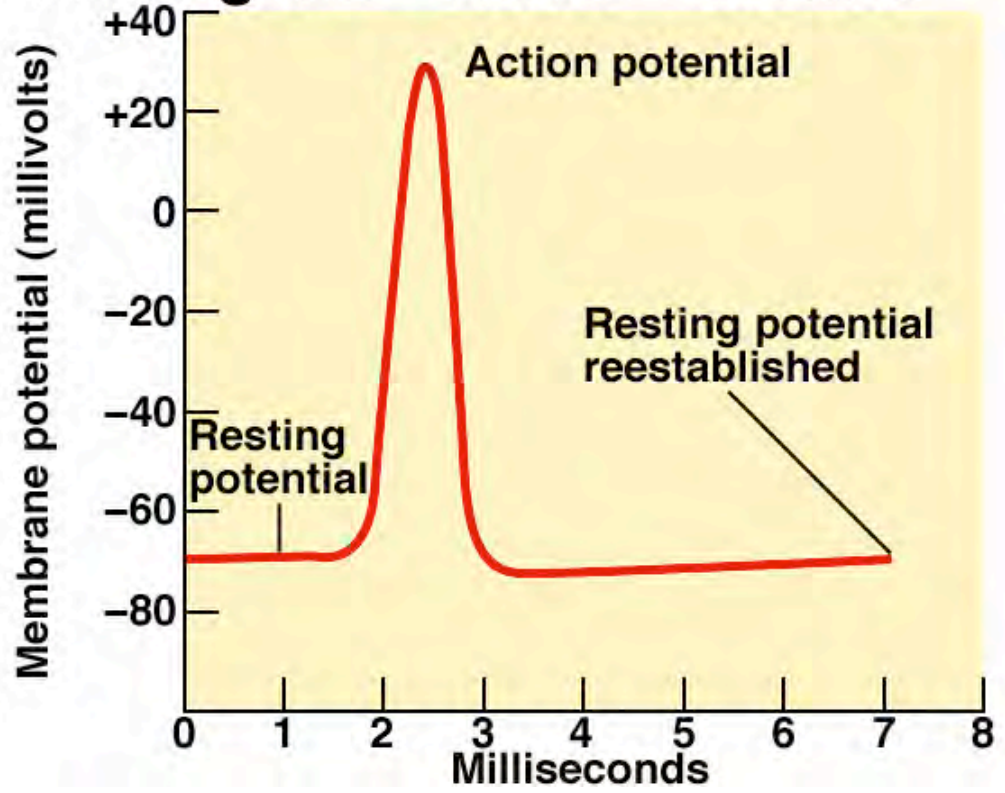


## Electrophysiology of Neurons

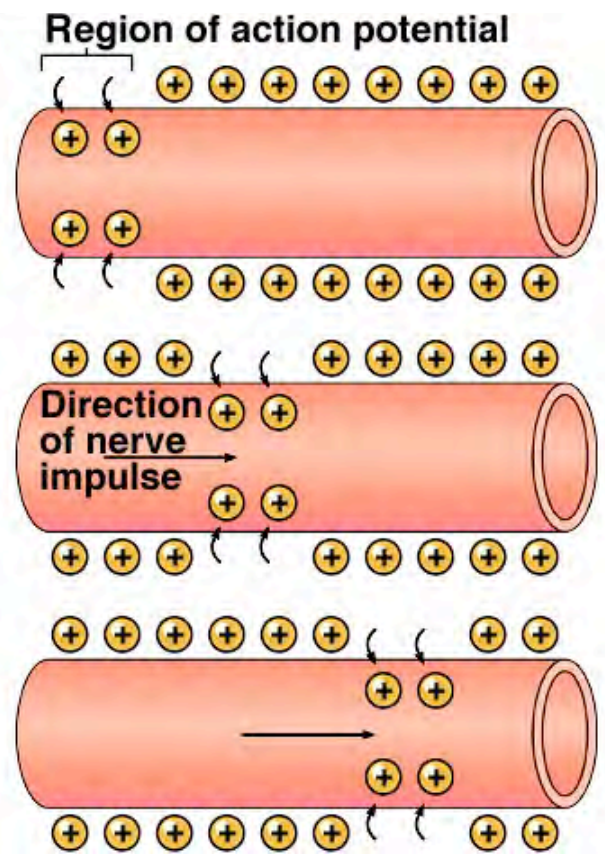
### C. **ACTION POTENTIALS:** (HOLE; pp. 350)

1. An **action potential** can be generated only in places where the *plasma membrane has an adequate density of voltage-gated ion channels*.  
An **action potential** can also occur **if local potentials arrive from multiple points** of origin on the cell and their **combined effect** is great enough to reach an **action potential**.
2. The **action potential** consists of rapid *dramatic changes in membrane voltage*.
3. The **axonal hillock** is the **generator potential**, and it must rise to **threshold** (the minimum voltage needed to open voltage-regulated sodium and potassium gates).  
**When it reaches threshold, the neuron "fires"**.

