

NERVOUS SYSTEM

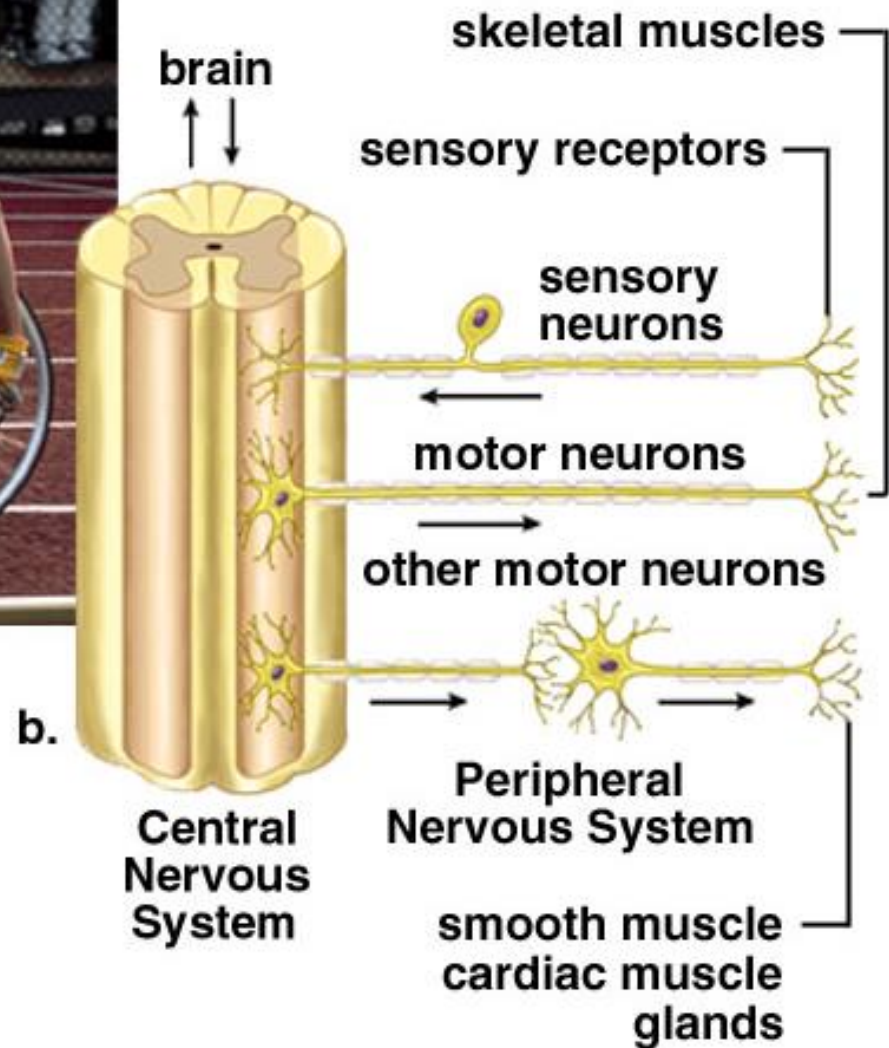
Functions of Nervous Tissue

- 1. Sensory Input:** Conduction of signals from sensory organs (eyes, ears, nose, skin, etc.) to *information processing centers* (brain and spinal cord).
- 2. Integration:** Interpretation of sensory signals and development of a response. Occurs in brain and spinal cord.
- 3. Motor Output:** Conduction of signals from brain or spinal cord to effector organs (muscles or glands). Controls the activity of muscles and glands, and allows the animal to *respond* to its *environment*.



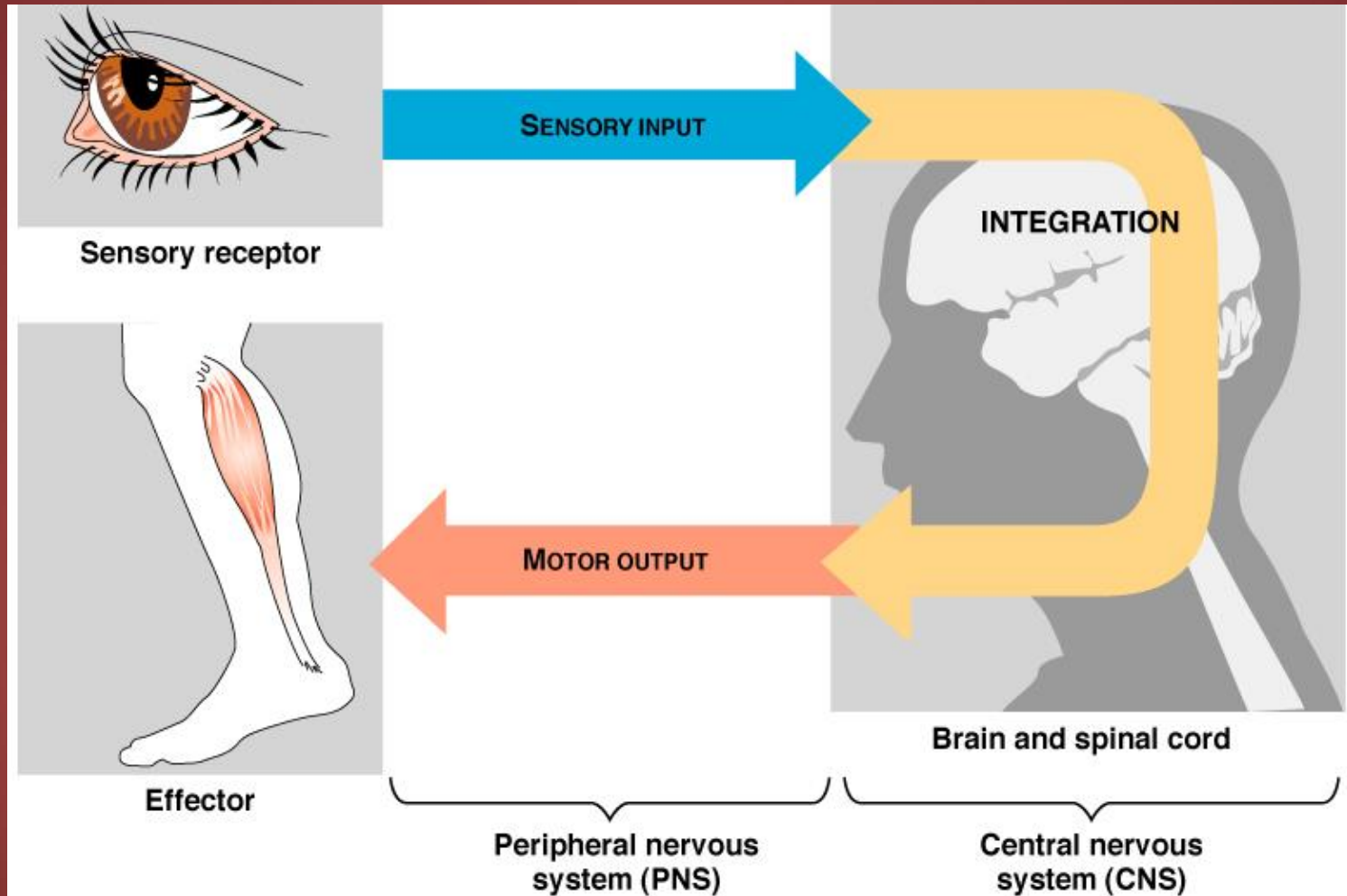
a.

Organization of Nervous System



b.

Nervous System Processes and Responds to Sensory Input



Cells of Nervous Tissue

1. Neuron: Nerve cell. Structural and functional unit of nervous tissue.

- Carry signals from one part of the body to another.

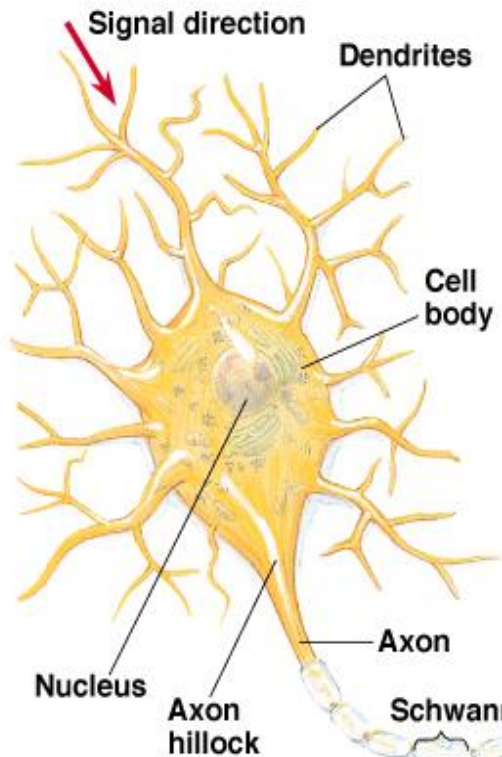
2. Supporting cells: Nourish, protect, and insulate neurons.

- There are roughly 50 supporting cells for every neuron.
- In humans, **Schwann cells** wrap around the axons of neurons, forming a ***myelin sheath*** that is essential for transmission of nerve impulses.

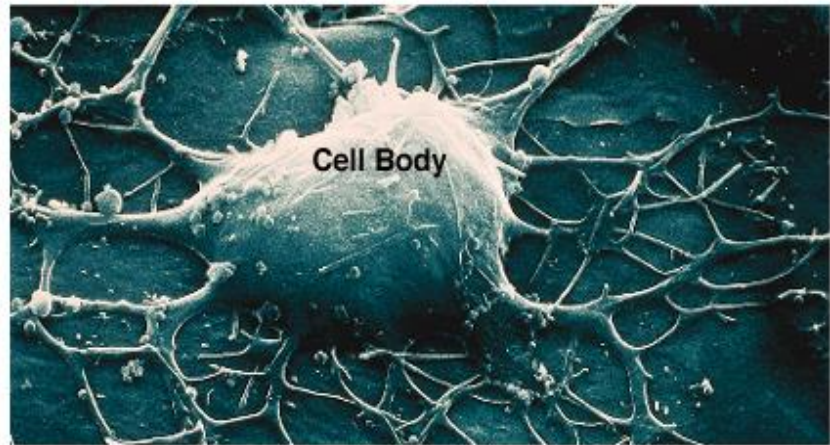
Neuron Structure

- Cell body : Contains nucleus and most organelles.
- Dendrites: Extensions that convey signals **towards** the cell body.
 - Short, numerous, and highly branched
- Axon: Extension that transmits signals **away** from the cell body to another neuron or effector cell.
 - Usually a long single fiber.
 - Axon is covered by a myelin sheath made up of many Schwann cells that are separated by small spaces (**Nodes of Ranvier**).

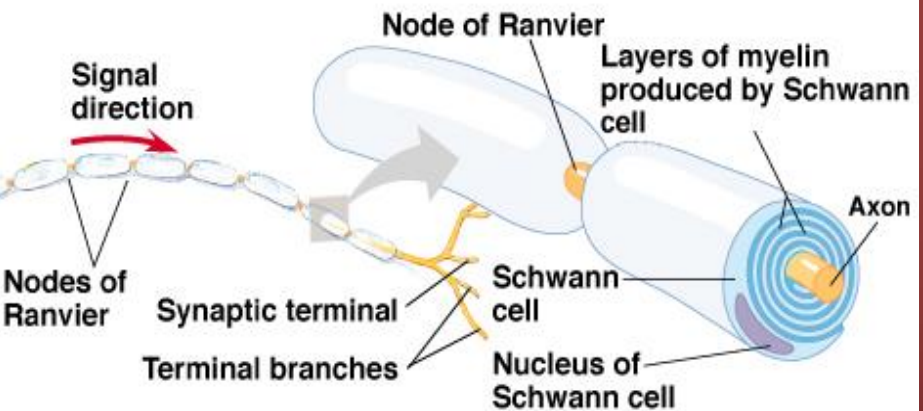
Structure of the Neuron



(a)



(b)



Neuron Structure

- Myelin sheath and nodes of Ranvier greatly speed up nerve impulses, which jump down axon from node to node.

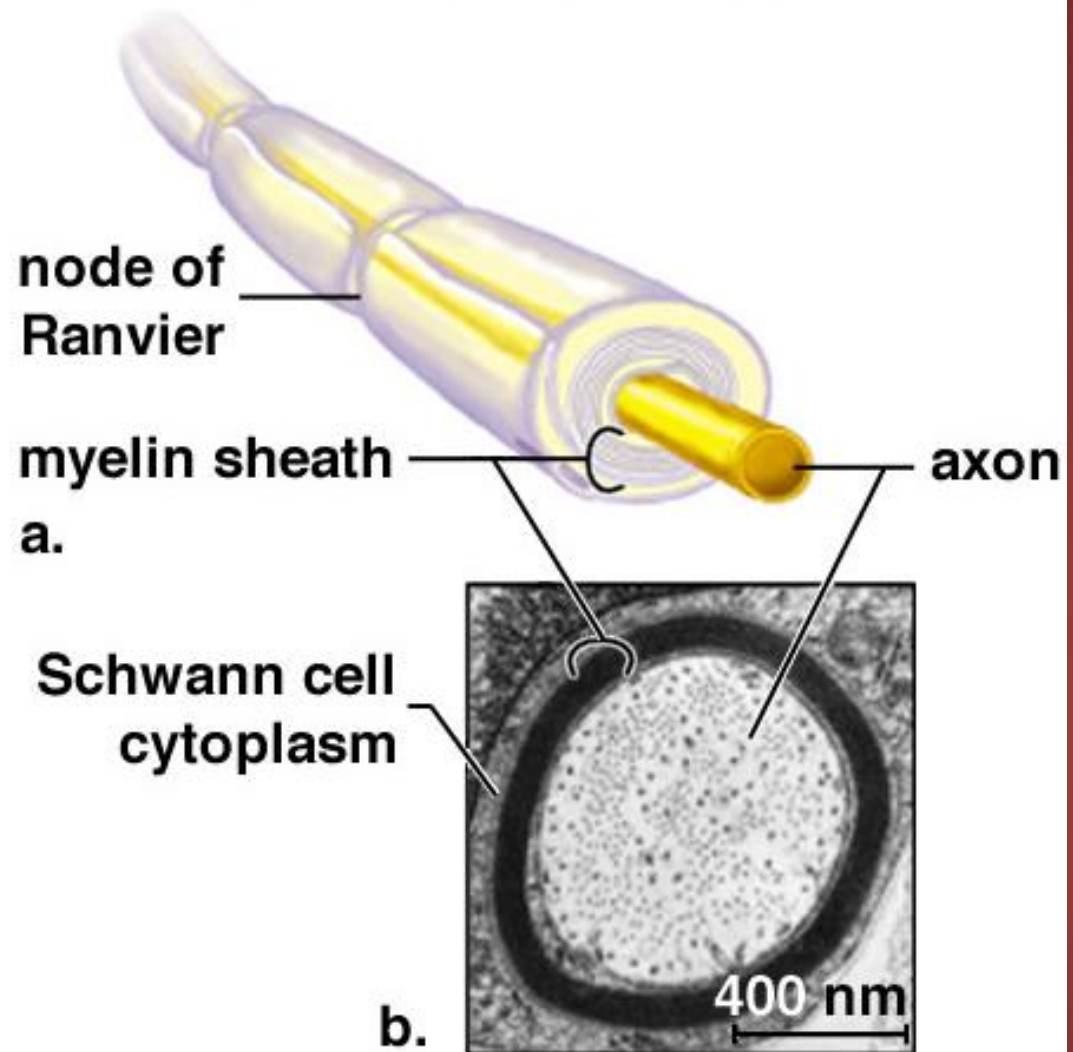
Speed of signal

Myelinated axon 100 meters/second

Unmyelinated axon 5 meters/second

- Multiple sclerosis: A disease in which a person's immune system destroys the myelin sheaths on their neurons.
 - Loss of muscle control
 - Impaired brain function
 - Death

Myelin Sheath



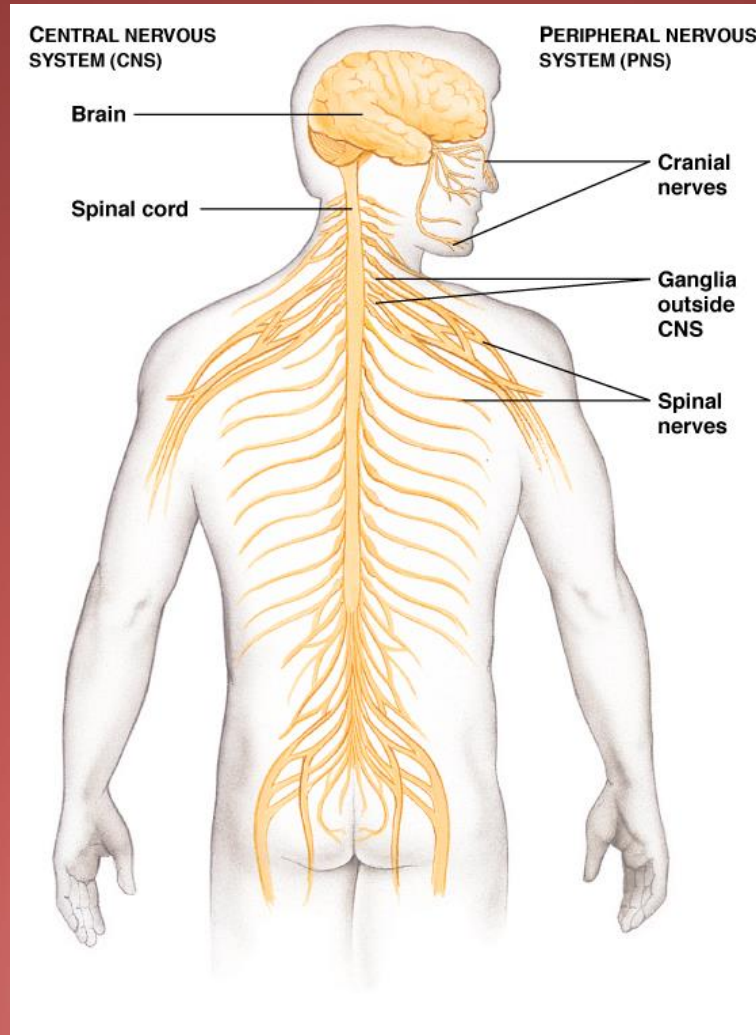
Central vs. Peripheral Nervous System

Central Nervous System (CNS): Brain & spinal cord.

Processing centers of nervous system.

Peripheral Nervous System (PNS): Nerves that carry signals in and out of the nervous system.

Human Nervous System



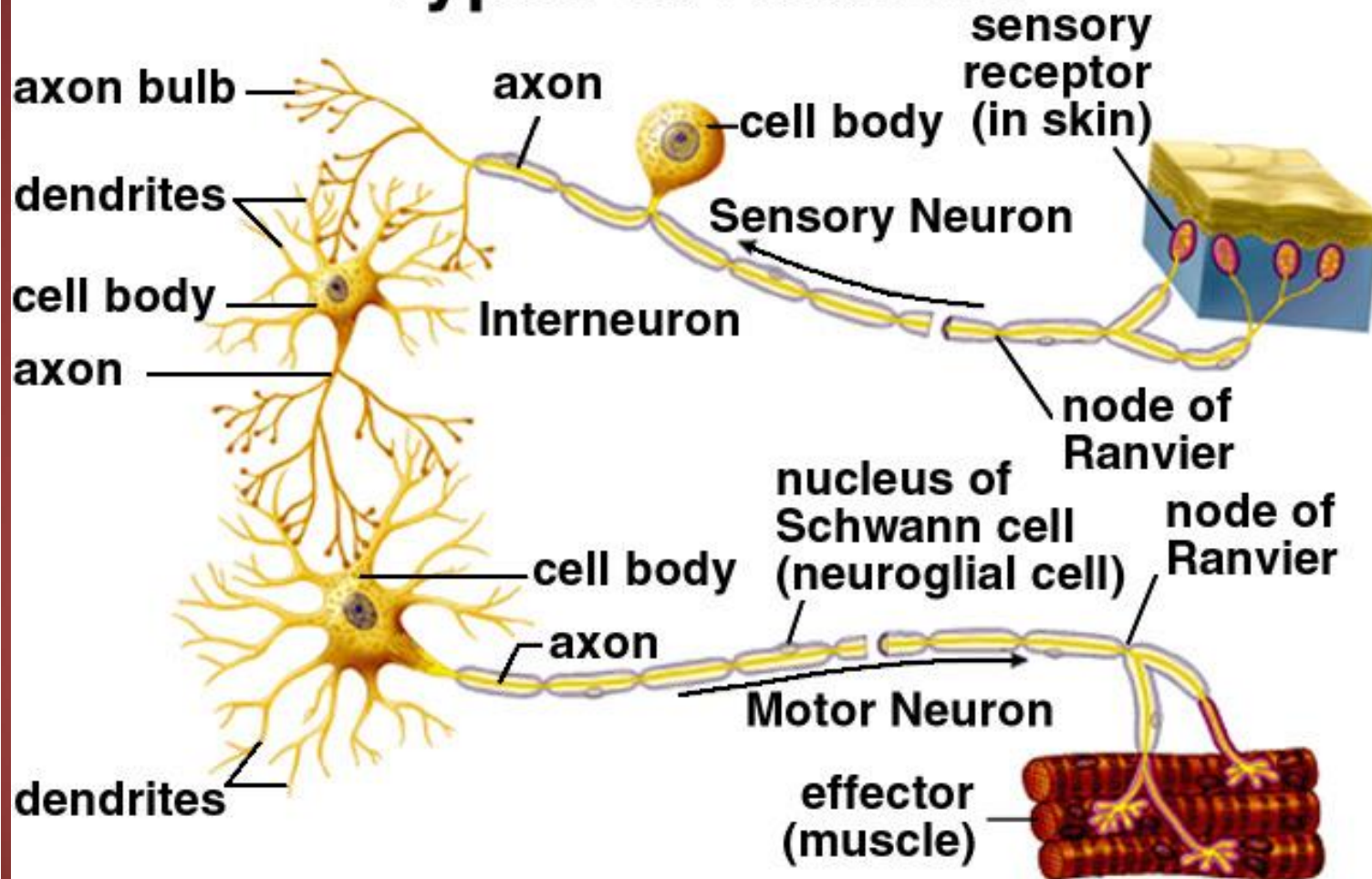
Three Types of Neurons

1. Sensory Neurons: Carry information from the stimulation of sensory organs (eyes, ears, etc.) to the central nervous system (CNS).

2. Interneurons: Found only in CNS. Integrate and process data from sensory neurons and send commands to motor neurons.

3. Motor Neurons: Receive information or commands from the CNS, and relay them to effector cells (muscles or glands) to elicit a response.

Types of Neurons



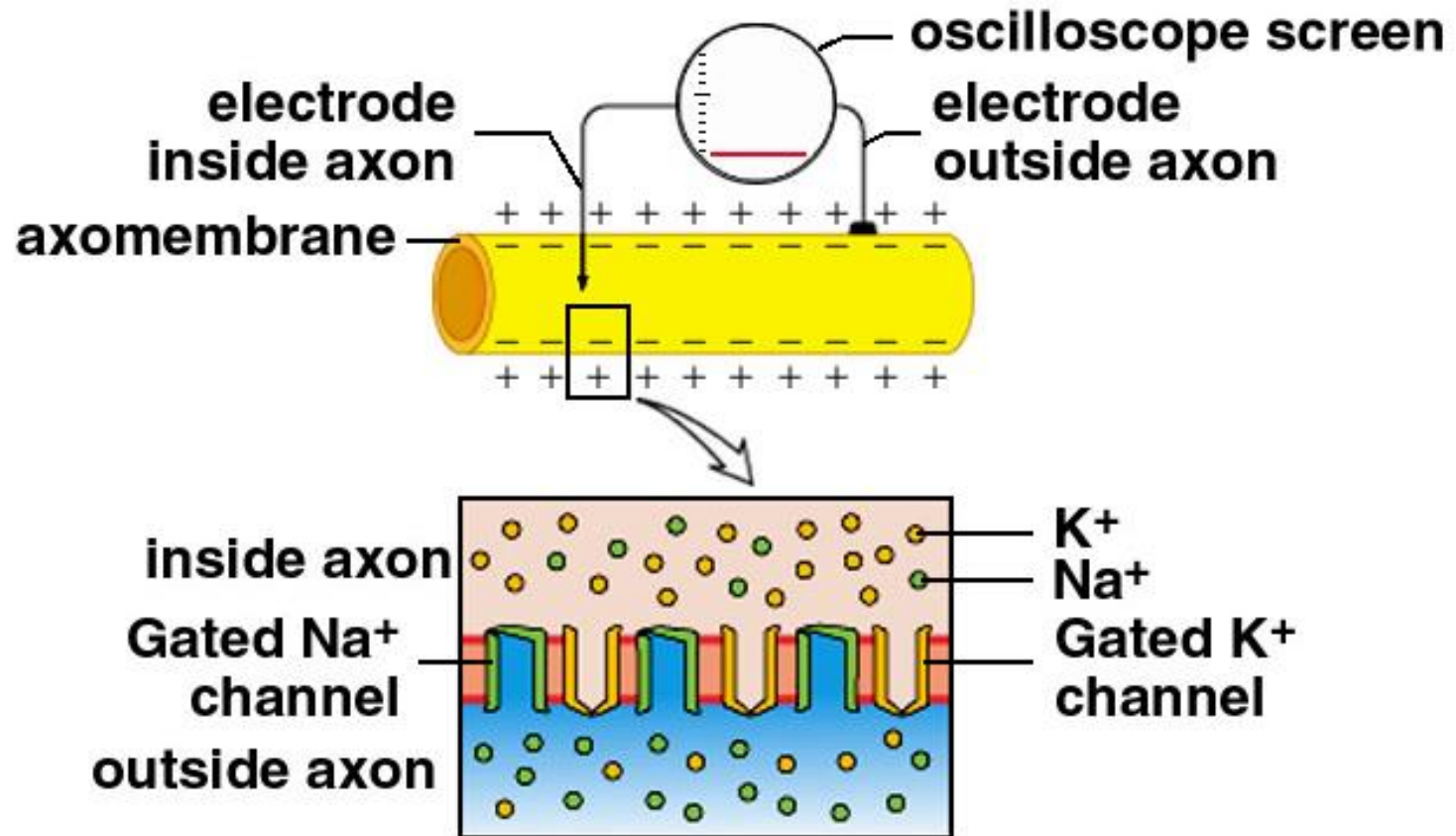
What is a Nerve Impulse?

An electrical signal that depends on the flow of ions across the neuron plasma membrane.

- Resting Potential: A neuron at rest has a *net negative charge* (-70 mV, equivalent to 5% of the voltage in AA battery).

The net negative charge is due to different ion concentrations across the neuron membrane.

Resting Potential



What is a Nerve Impulse?

An electrical signal that depends on the flow of ions across the neuron plasma membrane.

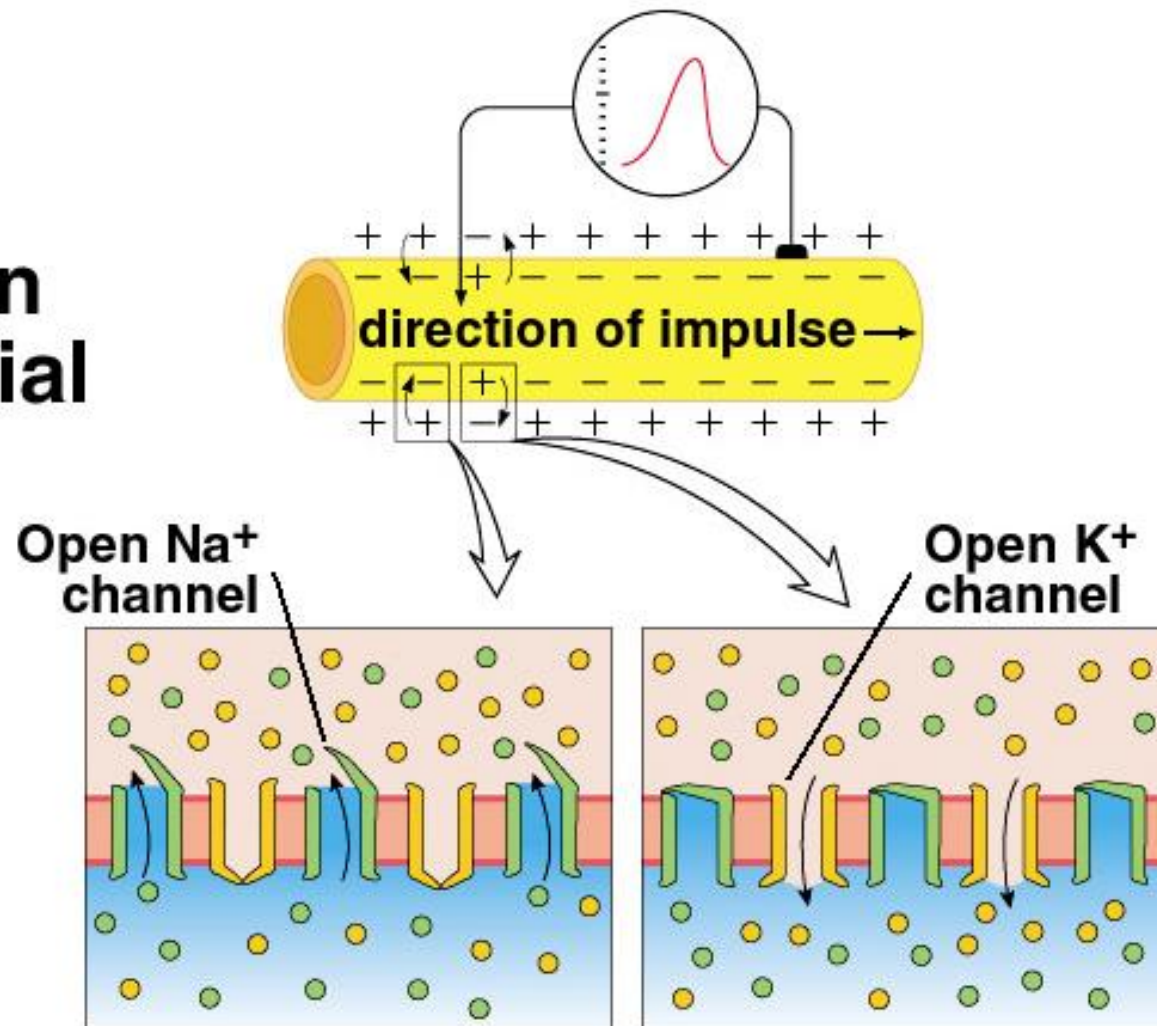
– Action Potential: When a neuron is stimulated above a certain threshold, this causes:

1. Depolarization: An influx of positive ions (Na^+) into the cell, caused by the opening of sodium channels.

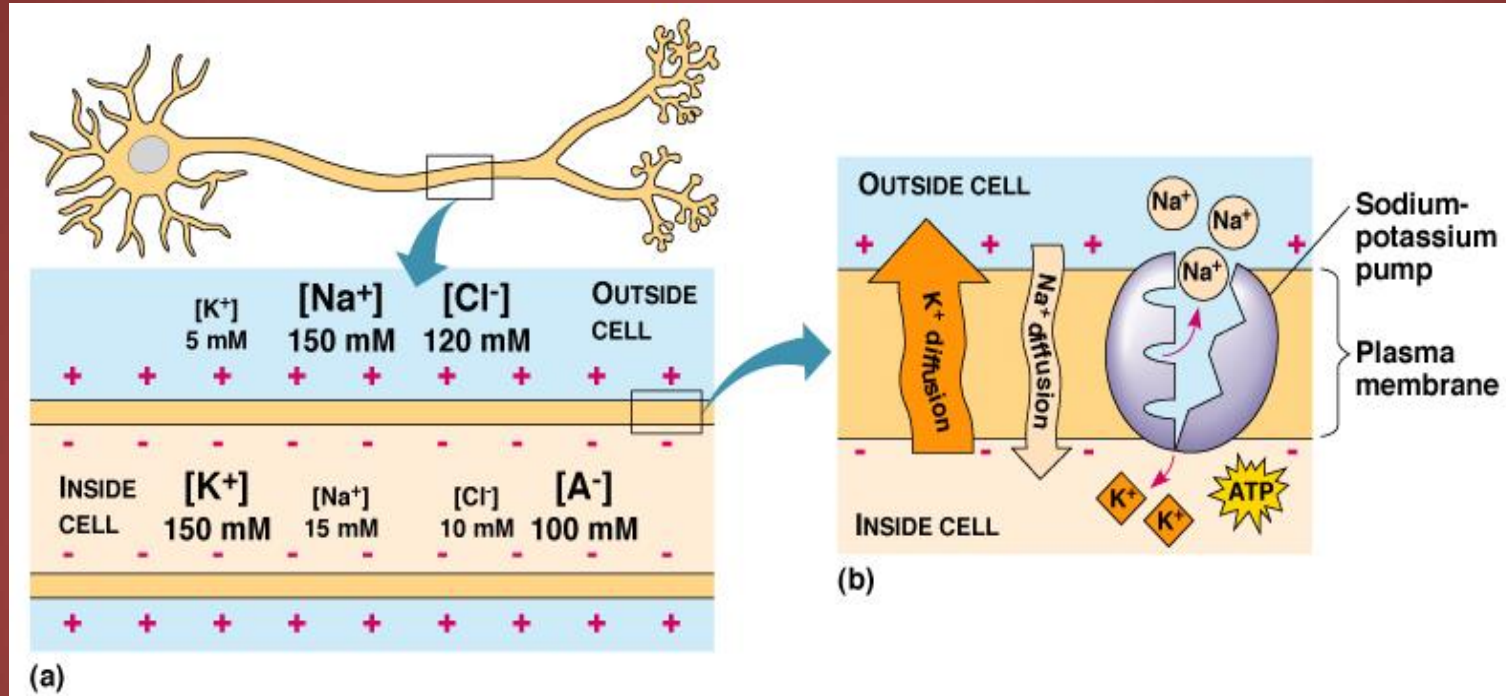
The inside of the cell becomes positively charged for a brief moment (1-2 milliseconds).

2. Repolarization: After a few milliseconds, the neuron allows *other positive ions (K^+) to leave the cell* so the inside of the cell becomes negatively charged once again.

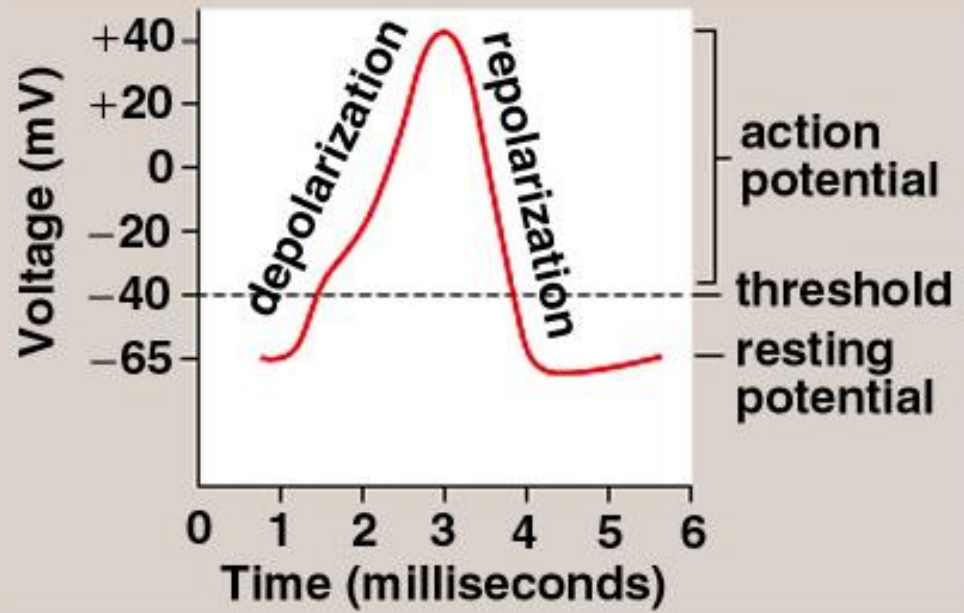
Action Potential



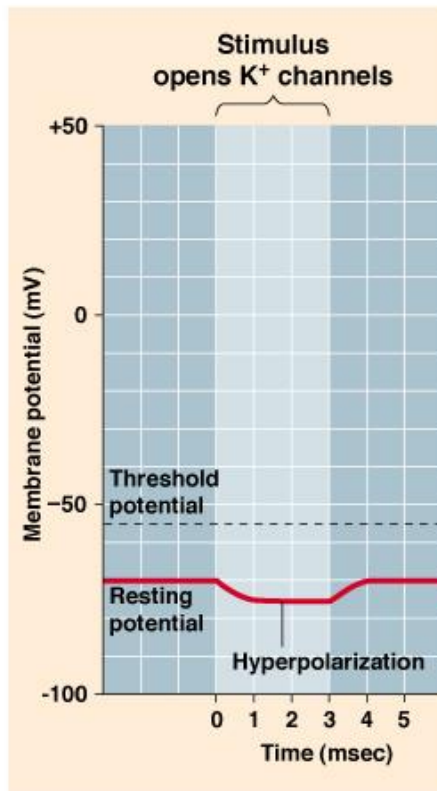
Resting Potential is Caused by Differences in Ion Concentrations Across Neuron Membrane



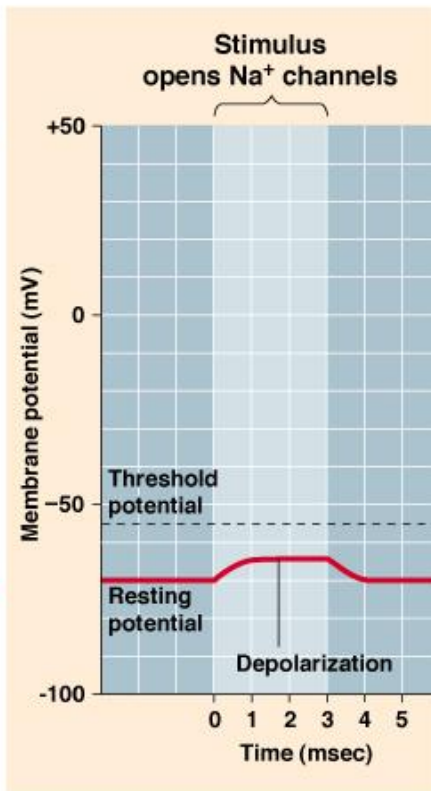
Resting and Action Potential



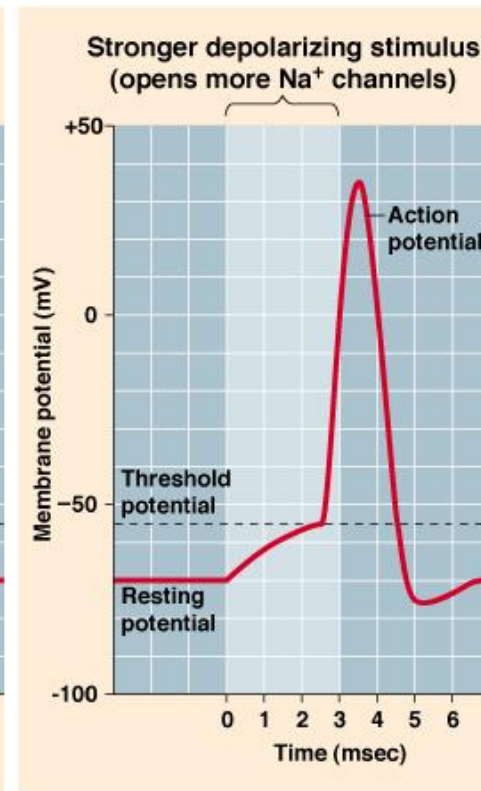
Action Potential Requires Stimulus Above a Certain Threshold



(a) Graded potential: hyperpolarization

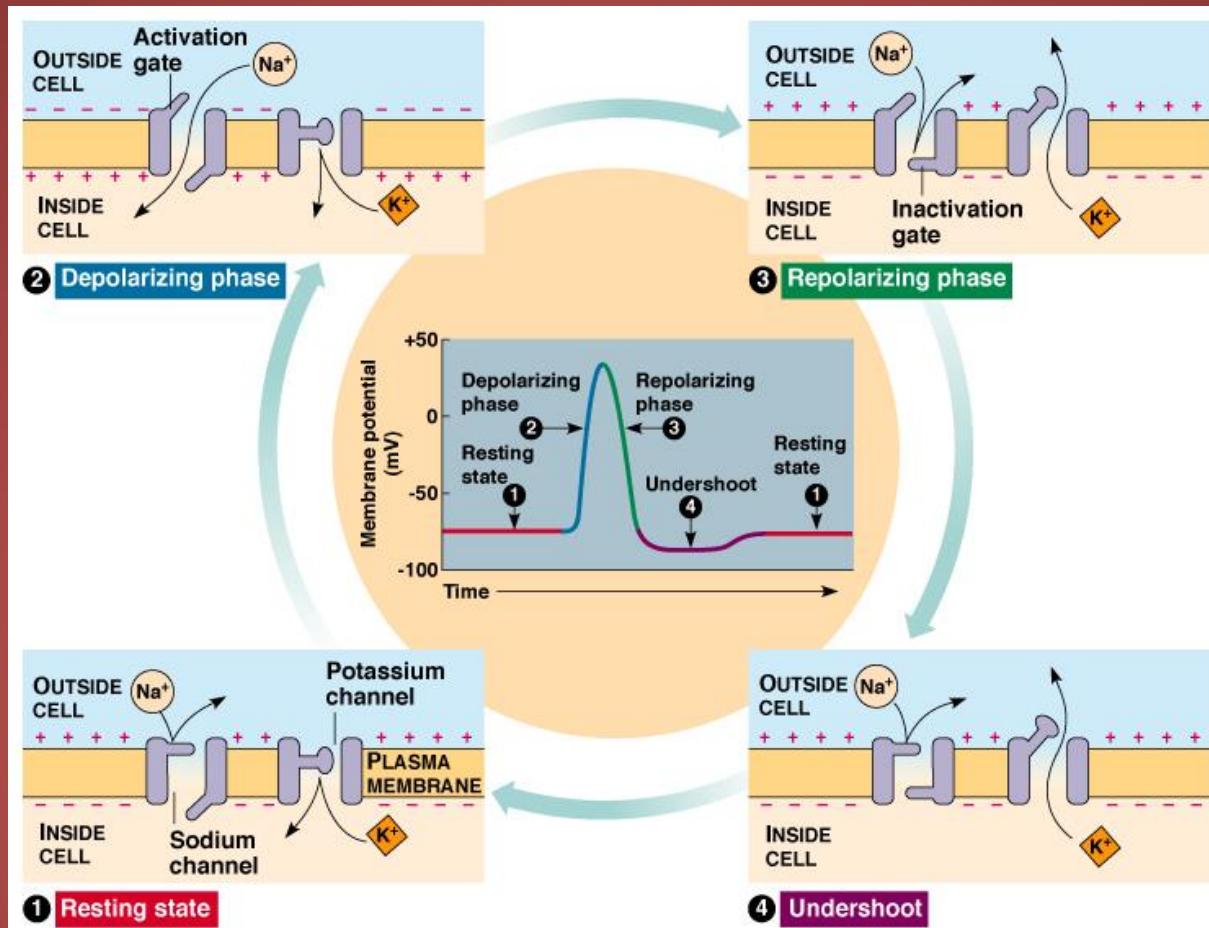


(b) Graded potential: depolarization



(c) Action potential

Nerve Impulses are Caused by Action Potentials



Neurons Communicate at Synapses

Synapse: Junction between two neurons or a neuron and an effector cell (muscle or gland). **There are two types of synapses:**

1. Electrical Synapse:

- Found in heart and digestive tract of human body.
- Action potentials pass directly from one neuron to another.