# Oscillogram – Action Potential



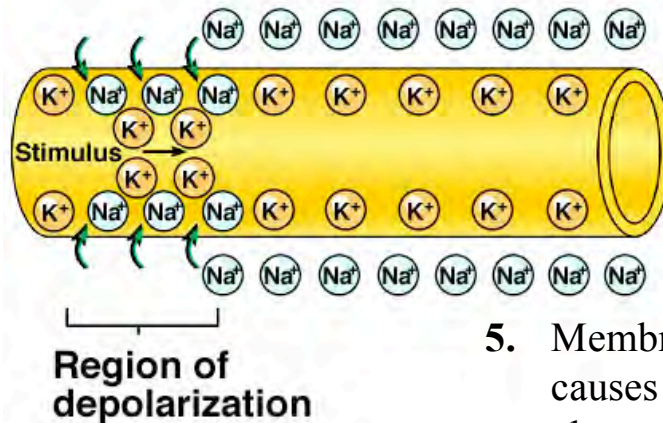
# Nerve Impulse



C. **ACTION POTENTIALS:** (HOLE; pp. 350)

4. At **threshold**, potassium gates open slowly and sodium gates open quickly, **depolarizing the membrane**.

The **polarity** of the membrane becomes **reversed** in comparison to the RMP.



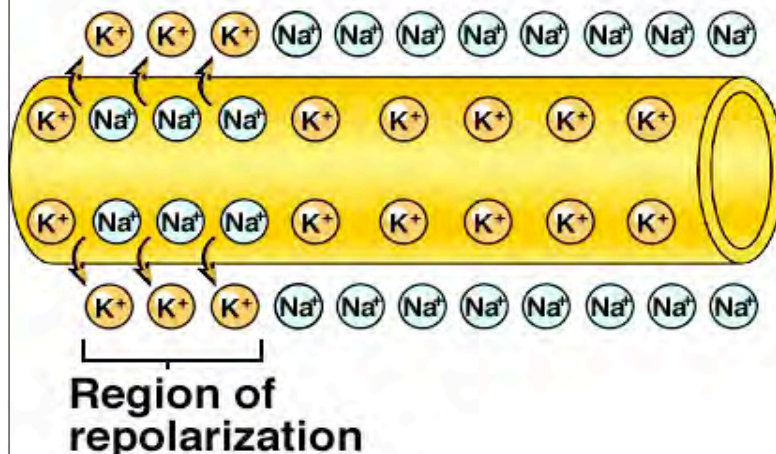
5. Membrane **depolarization** causes sodium gates to close, and the **voltage stops rising**.

C. **ACTION POTENTIALS:** (HOLE; pp. 348)

6. Potassium gates are now fully **open**.

Potassium ions rush out of the cell, causing **membrane voltage to drop rapidly**, reaching **hyperpolarization**.

7. The original distribution of sodium and potassium are restored and **RMP is reestablished**.



8. As in muscles, nerve fibers obey the **all or none law**. An increase in the intensity of a stimulation will **NOT** result in a stronger impulse-  
*simply more impulses per unit time.*

## REVIEW POINTS

### **NORMALLY:**

The RMP is maintained by the **sodium-potassium pump**, which **removes three sodium ions from the cell** for every **two potassium ions it brings in**, and therefore has the net effect of contributing to the **negative intracellular charge**.

### **DURING NERVE or MUSCLE CELL STIMULATION:**

When a nerve or muscle cell is stimulated, **ion gates** in the membrane open, **sodium ions rush in**, and **potassium ions rush out**, resulting in **changes** in membrane voltage called an **action potential**.

### **Electrophysiology:**

**The study of the electrical activity in cells.**

**This slide is from the Muscle Lectures.**

## REVIEW POINTS

TABLE	10.3	Events Leading to Nerve Impulse Conduction
<ol style="list-style-type: none"> <li>1. Nerve fiber membrane maintains resting potential by diffusion of <math>\text{Na}^+</math> and <math>\text{K}^+</math> down their concentration gradients as the cell pumps them up the gradients.</li> <li>2. Neurons receive stimulation, causing local potentials, which may sum to reach threshold.</li> <li>3. Sodium channels in a local region of the membrane open.</li> <li>4. Sodium ions diffuse inward, depolarizing the membrane.</li> <li>5. Potassium channels in the membrane open.</li> <li>6. Potassium ions diffuse outward, repolarizing the membrane.</li> <li>7. The resulting action potential causes an electric current that stimulates adjacent portions of the membrane.</li> <li>8. Series of action potentials occurs sequentially along the length of the nerve fiber as a nerve impulse.</li> </ol>		

**D. REFRACTORY PERIOD:** (HOLE; pp. 353)

The short time following a nerve impulse during which a threshold stimulus will not trigger another impulse on an axon.

**Absolute Refractory period:**

Axon is changing its Na<sup>+</sup> permeability and ***CANNOT be stimulated.***

**Relative Refractory period:**

Membrane is reestablishing its original resting potential (RMP).

During this time, a threshold stimulus with a high intensity ***MAY trigger an impulse.***

**E. SIGNAL CONDUCTION: Unmyelinated Fibers**

1. An **unmyelinated fiber** has voltage-gated sodium ion channels along its **entire length**.
2. The impulse travels at a rate of **0.5 to 2.0 m/sec**.

**F. SIGNAL CONDUCTION: Myelinated Fibers**

1. ***Saltatory conduction*** occurs in ***myelinated fibers***. *Action potential is reached at each node of Ranvier, and travels to the next node.*
2. The impulse travels at speeds up to **130 m/sec. !!!**

# Nerve Impulse on Myelinated Fiber