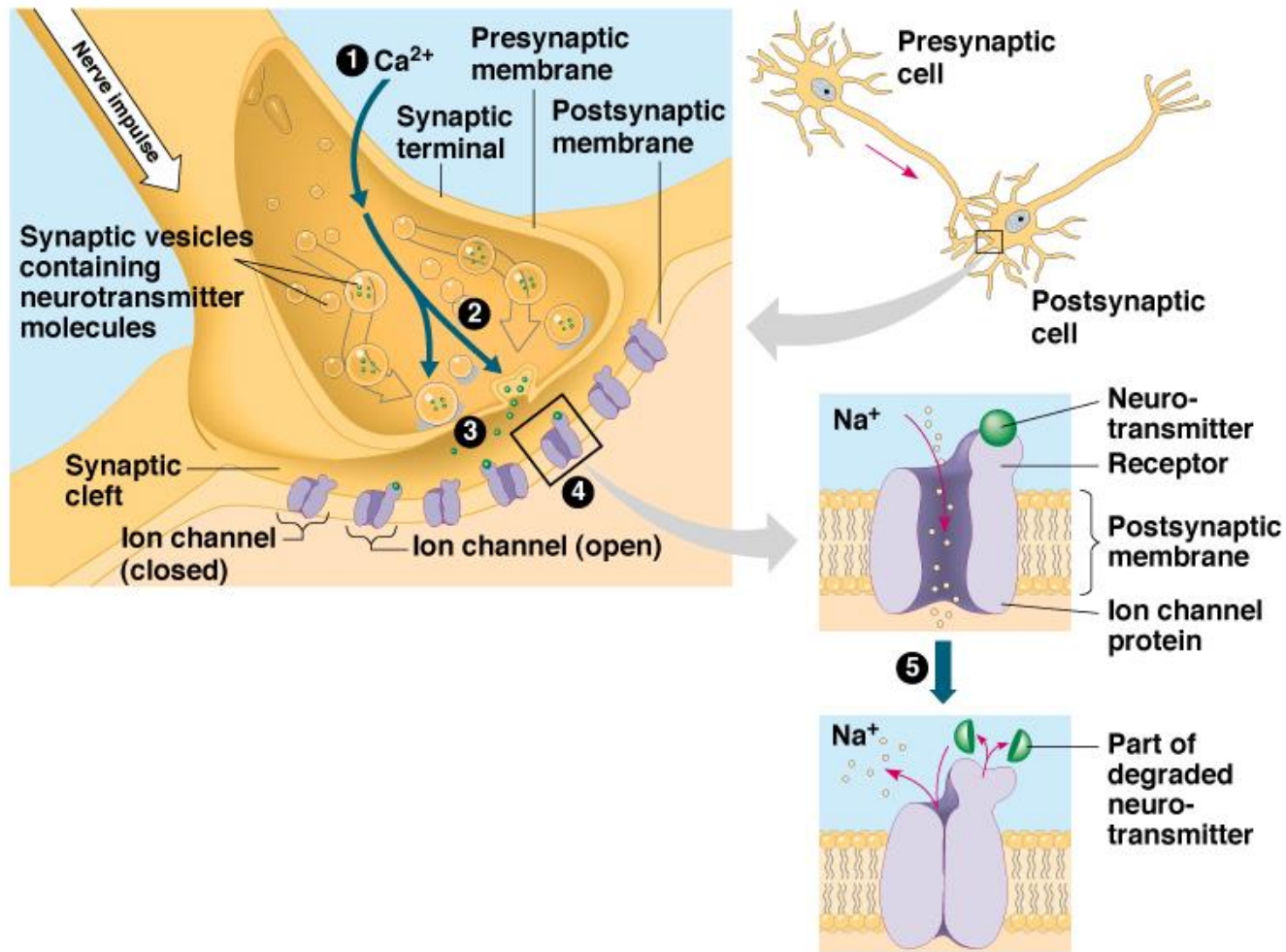
2. Chemical Synapse:

- Found in CNS, muscles, and most other organs.
- Require **neurotransmitters**: Chemicals that convey messages from one neuron to another.
- **Transmitting neuron** releases neurotransmitters which cross synapse and cause an action potential in the **receiving neuron**.

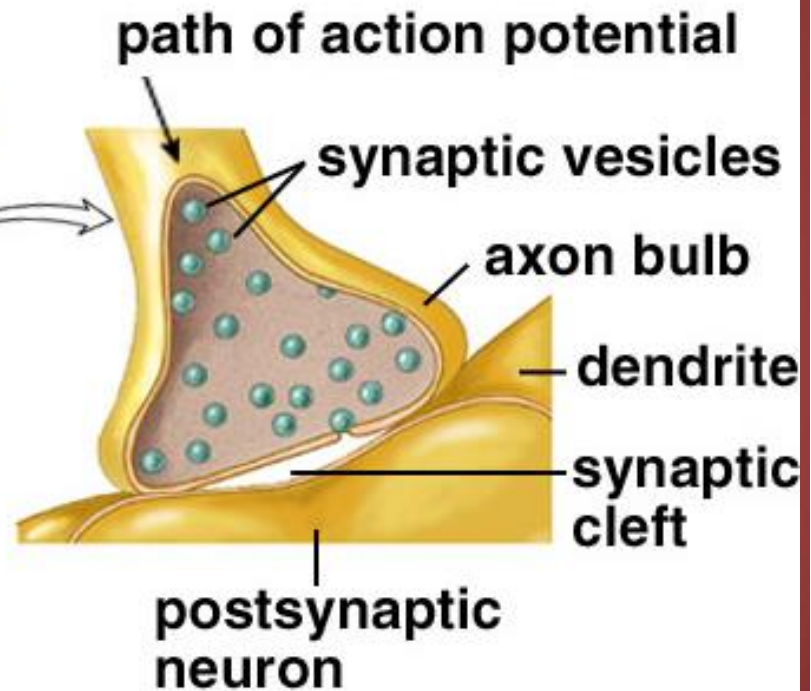
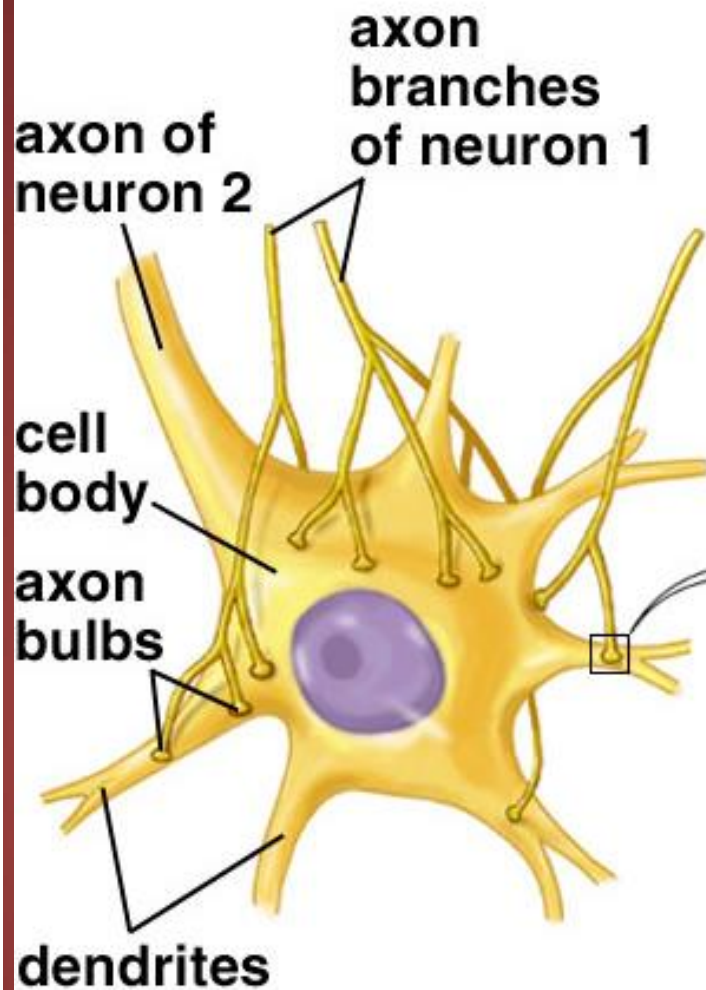
Synapse

- Functional connection between a neuron and another cell.
- Different types of synapses involve:
 - Axonodendritic:
 - Axon of one neuron and dendrite of another neuron.
 - Axosomatic:
 - Axon of one neuron and cell body of another neuron.
 - Axoaxonic:
 - Axon of 1 neuron and axon of another neuron.
- Transmission in **one direction only**.

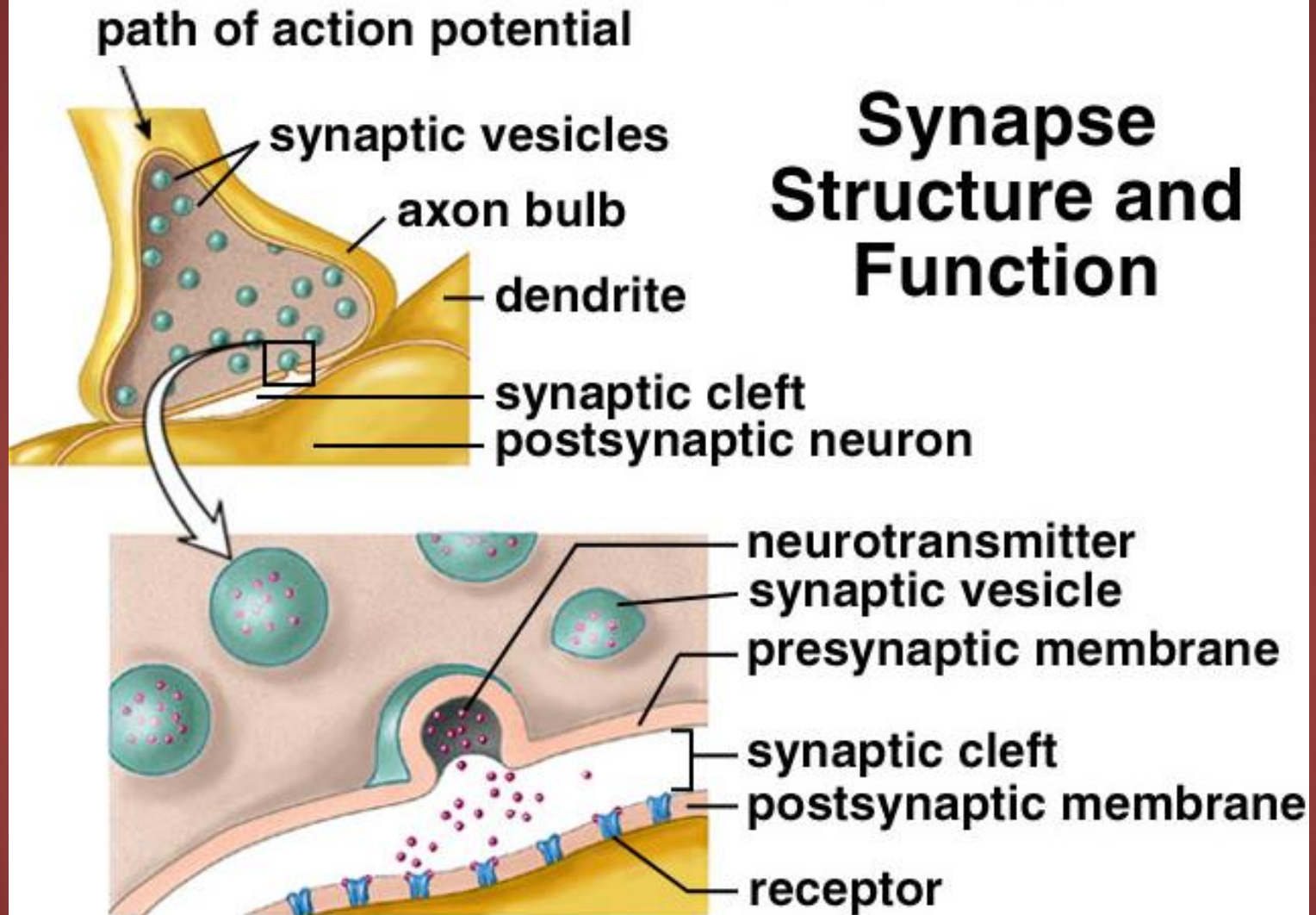
Chemical Synapses Use Neurotransmitters

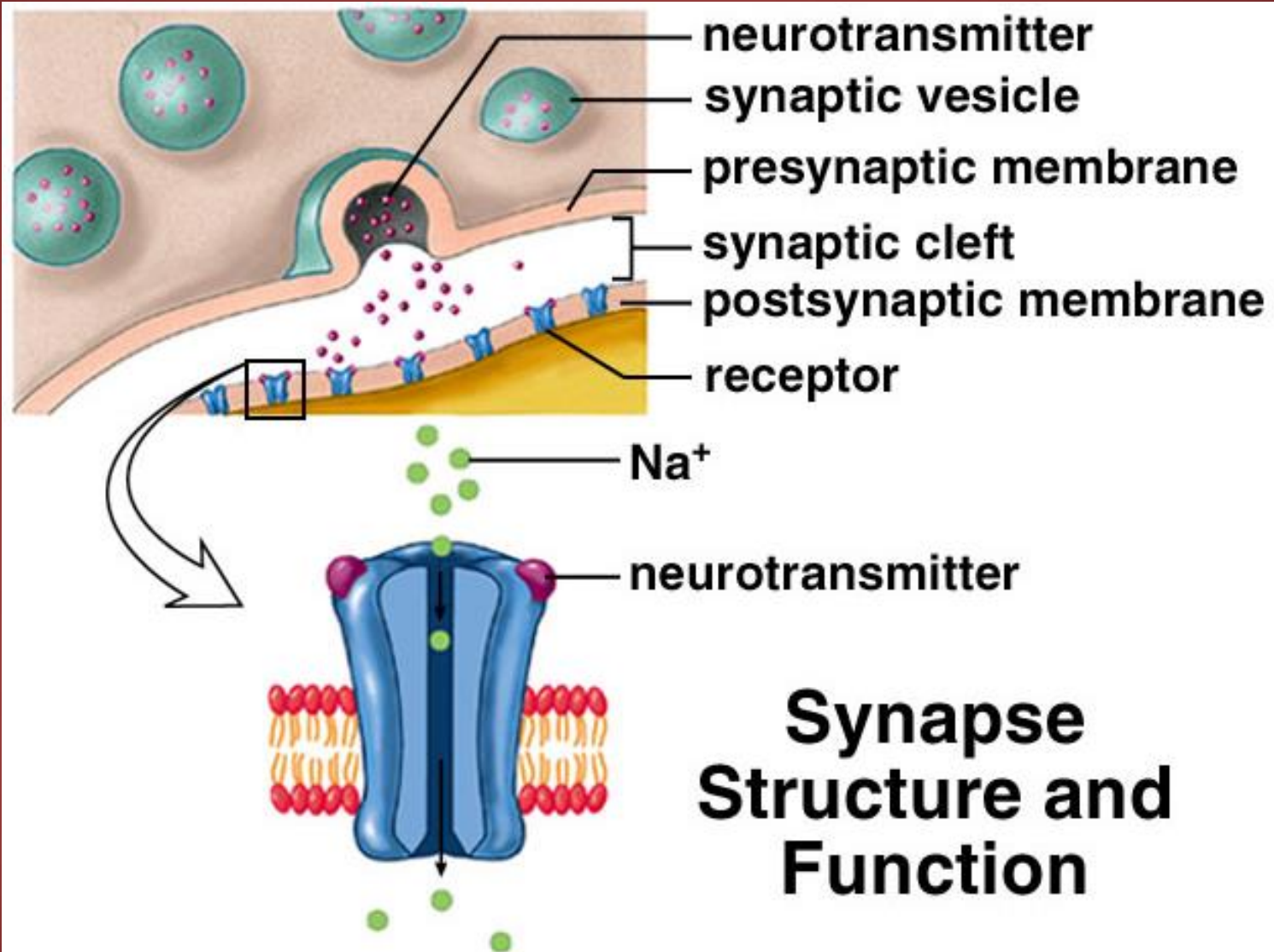


Synapse Structure and Function



Synapse Structure and Function

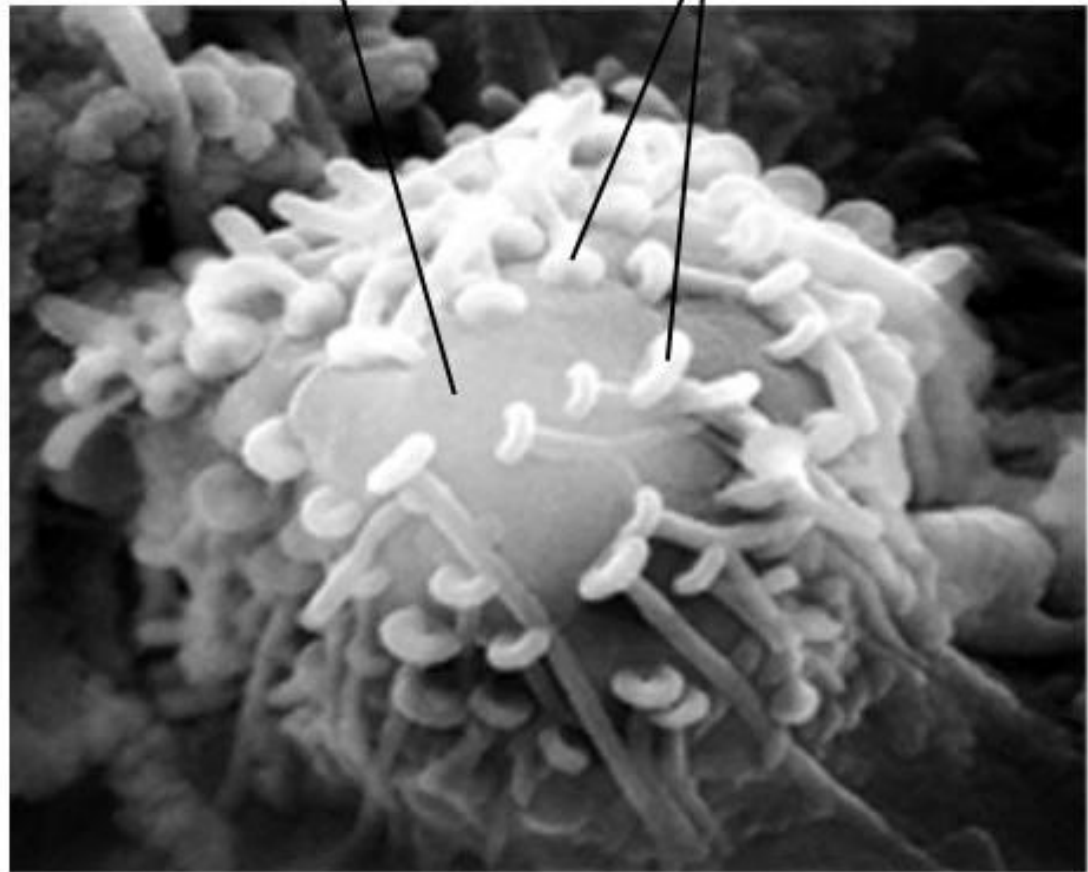




Synapse Structure and Function

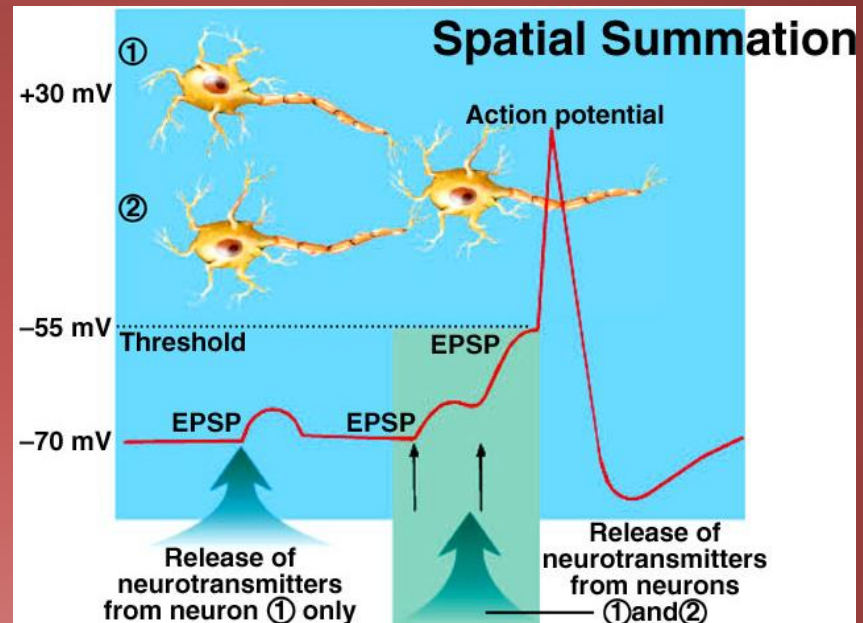
cell body
of
postsynaptic cell

axon bulbs



Synaptic Integration

- EPSPs can summate, producing AP.
 - Spatial summation:
 - Numerous boutons converge on a single postsynaptic neuron (distance).
 - Temporal summation:
 - Successive waves of neurotransmitter release (time).



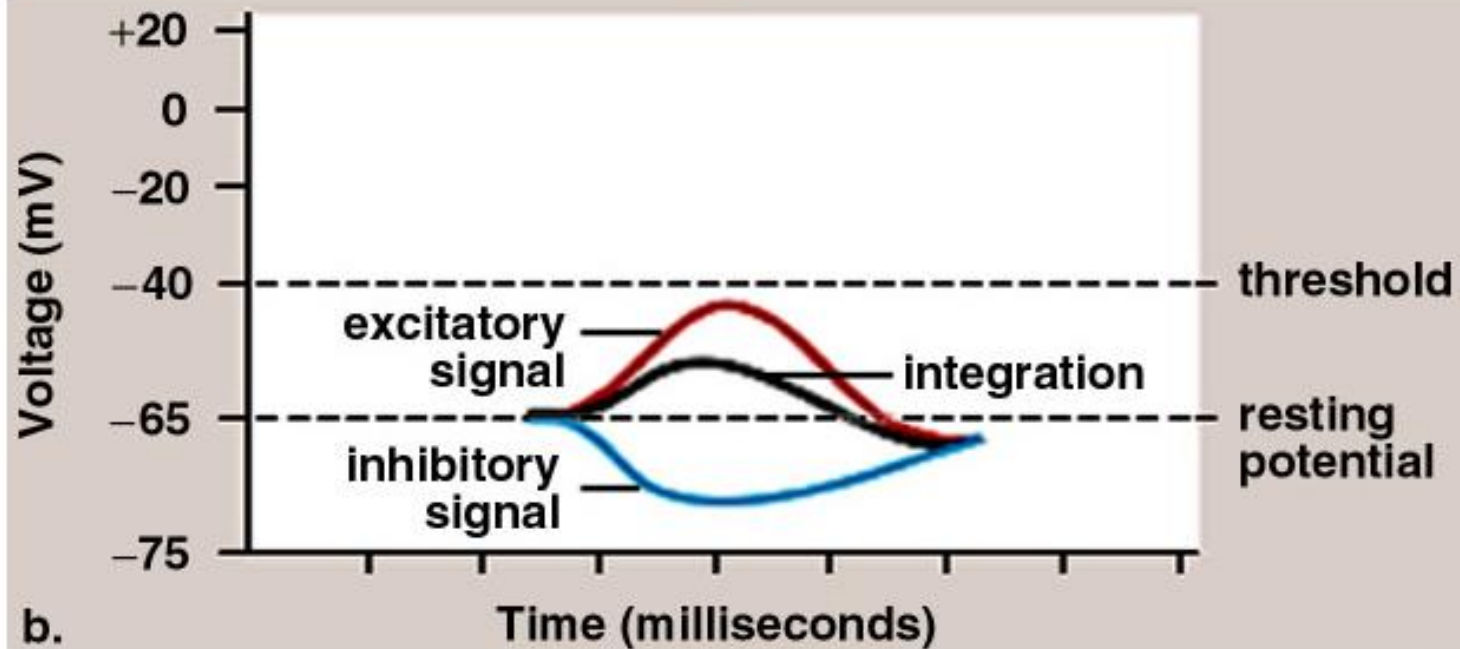
excitatory synapse

cell body

inhibitory synapse

Integration

a.



Long-Term Potentiation

- Neuron is stimulated at high frequency, enhance excitability of synapse.
 - Improved efficacy of synaptic transmission.
- Glutamate binds to AMPA receptors, opening Ca^{++} channels in postsynaptic membrane.
 - Increases the # of AMPA receptors, increasing ability to depolarize.
- Diffusion of Ca^{++} may activate NO, stimulating release of more glutamate.

Important Neurotransmitters

Dopamine:

- High levels are associated with schizophrenia.
- Low levels are associated with Parkinson's disease.

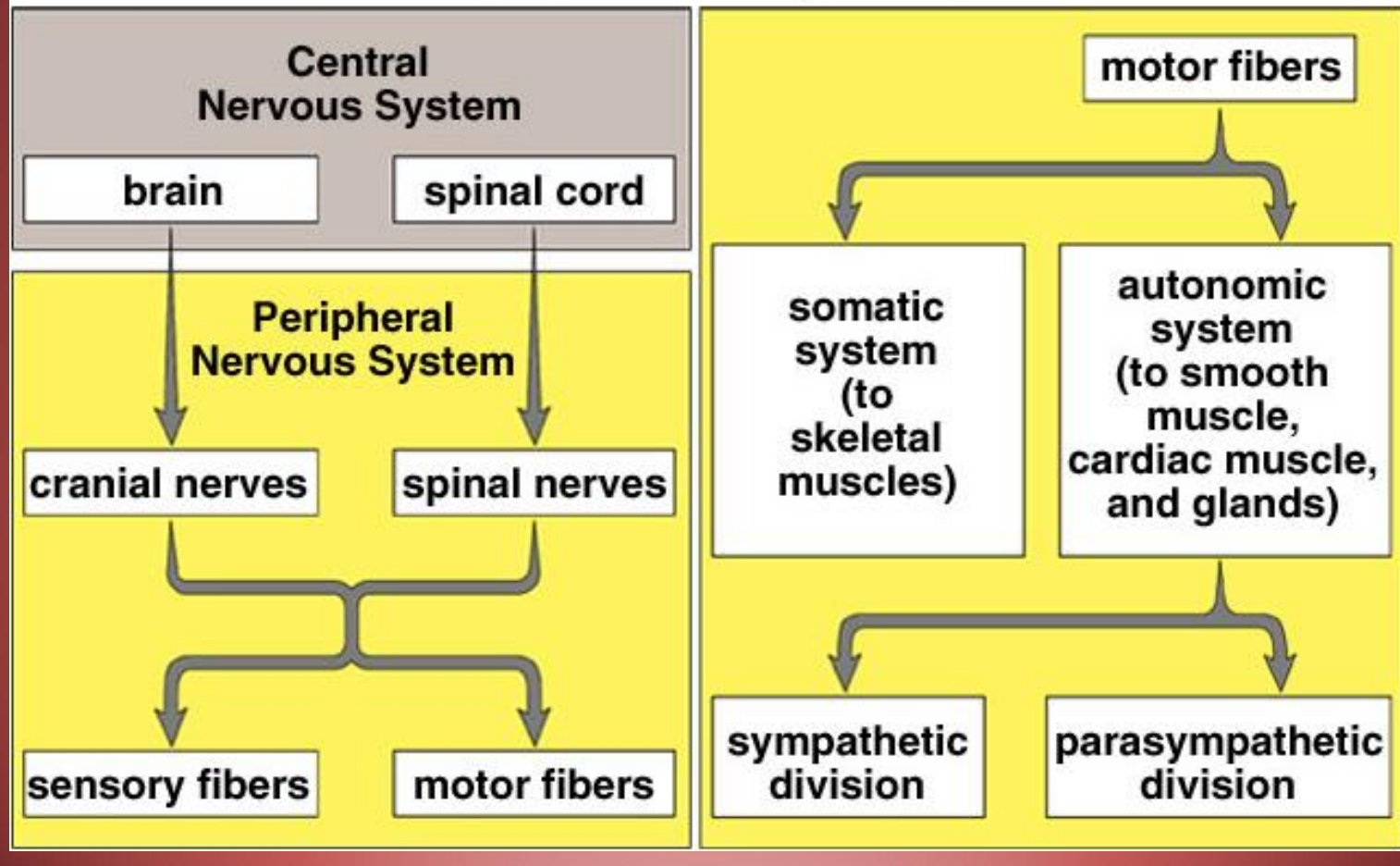
Serotonin and Norepinephrine:

- Affect mood, sleep, attention, and learning.
- Low levels are associated with depression.
- Prozac increases the amount of serotonin at synapses.

Endorphins:

- Small peptides that decrease pain perception by CNS.
- Natural painkillers produced in times of stress (childbirth).
- Also decrease urine output, depress respiration, and cause euphoria and other emotional effects on brain.
- Heroin and morphine mimic action of endorphin.

Organization of the Nervous System

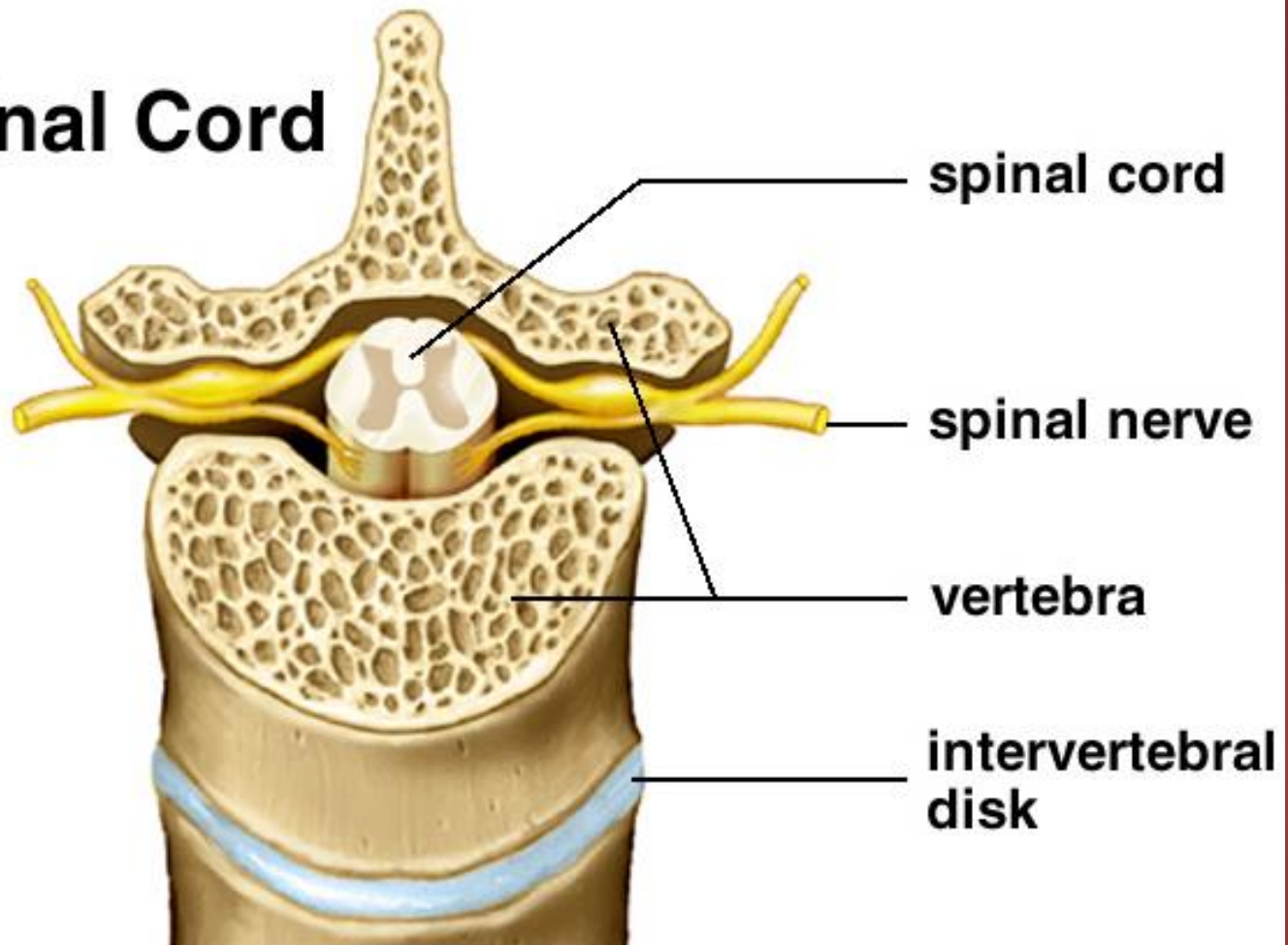


Central vs. Peripheral Nervous System

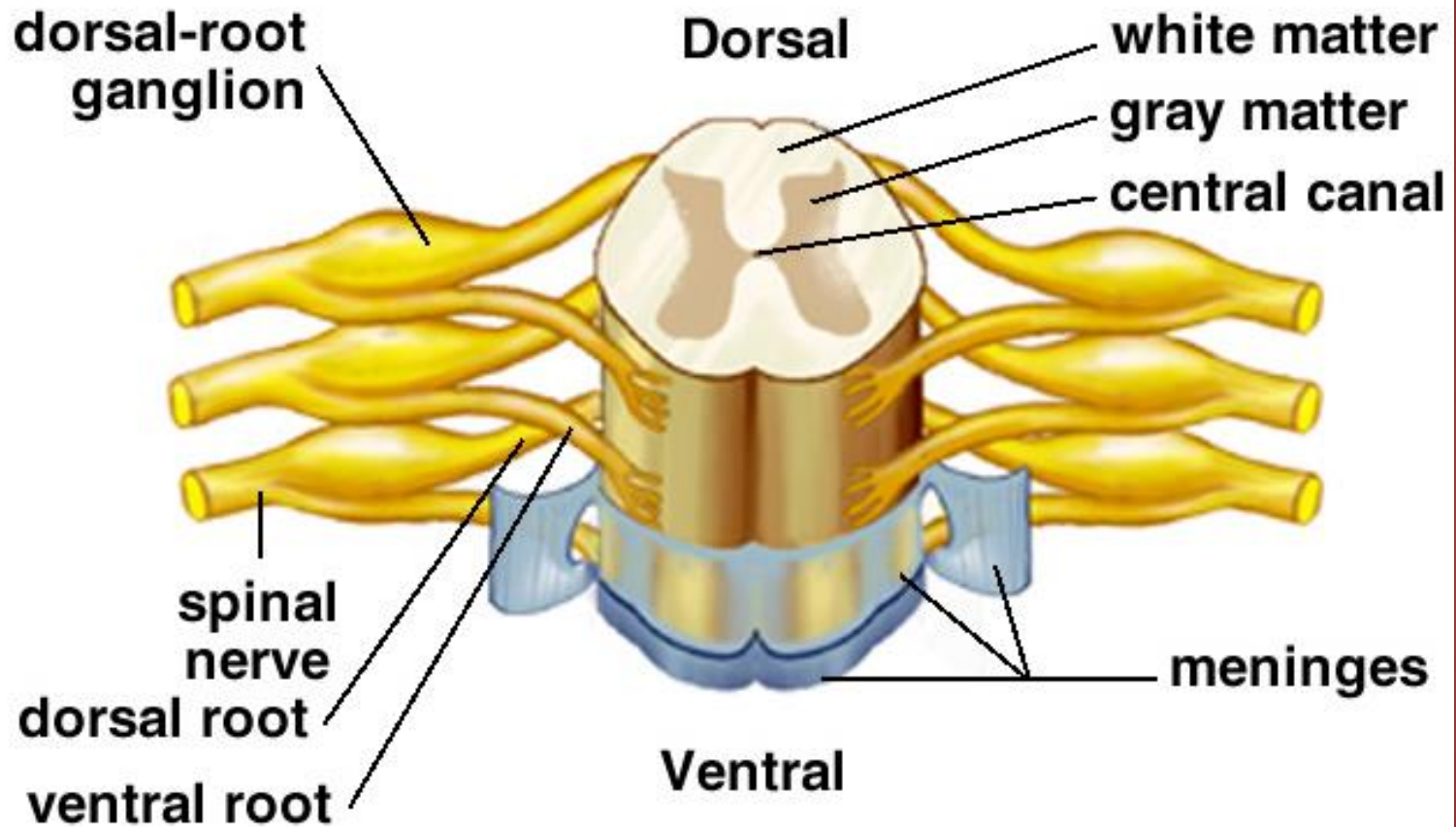
Central Nervous System (CNS):

- Spinal Cord: Lies inside vertebral column.
 - Receives sensory information from skin and muscles.
 - Sends out motor commands for movement.
 - Reflexes: Unconscious responses to a stimulus.
Only sensory and motor neurons are involved.

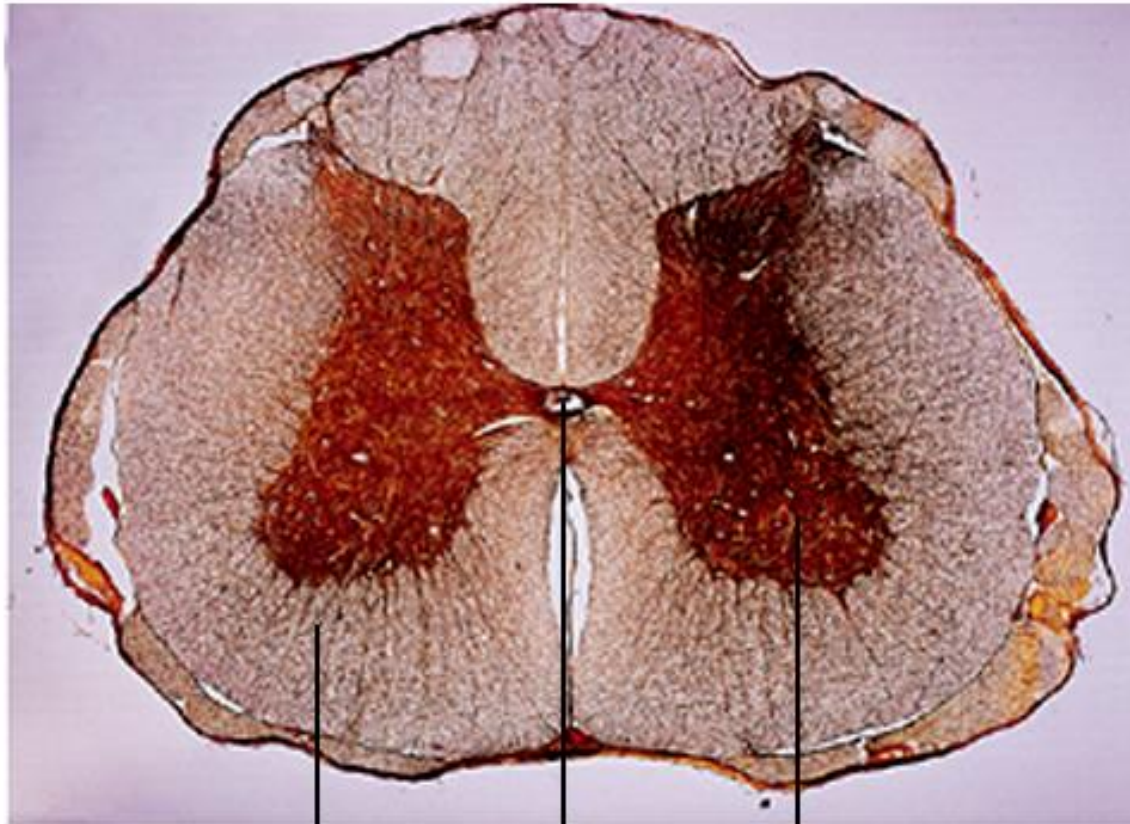
Spinal Cord



Spinal Cord



Spinal Cord

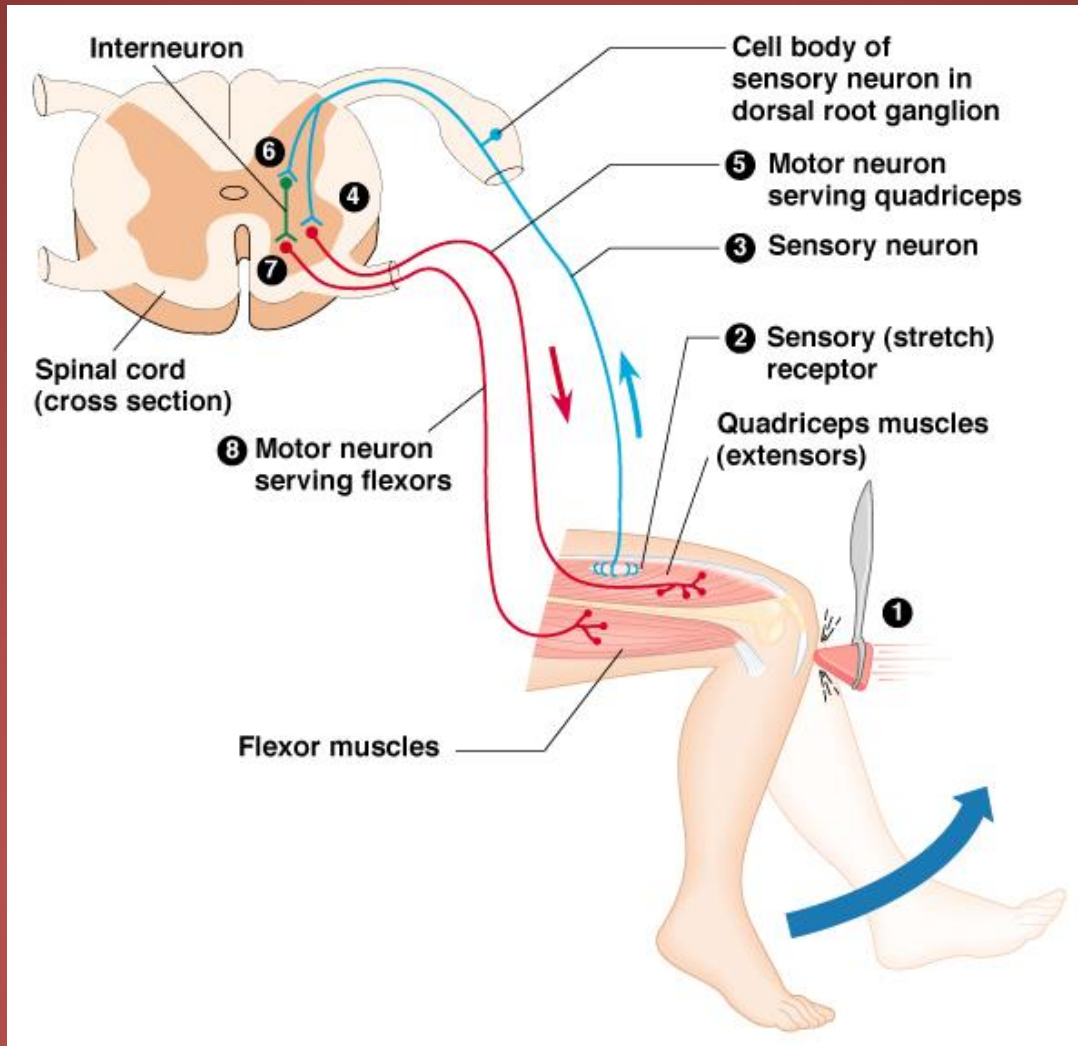


white
matter

central
canal

gray
matter

Knee-Jerk Reflex Involves Spinal Cord, not Brain



Central Nervous System

– **Brain**: Master control center. Over 100 billion neurons and many more supporting cells.

- Emotion
- Intellect
- Controls some muscles and spinal cord
- Homeostatic centers

– **Brain**: Protected by:

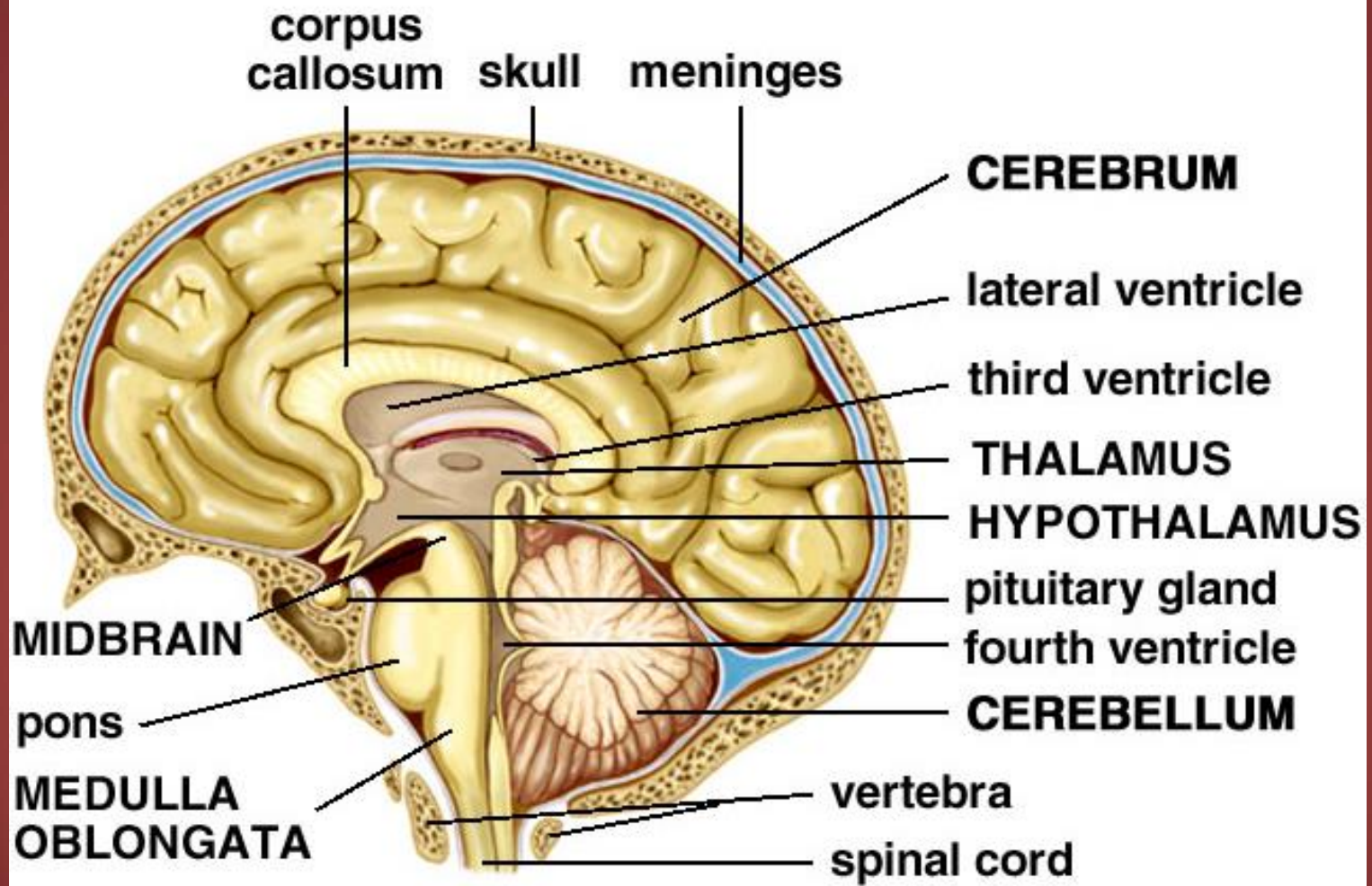
- **Skull**
- **Meninges**: Three layers of tissue covering brain.
- **Cerebrospinal Fluid**: Liquid surrounding brain.
- **Blood-brain barrier**: Maintains stable environment and protects brain from infection and many harmful chemicals.

Central Nervous System

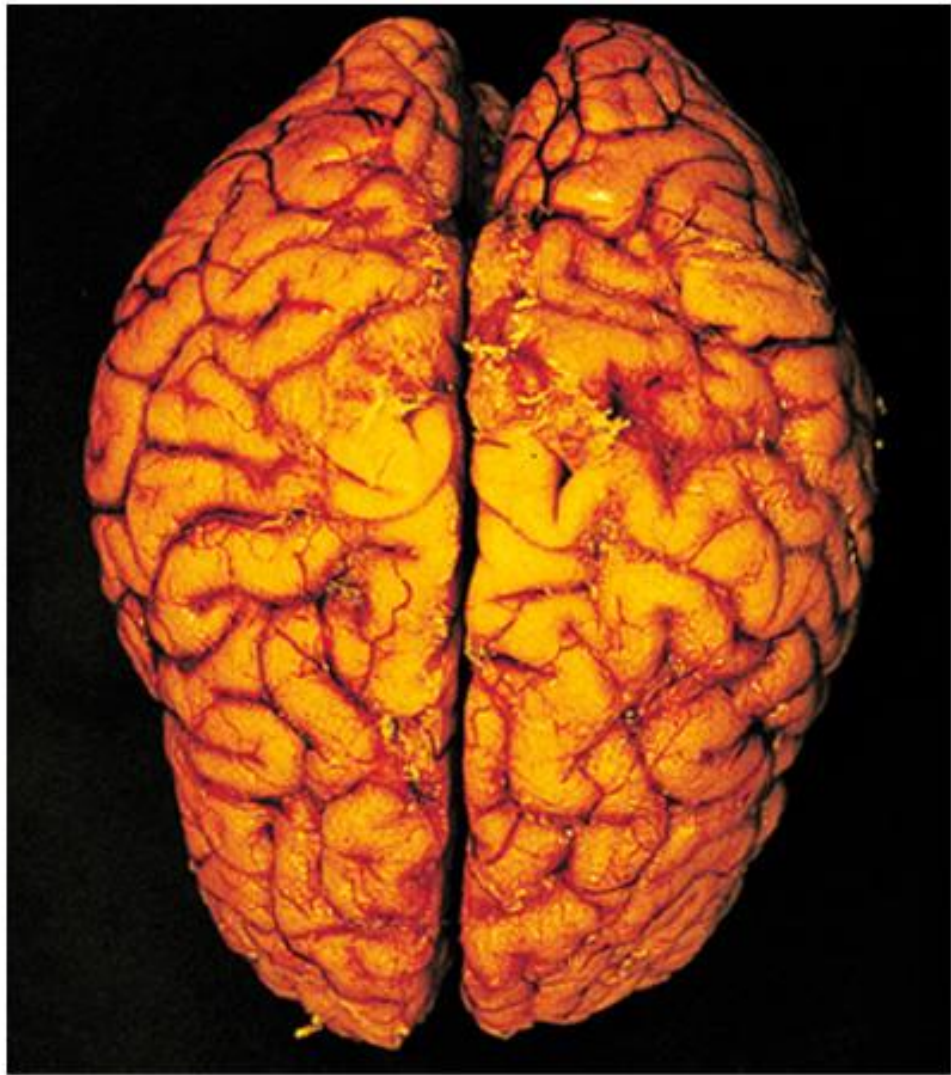
– Cerebral Cortex:

- Less than 5 mm thick
- Highly folded, occupies over 80% of total brain mass.
- Contains 10 billion neurons and billions of synapses.
- Left and right hemispheres are divided into 4 lobes
- Intricate neural circuitry is responsible for many unique human traits:
 - Reasoning
 - Mathematical ability
 - Language skills
 - Imagination
 - Personality traits
 - Artistic talent
 - Sensory perception
 - Motor function

The Human Brain

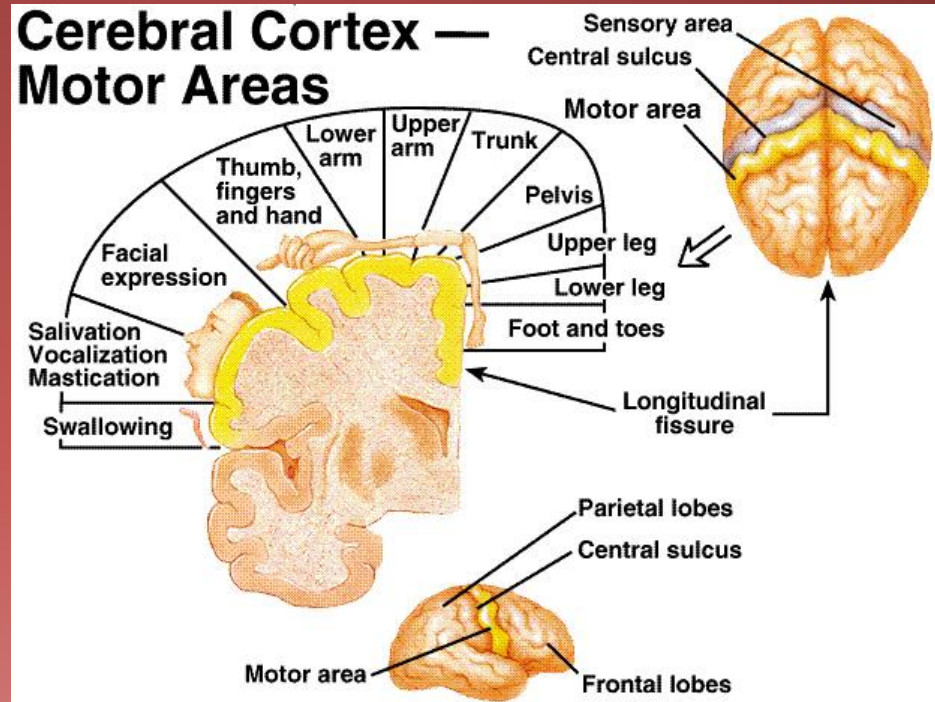


Human Brain



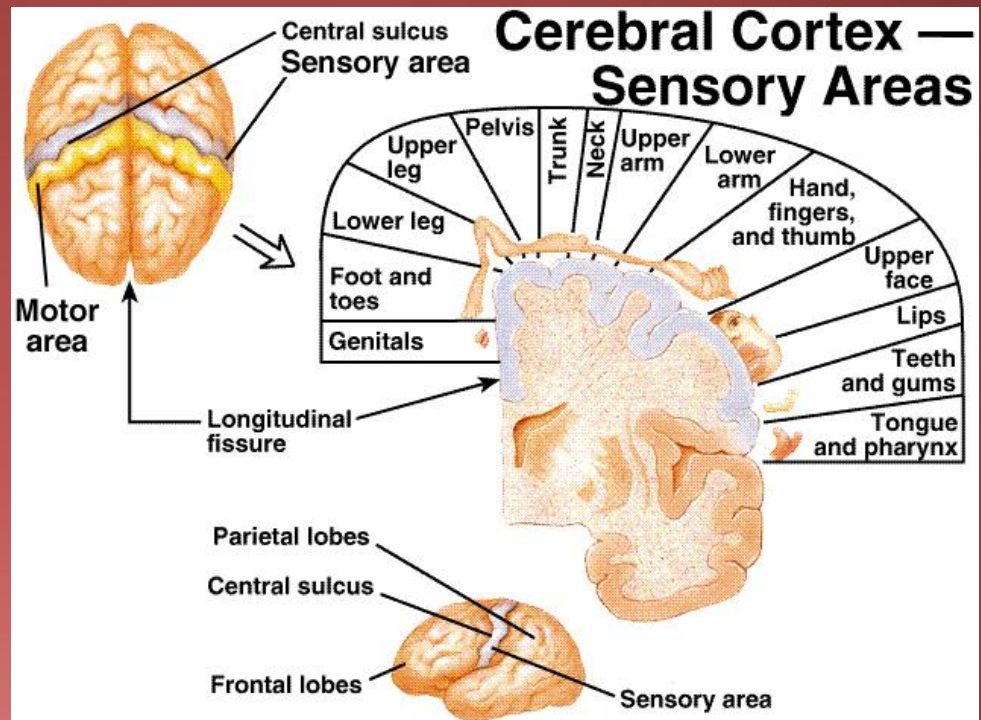
Cerebral Cortex

- Frontal:
- Precentral gyri:
- Involved in motor control.
- Body regions with the greatest number of motor innervation are represented by largest areas of motor cortex.



Parietal Lobe

- Primary area responsible for perception of somatesthetic sensation.
- Body regions with highest densities of receptors are represented by largest areas of sensory cortex.

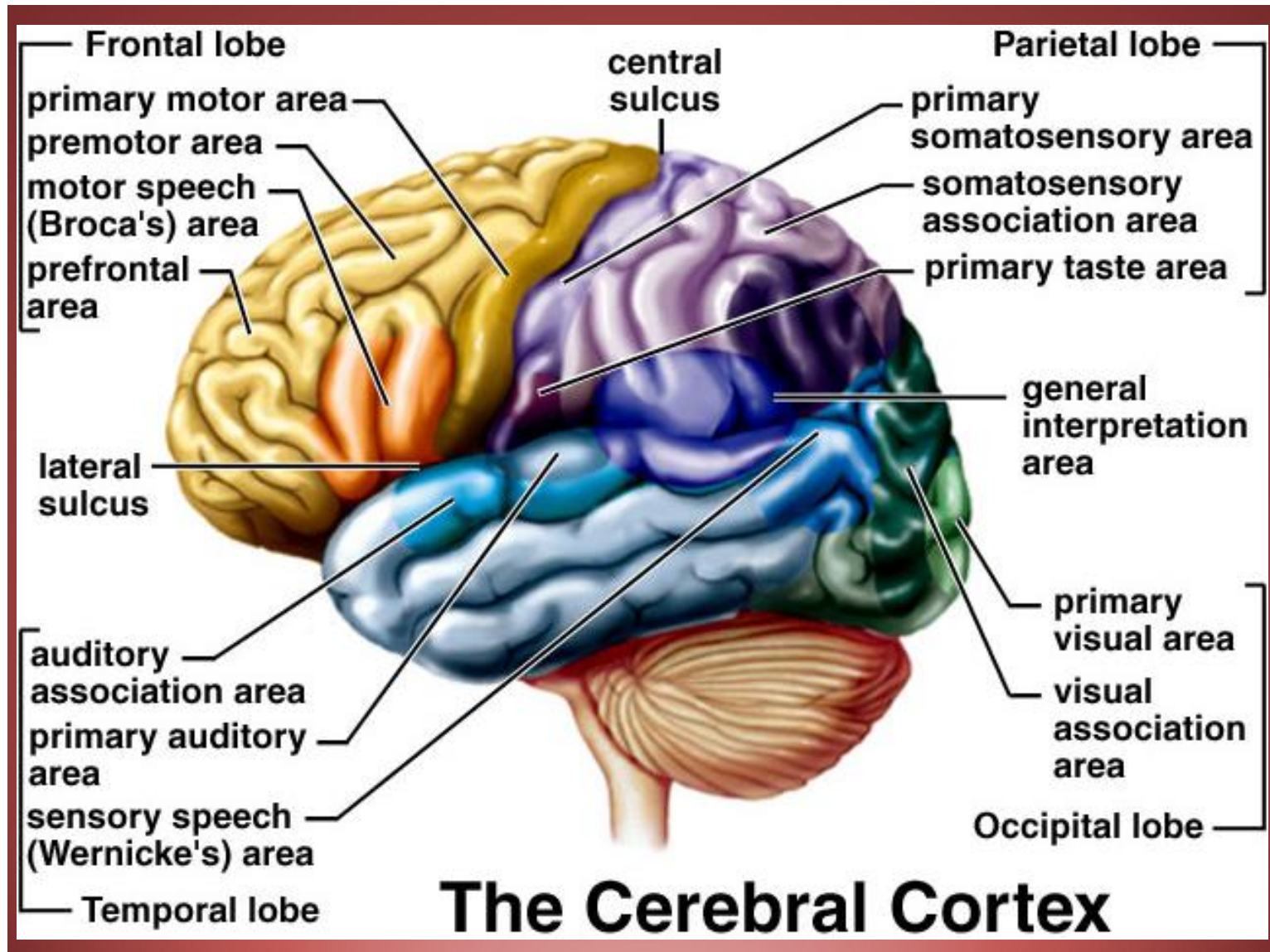


Cerebrum

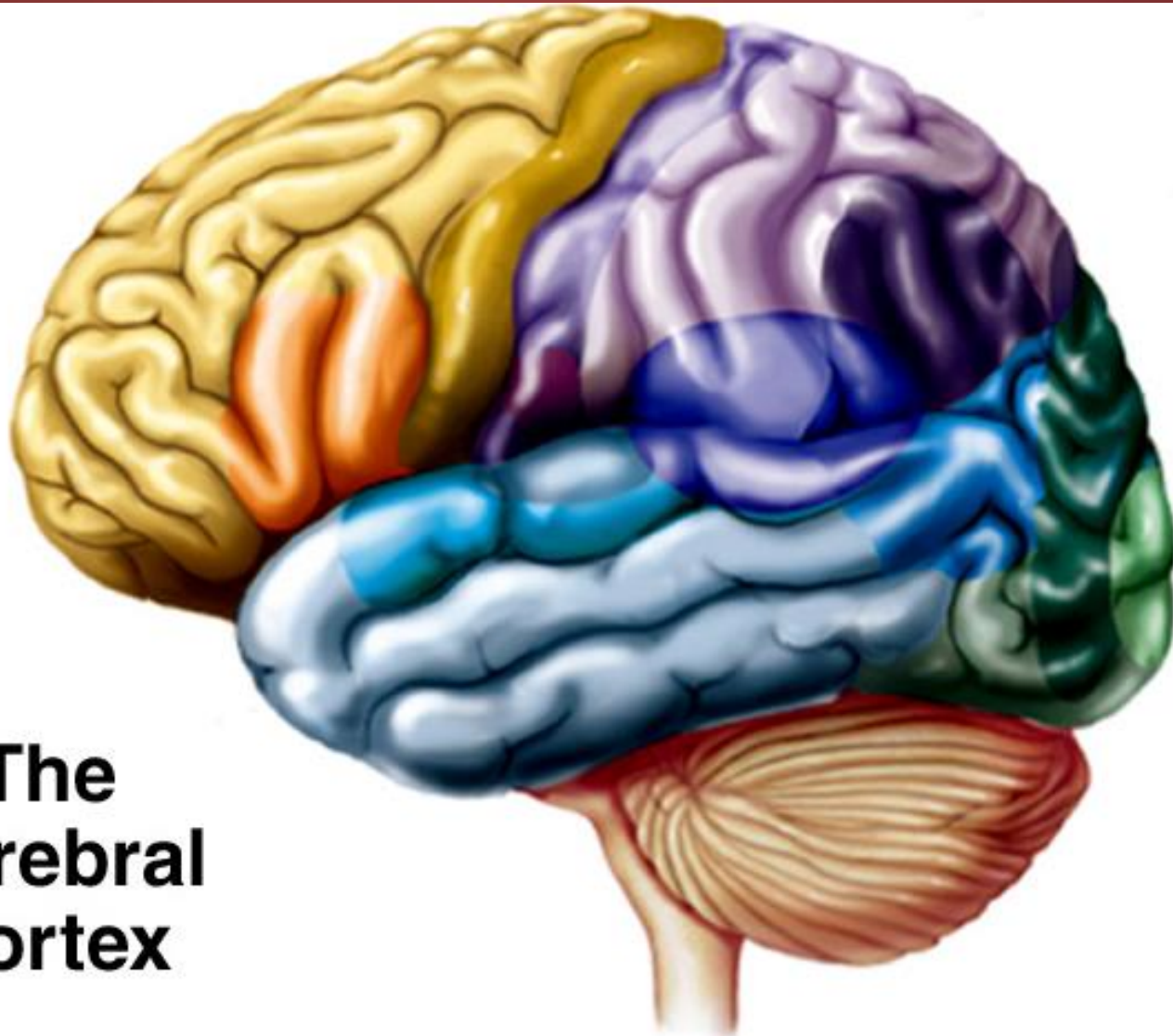
- Temporal:
 - Interpretation of auditory centers that receive sensory fibers from cochlea.
 - Interpretation and association of auditory and visual information.
- Occipital:
 - Primary area responsible for vision and coordination of eye movements.
- Deep insula:
 - Involved in memory.

Basal Nuclei

- Also called basal ganglia. Contains:
 - Corpus striatum:
 - Caudate nucleus
 - Lentiform nucleus:
 - Putman and globus pallidus
- Masses of gray matter composed of neuronal cell bodies.
- Function:
 - Control of skeletal muscles.
 - Control of voluntary movements.

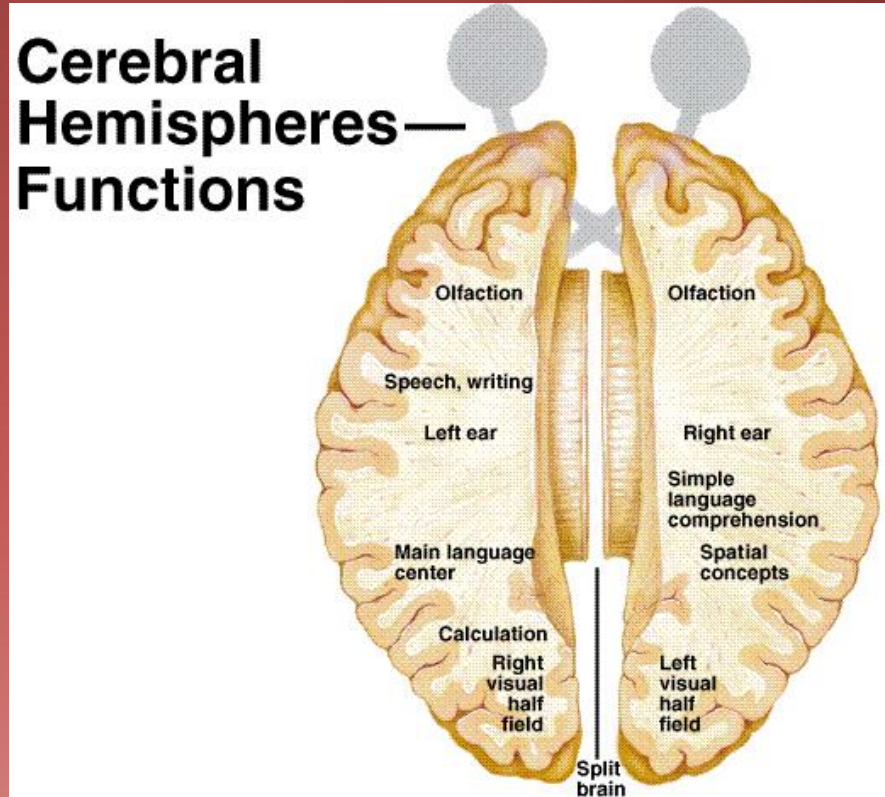


The Cerebral Cortex



Cerebral Lateralization

- Cerebral Dominance.
- Specialization of one hemisphere.
- Left hemisphere:
 - More adept in language and analytical abilities.
- Right hemisphere:
 - Limited verbal ability.
 - Most adept at visuospatial tasks.



Diencephalon

- Comprised of the:
 - Thalamus
 - Hypothalamus
 - Pituitary gland

Thalamus

- Composes the majority of the diencephalon.
- Forms most of the walls of the 3rd ventricle.
- Acts as relay center for all sensory information (except olfactory) to the cerebrum

Hypothalamus

- Contains neural centers for hunger, thirst, and body temperature.
- Contributes to the regulation of sleep, wakefulness, emotions and sexual performance.
- Stimulates hormonal release from anterior pituitary.
- Produces ADH and oxytocin.
- Coordinates sympathetic and parasympathetic reflexes.

Pituitary Gland

- Posterior pituitary:
 - Releases ADH and oxytocin.
- Anterior pituitary:
 - Regulates secretion of hormones of other endocrine glands.

Midbrain

- Contains:
 - Corpora quadrigemina
 - Cerebral peduncles
 - Substantia nigra
 - Red nucleus
- Functions:
 - Visual reflexes.
 - Relay center for auditory information.
 - Motor coordination.

Hindbrain

- Metencephalon:
- Pons:
 - Contains the apneustic and pneumotaxic respiratory centers.
- Cerebellum:
 - Receives input from proprioceptors.
 - Participates in coordination of movement.

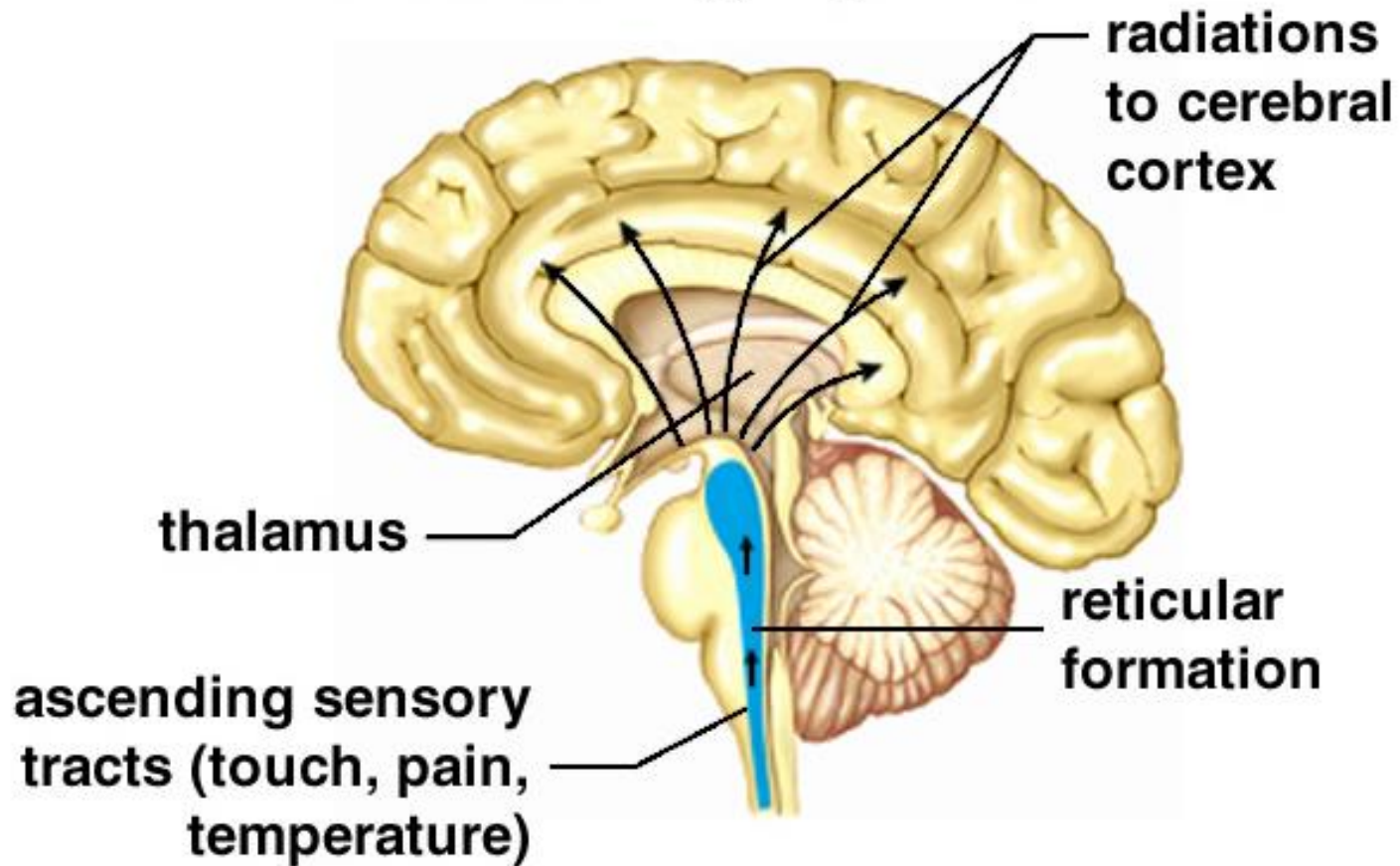
Hindbrain

- Myelencephalon (medulla):
 - All descending and ascending fiber tracts between spinal cord and brain must pass through the medulla.
 - Vasomotor center:
 - Controls autonomic innervation of blood vessels.
 - Cardiac control center:
 - Regulates autonomic nerve control of heart.
 - Regulates respiration with the pons.

Reticular Activating System

- Complex network of nuclei (masses of gray matter) that runs the length of the brain stem
- Functions:
 - Receives sensory signals and sends it to higher centers
 - Receives motor signals and sends it to the spinal cord
- Reticular Activating Portion (RAS) causes arousal via the cerebellum and may filter out unnecessary sensory stimuli.
 - Damage can cause a coma

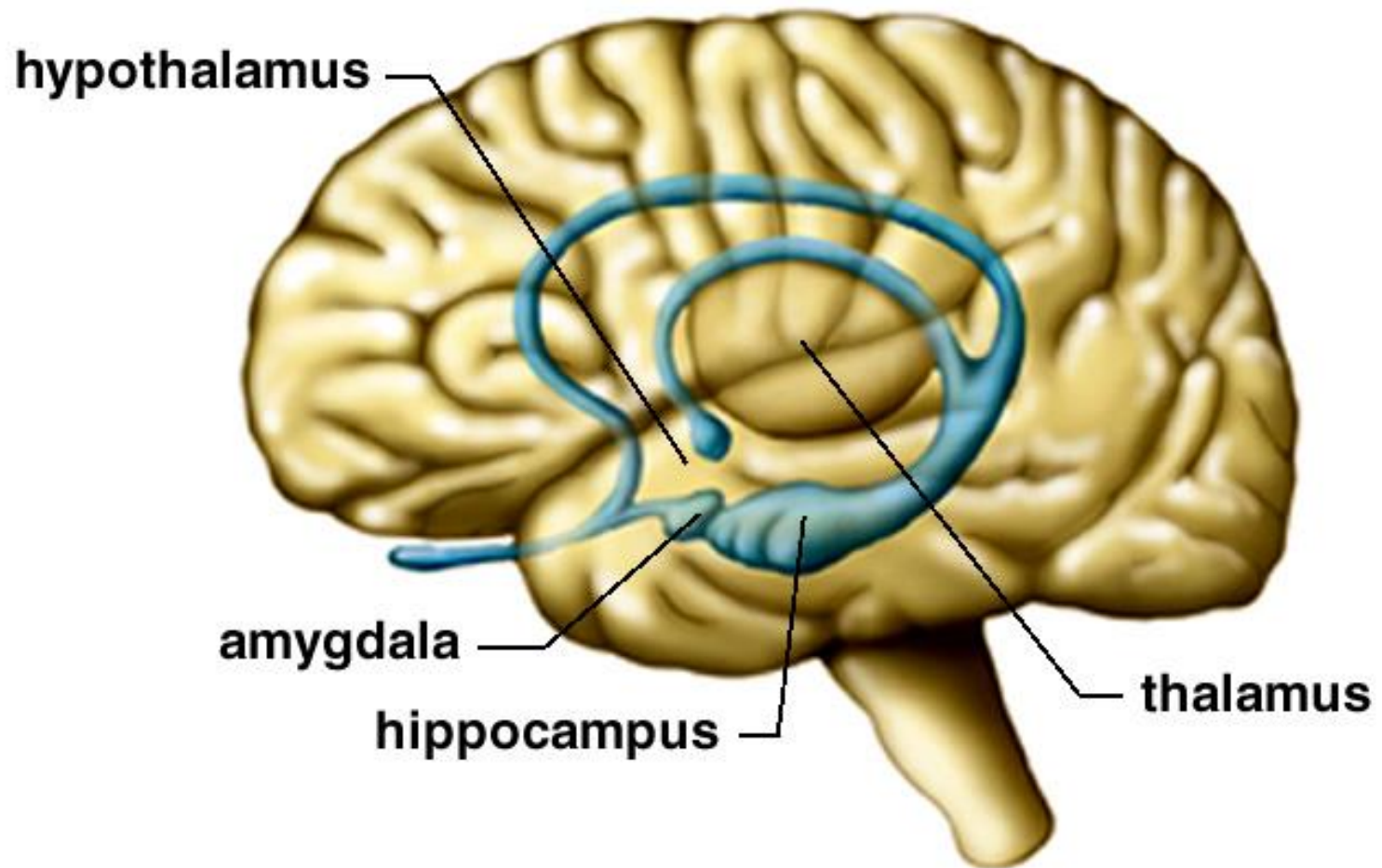
The Reticular Activating System



Emotion and Motivation

- Limbic system:
- Center for basic emotional drives.
- Closed circuit between limbic system, thalamus and hypothalamus.
 - Amygdala produces rage and aggression.
 - Amygdala and hypothalamus produce fear.
 - Hypothalamus contains feeding and satiety centers.
 - Hypothalamus and limbic system involved in the regulation of sexual drive and behavior.
 - Hypothalamus and frontal cortex function in goal directed behavior.

The Limbic System



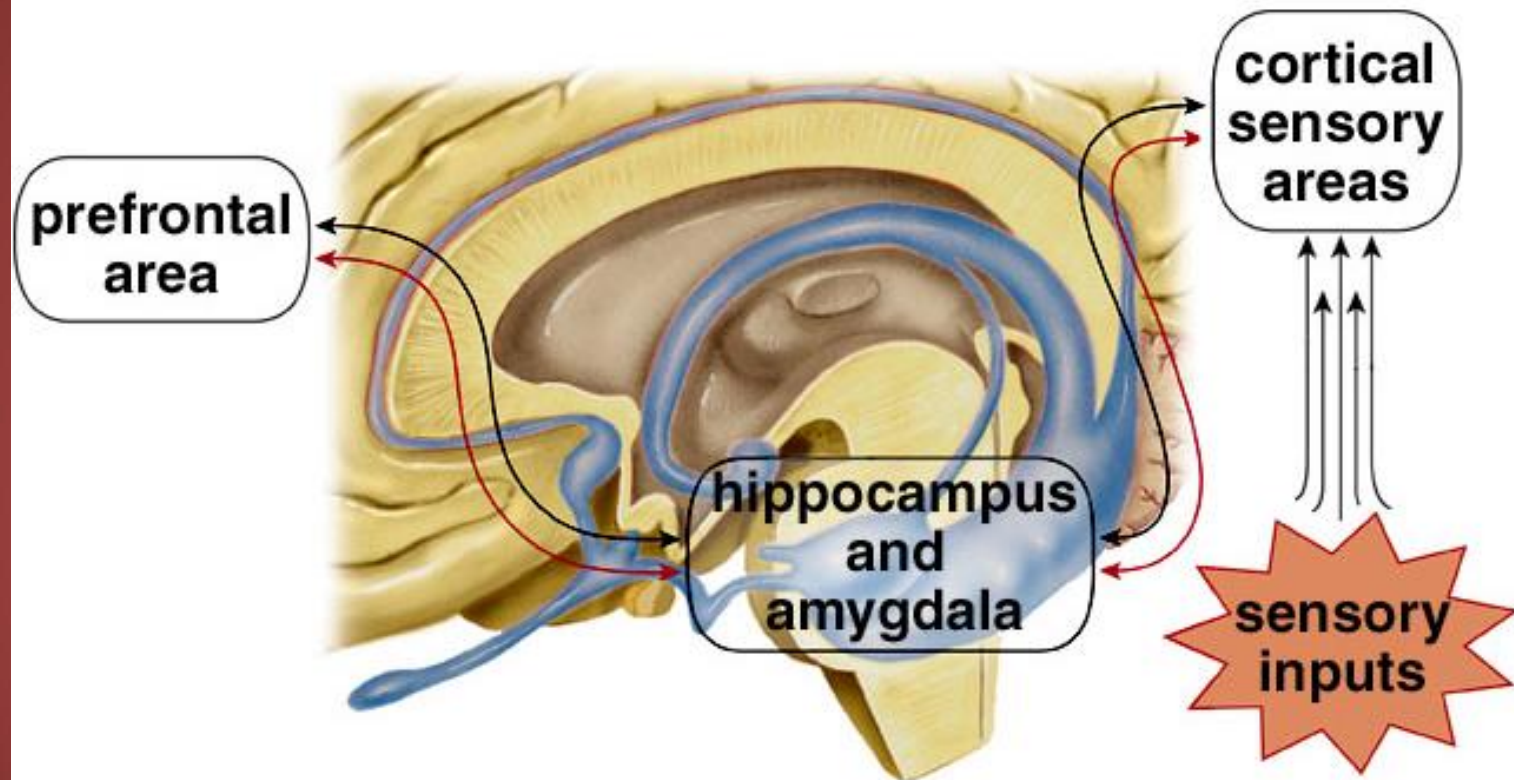
Memory

- Short-term:
 - Memory of recent events.
- Medial temporal lobe: consolidates short term into long term memory.
- Hippocampus is critical component of memory.
- Acquisition of new information, facts and events requires both the medial temporal lobe and hippocampus.

Memory

- Long-term:
 - Requires activation of genes, leading to protein synthesis.
 - Growth of dendritic spines.
 - Formation of new synaptic connections.
- Cerebral cortex stores factual information.
- Prefrontal lobes involve retrieval of parts of memories from different areas of the brain to use as a whole.

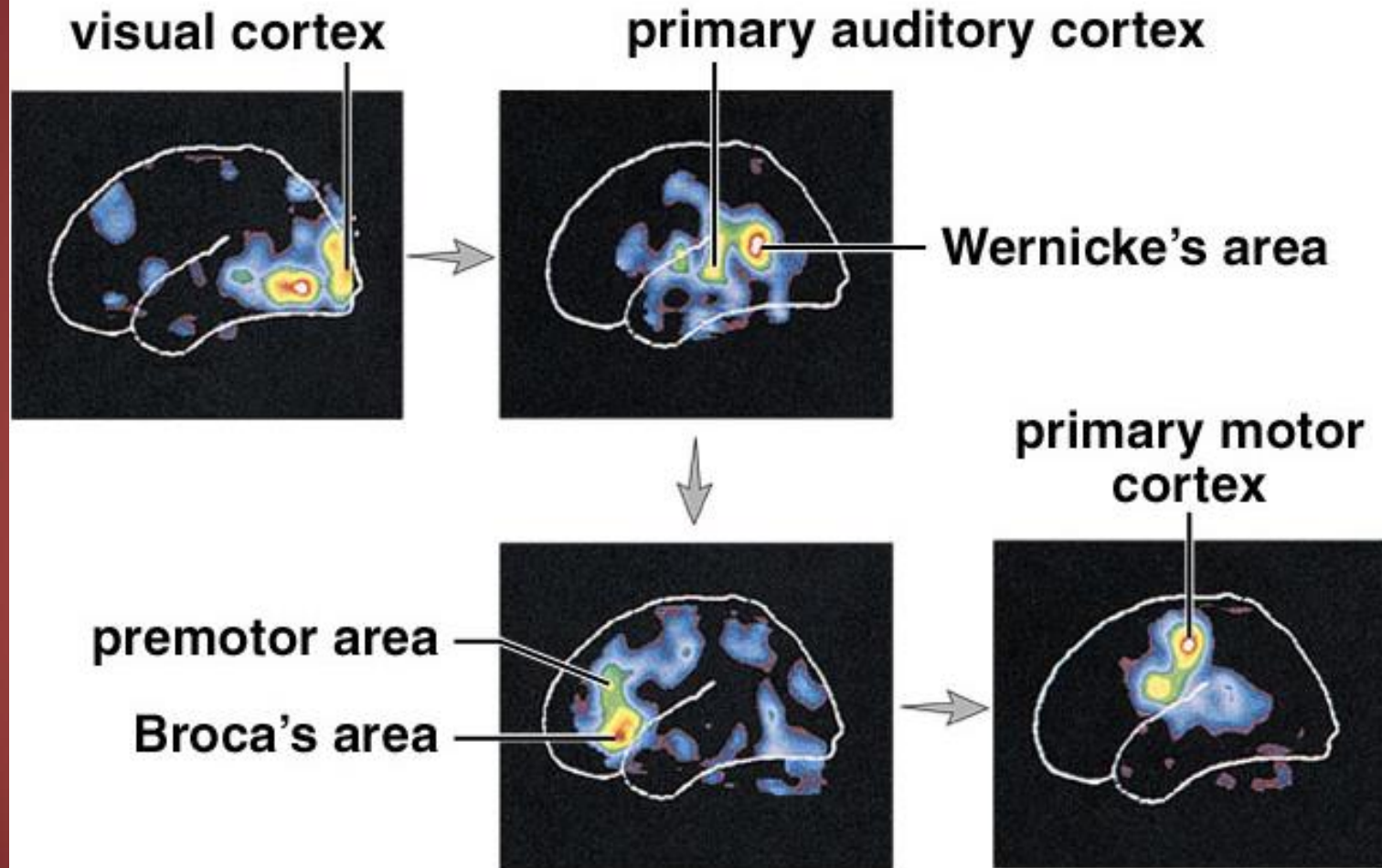
Long-Term Memory Circuits



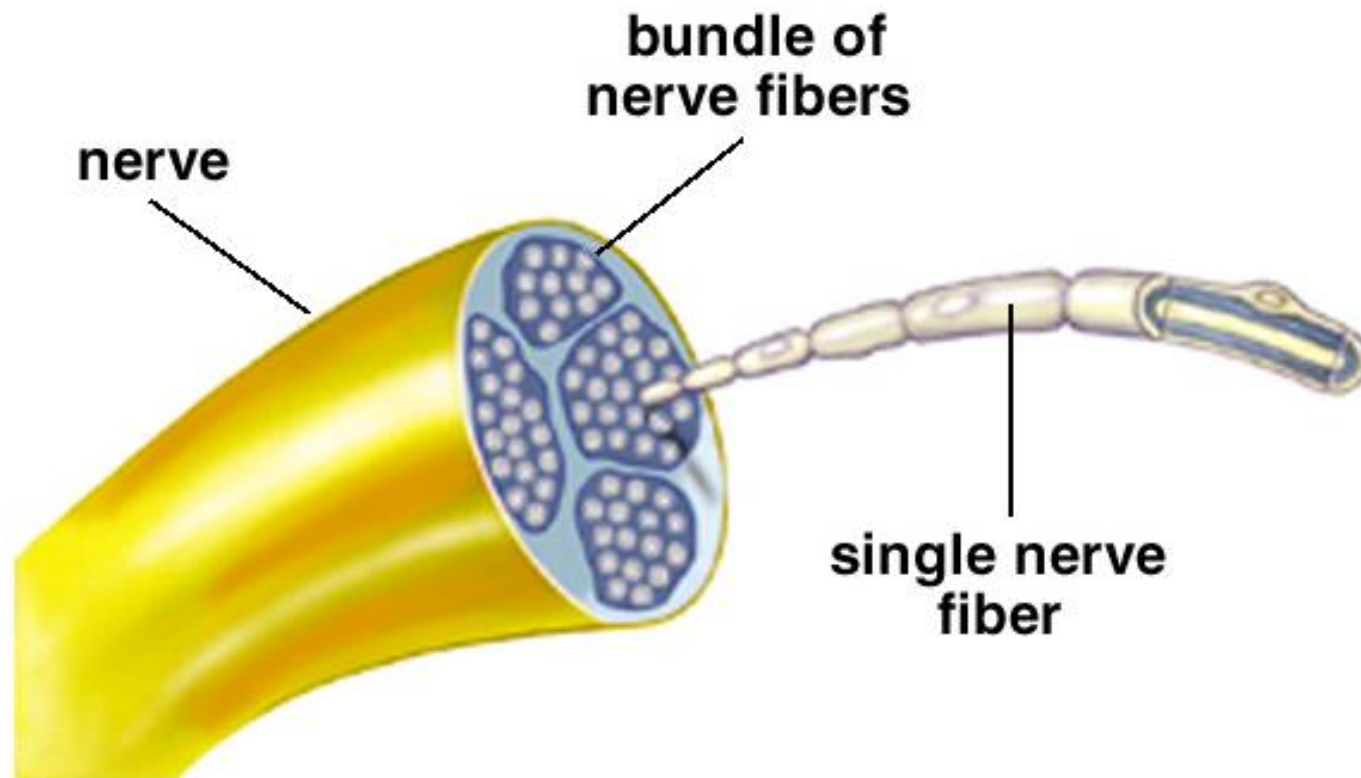
Language

- Broca's area:
 - Involves articulation of speech.
 - In damage to Broca's area, comprehension of speech is unimpaired.
- Wernicke's area:
 - Involves language comprehension.
 - In damage to Wernicke's area, language comprehension is destroyed, but can still speak.
- Angular gyrus:
 - Center of integration of auditory, visual, somatesthetic information.

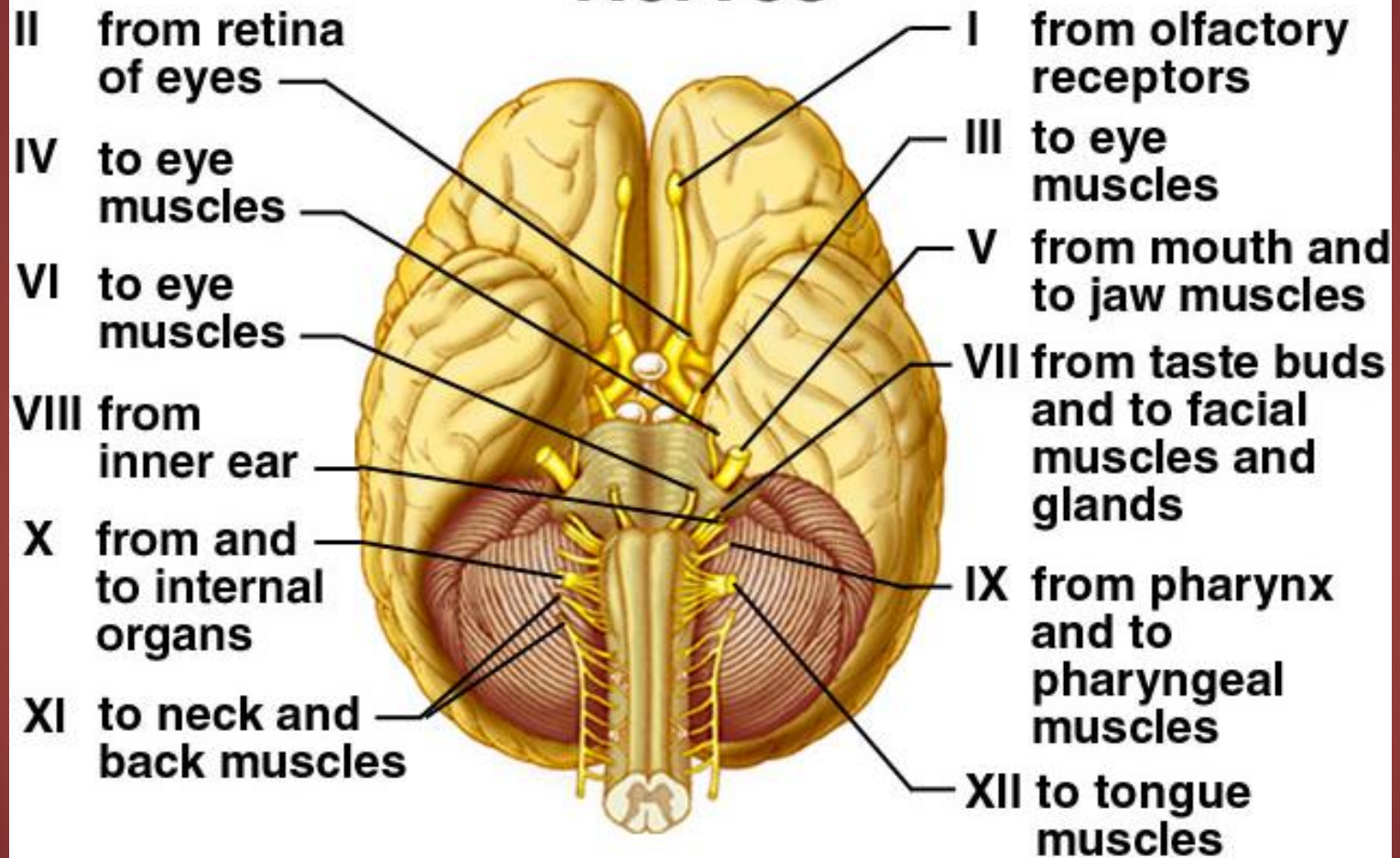
Language and Speech



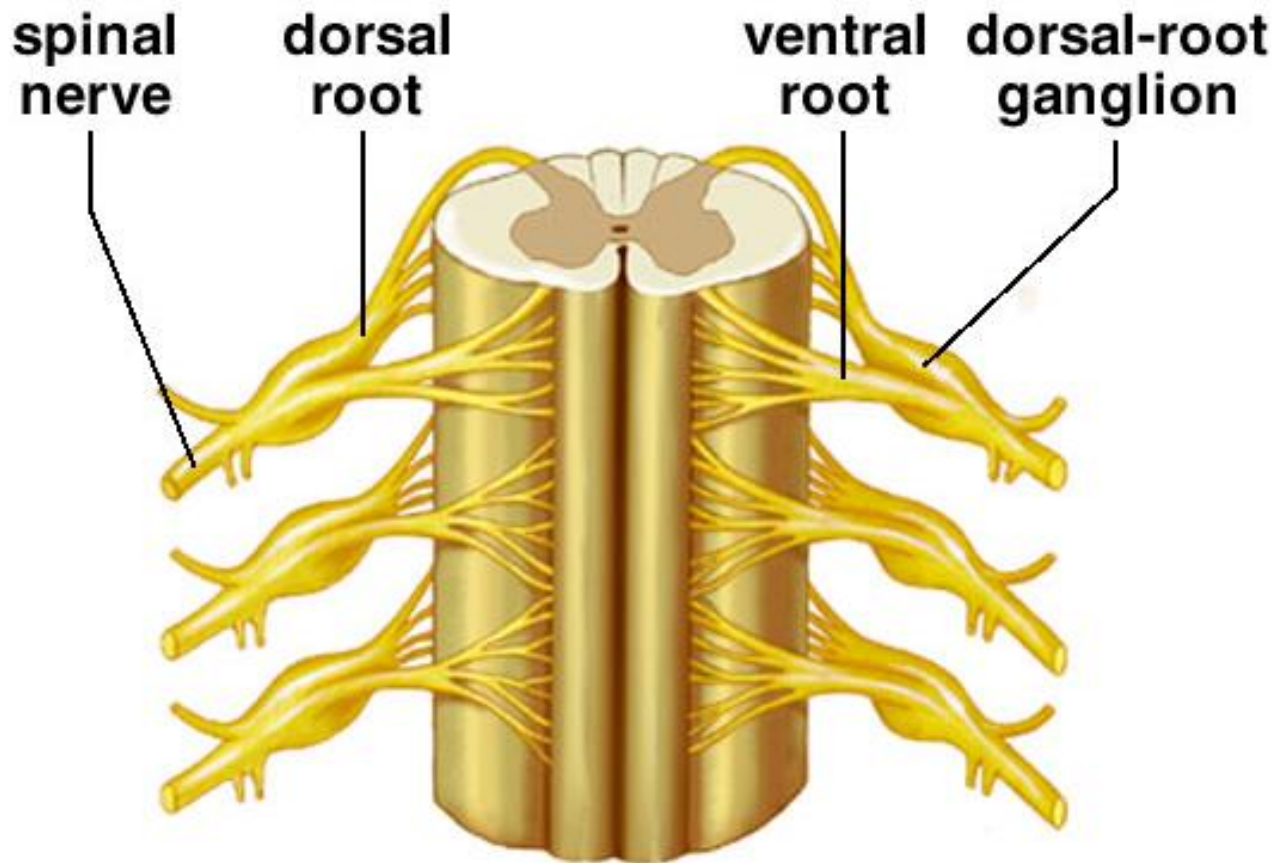
Nerve Function



Cranial and Spinal Nerves

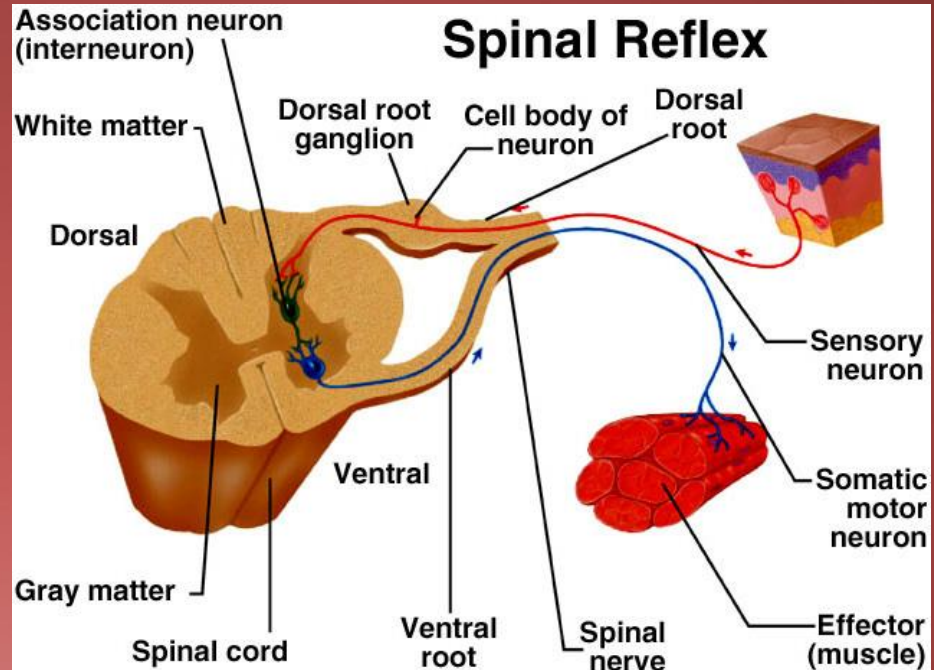


Cranial and Spinal Nerves

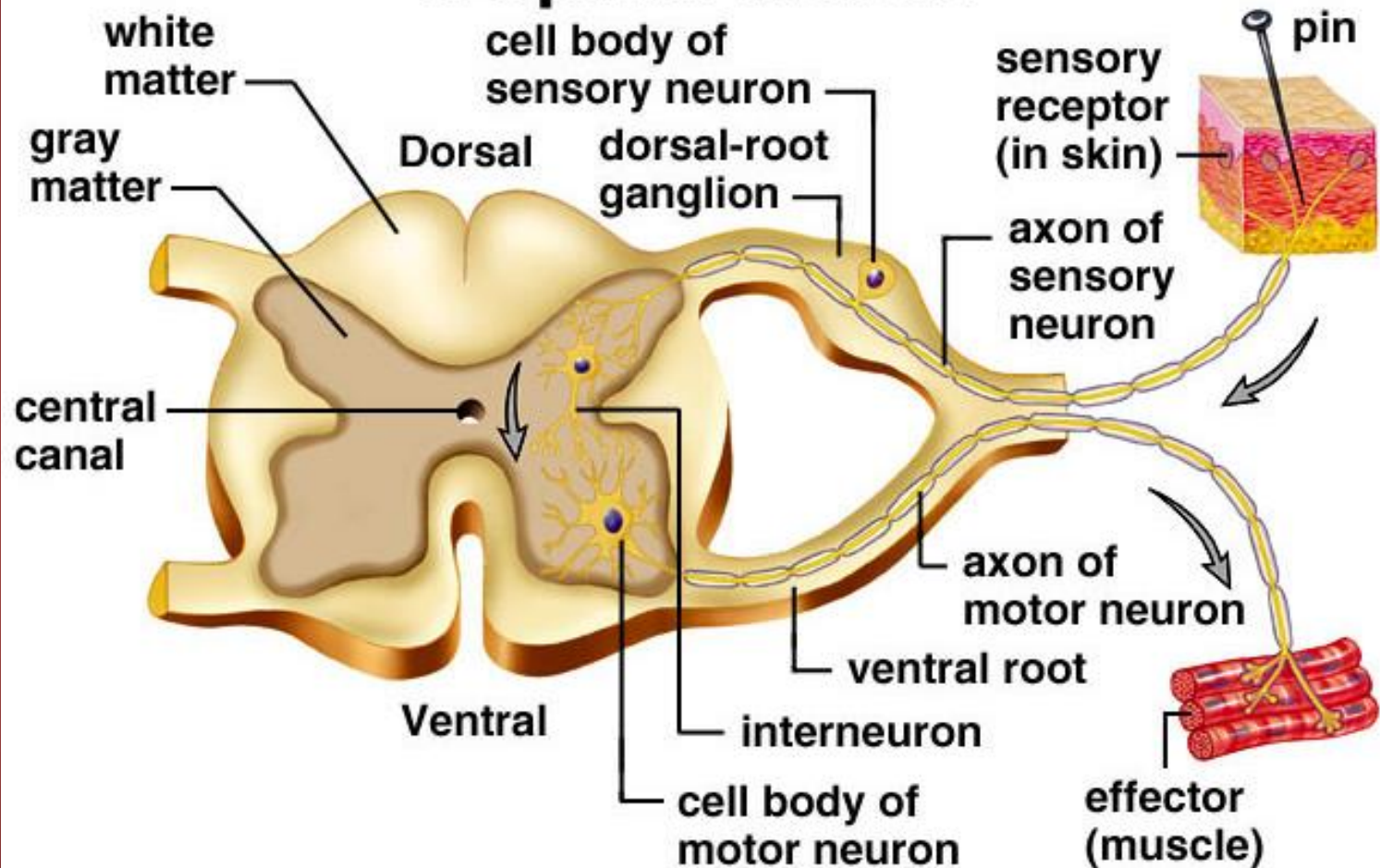


Reflex Arc

- Stimulation of sensory receptors evokes AP that are conducted into spinal cord.
- Synapses with motor neuron.
- Conducts impulses to muscle and stimulates a reflex contraction.
- Brain is not directly involved.



Reflex Arc Showing Path of a Spinal Reflex

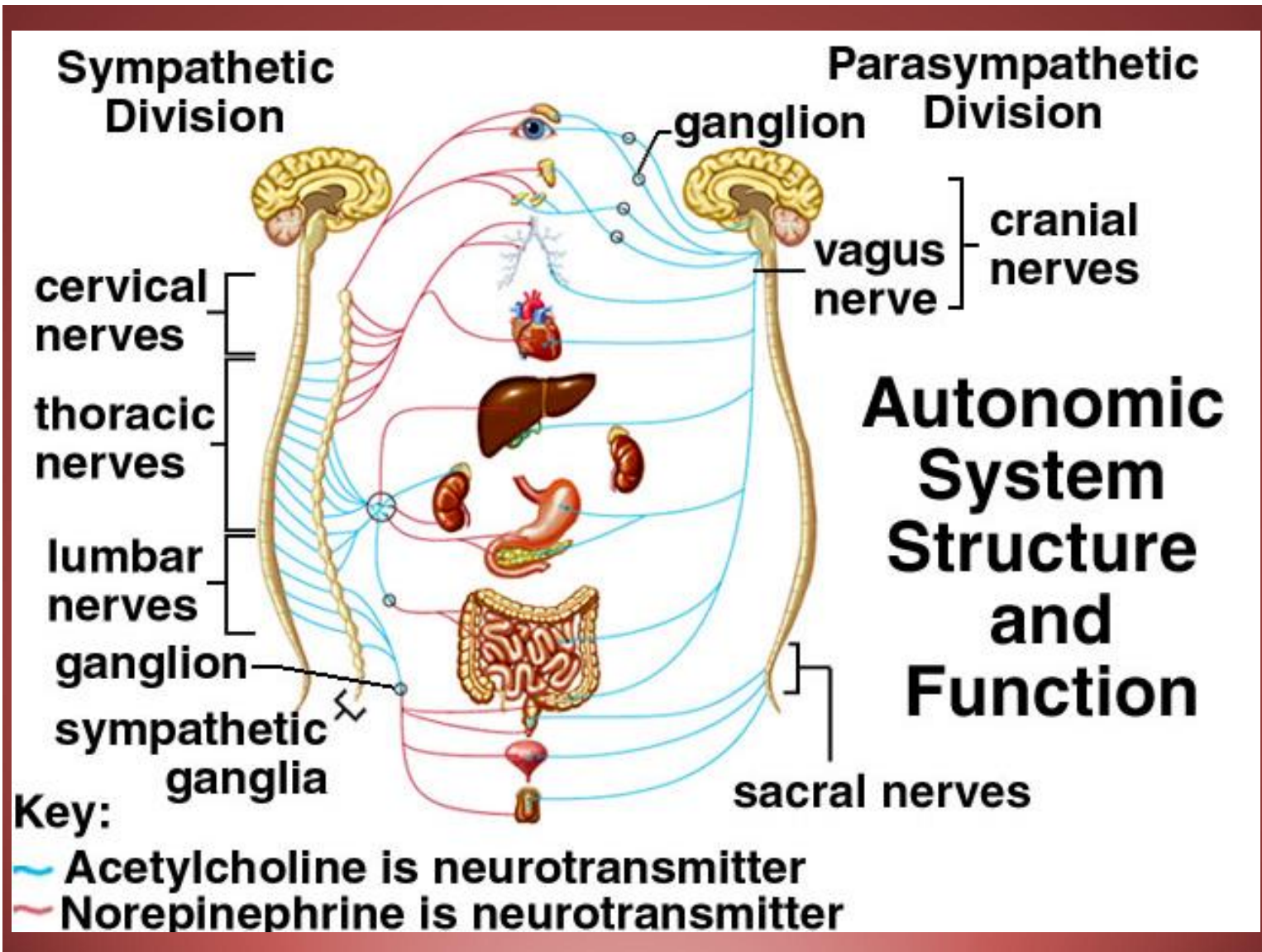


Neural Control of Involuntary Effectors

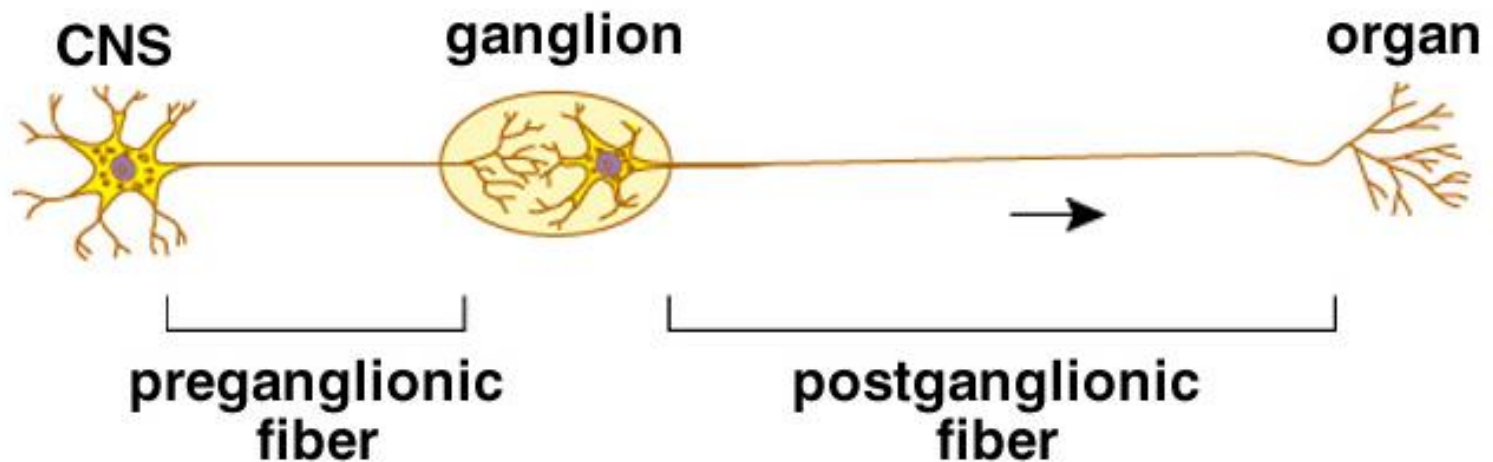
- ANS:
- Innervate organs not usually under voluntary control.
- Effectors include cardiac and smooth muscles and glands.
- Effectors are part of visceral organs and blood vessels.

Divisions of the ANS

- Sympathetic Nervous System
- Parasympathetic Nervous System
 - Both have preganglionic neurons that originate in CNS.
 - Both have postganglionic neurons that originate outside of the CNS in ganglia.



Sympathetic Division

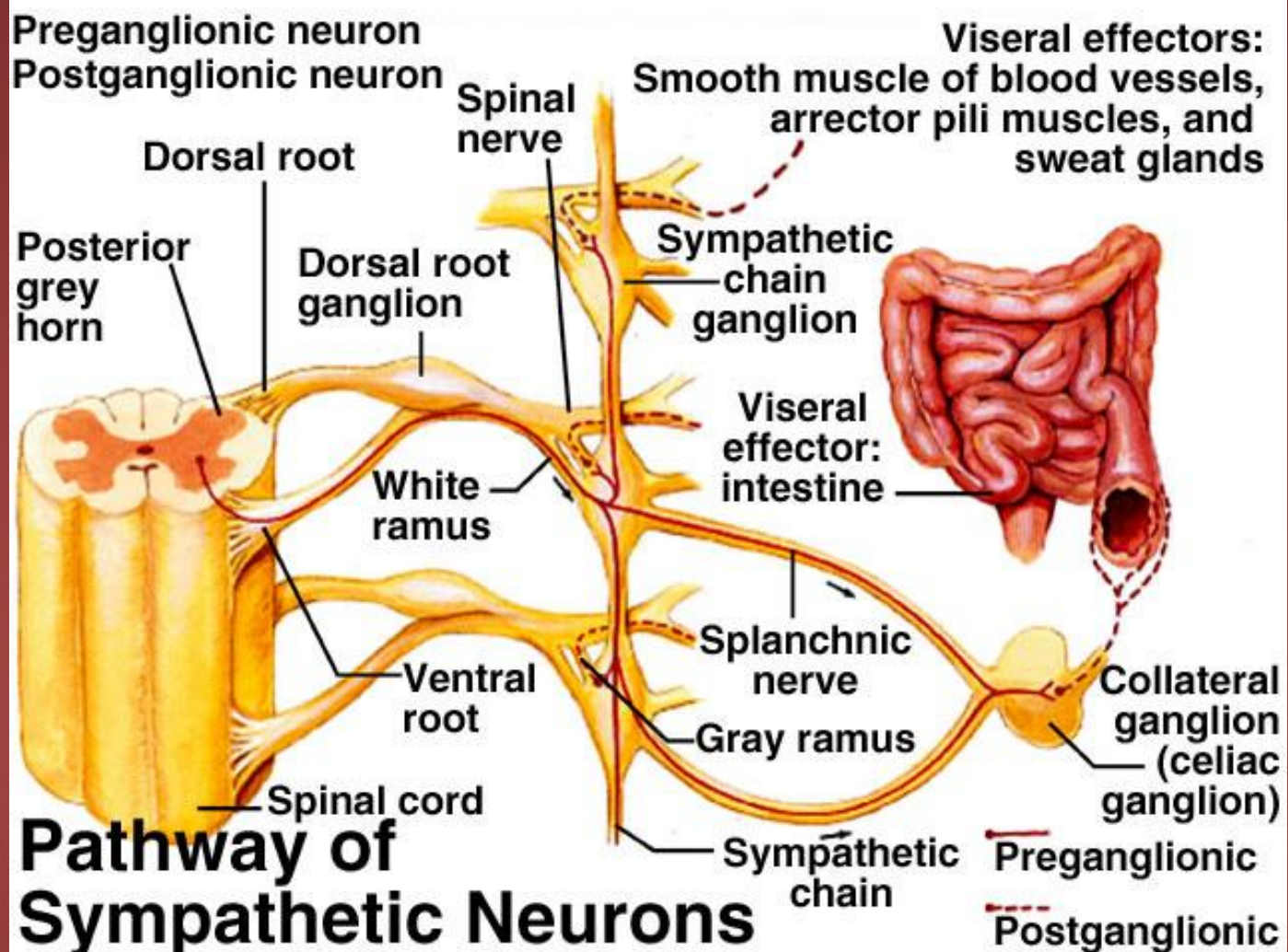


Sympathetic Division

- Myelinated preganglionic exit spinal cord in ventral roots at T1 to L2 levels.
- Travel to ganglia at different levels to synapse with postganglionic neurons.
- Divergence:
 - Preganglionic fibers branch to synapse with numerous postganglionic neurons.
- Convergence:
 - Postganglionic neuron receives synaptic input from large # of preganglionic fibers.

Sympathetic Division

- Mass activation:
 - Divergence and convergence cause the SNS to be activated as a unit.
- Axons of postganglionic neurons are unmyelinated to the effector organ.
- Preganglionic neuron is short.
- Post-ganglionic neuron is long.



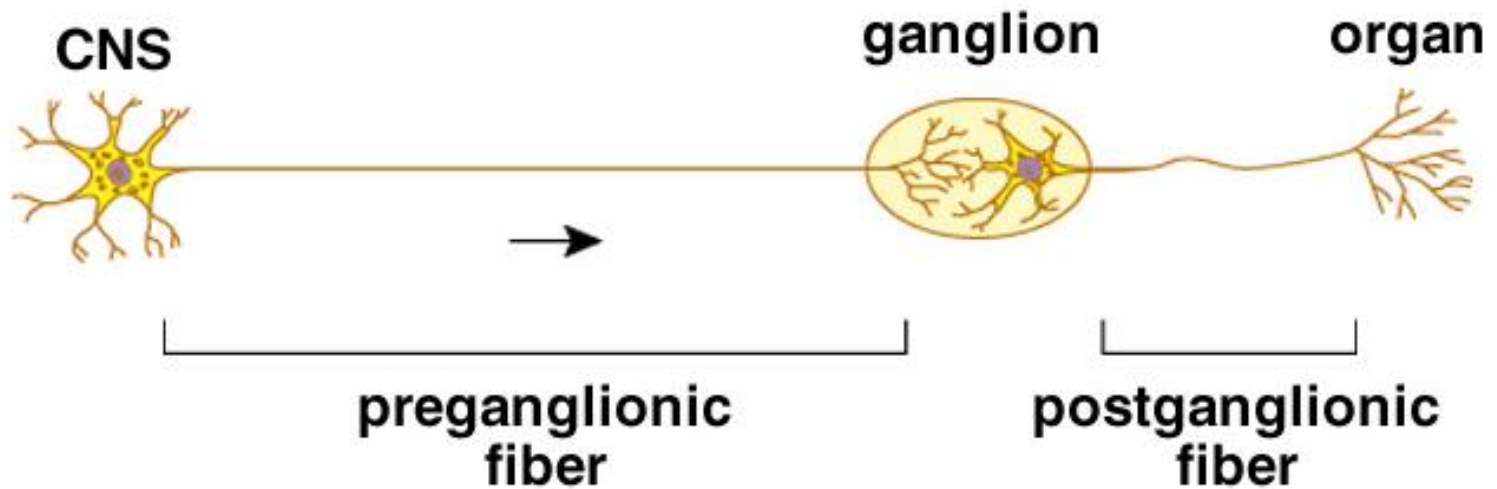
Adrenal Glands

- Adrenal medulla secretes epinephrine and norepinephrine when stimulated by the SNS.
- Innervated by preganglionic sympathetic fibers.
- Stimulated by mass activation.

Sympathetic Effects

- Fight or flight response.
- Release of norepinephrine from postganglionic fibers and epinephrine from adrenal medulla.
- Mass activation prepares for intense activity.
 - Heart rate increases.
 - Bronchioles dilate.
 - [glucose] increases.

Parasympathetic System



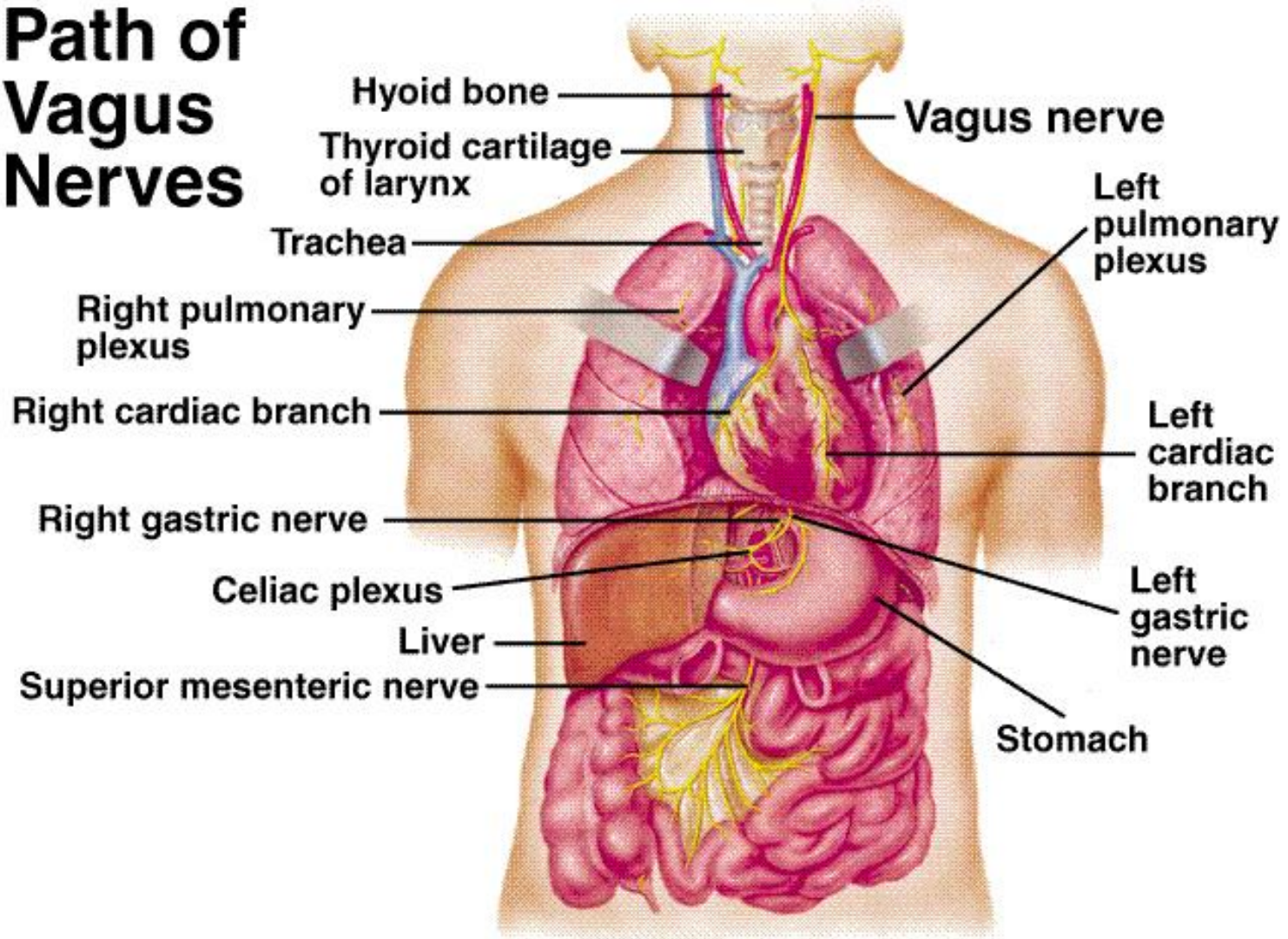
Parasympathetic Division

- Preganglionic fibers originate in midbrain, medulla, and pons; and in the 2-4 sacral levels of the spinal cord.
- Preganglionic fibers synapse in ganglia located next to or within organs innervated.
- Do not travel within spinal nerves.
 - Do not innervate blood vessels, sweat glands, and arrector pili muscles.

Parasympathetic Division

- 4 of 12 pairs of cranial nerves contain preganglionic parasympathetic fibers.
- Preganglionic fibers are long, postganglionic fibers are short.
- Vagus:
 - Innervate heart, lungs esophagus, stomach, pancreas, liver, small intestine and upper half of the large intestine.

Path of Vagus Nerves



Parasympathetic Division

- Preganglionic fibers from the sacral level innervate the lower half of large intestine, the rectum, urinary and reproductive systems.

Parasympathetic Effects

- Stimulation of separate parasympathetic nerves.
- Release ACh.
- Relaxing effects:
 - Decrease heart rate (HR).
 - Dilate blood vessels.
 - Increase GI activity.

Neurotropic Drugs

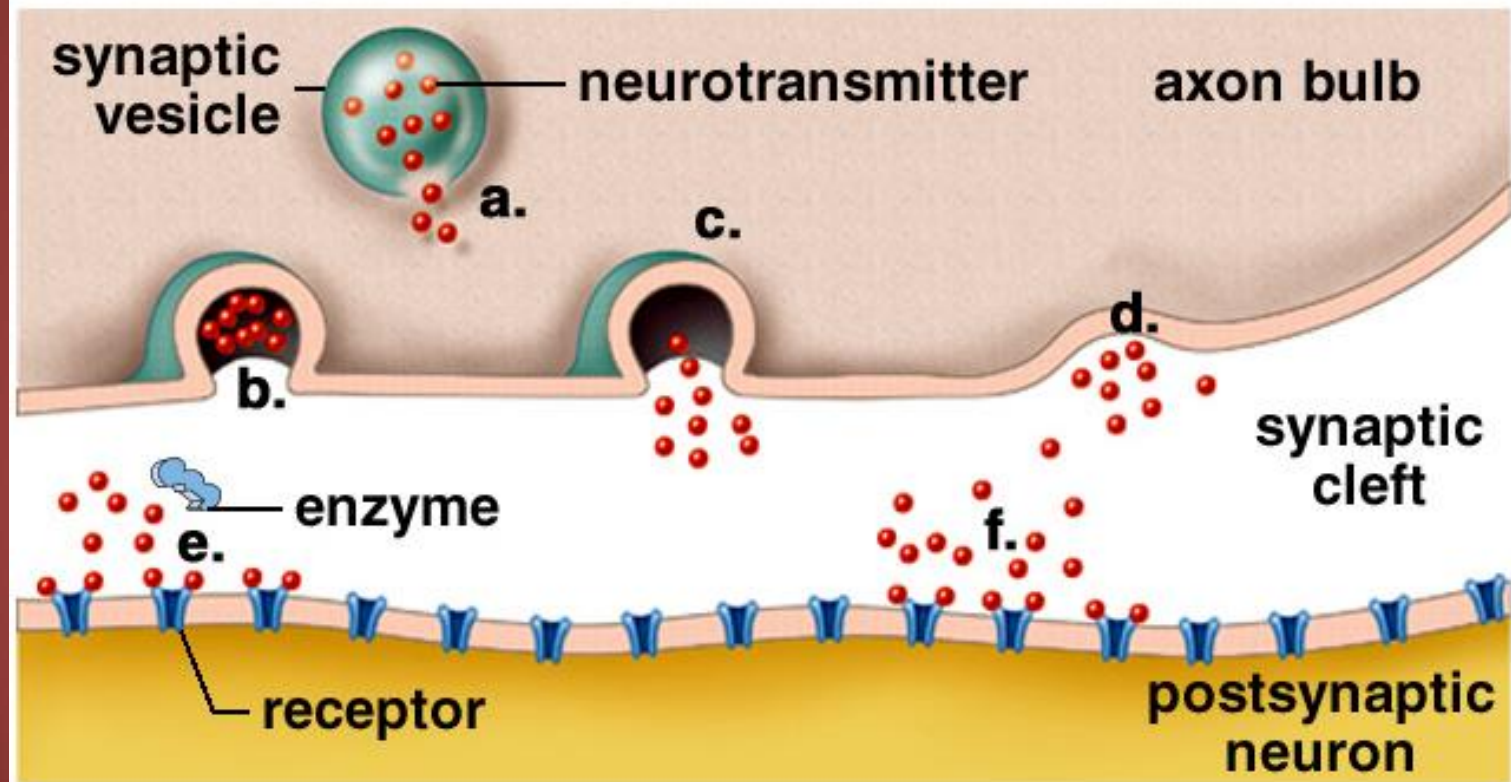
Stimulants:

- Include caffeine, cocaine, and amphetamines.
- Increase the activity of the CNS by altering effect of neurotransmitters at chemical synapses.

Depressants:

- Include alcohol and Valium.
- Decrease the activity of the CNS by altering effect of neurotransmitters at chemical synapses.

Drug Action at a Synapse



Diseases of the Nervous System

I. Alzheimer's Disease

- Most common form of dementia in U.S.
- Unknown cause, probably both genetic and environmental factors are important.
- No effective treatment
- Certain diagnosis is usually only possible through discovery of typical brain lesions during autopsy.
- Usually affects elderly: Over 4 million cases in U.S.
 - 10% of those over 65
 - Almost half of those over 85
- Symptoms progress over time. Three stages:
 - **Mild Stage**: Forgetfulness, minor disorientation, mild personality changes, depression, difficulty in finding right words during conversation, and performing arithmetic calculations (e.g.: balancing checkbook).

Diseases of the Nervous System

I. Alzheimer's Disease (Continued)

– Stages of Alzheimer's Disease:

- **Moderate Stage:** Noticeable memory loss, difficulty performing everyday tasks (bathing, dressing, cooking, driving, operating appliances), may wander off, confuse day and night, fails to recognize acquaintances and distant relatives.
- **Severe Stage:** Very limited speech (less than 12 words), eventually becomes mute and uncomprehending, loses all self-care ability, can't recognize closest relatives, friends, or caregivers, becomes incontinent, progressively loses ability to walk, stand, sit up, smile, and hold head up. Many patients die from complications like pneumonia.

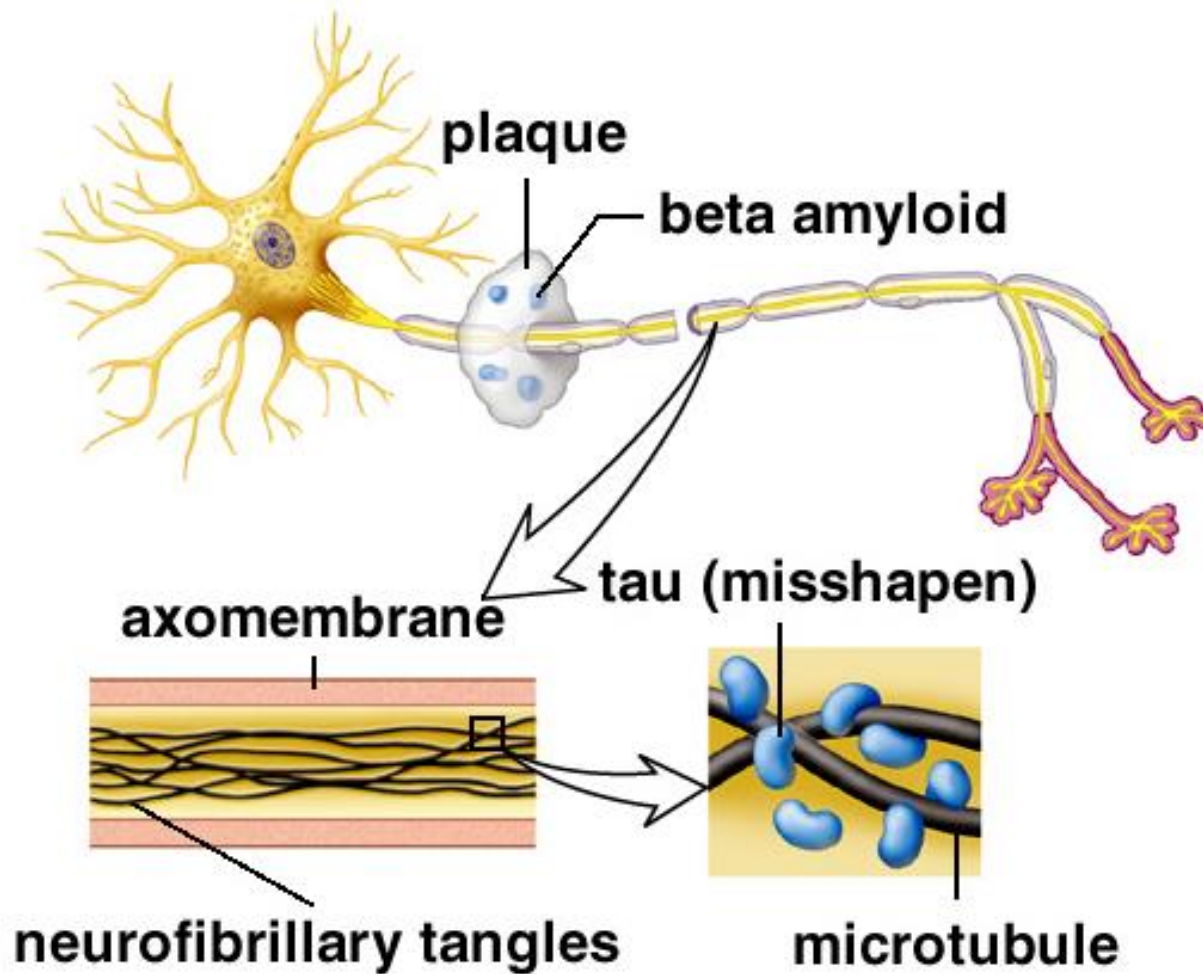
Brain Atrophy in Alzheimer's Disease



Definite diagnosis of Alzheimer's usually requires post-mortem brain examination.

Notice pronounced atrophy with wide sulci (grooves) in frontal and parietal regions.

Alzheimer's Disease



Human Systems

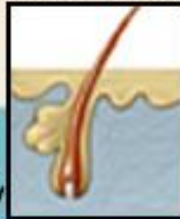
How the Nervous System works with other body systems



Integumentary System

Brain controls nerves that regulate size of cutaneous blood vessels, activate sweat glands and arrector pili muscles.

Skin protects nerves, helps regulate body temperature; skin receptors send sensory input to brain.



Skeletal System

Receptors send sensory input from bones and joints to brain.

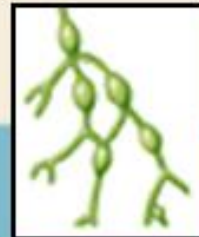
Bones protect sense organs, brain, and spinal cord; store Ca^{2+} for nerve function.



Lymphatic System/Immunity

Microglia engulf and destroy pathogens.

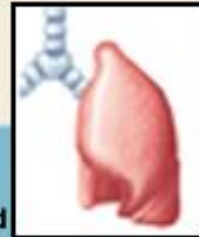
Lymphatic vessels pick up excess tissue fluid; immune system protects against infections of nerves.



Respiratory System

Respiratory centers in brain regulate breathing rate.

Lungs provide oxygen for neurons and rid the body of carbon dioxide produced by neurons.



Human Systems



Muscular System

Brain controls nerves that innervate muscles; receptors send sensory input from muscles to brain.



Muscle contraction moves eyes, permits speech, and creates facial expressions.

Endocrine System

Hypothalamus is part of endocrine system; nerves innervate certain glands of secretion.



Sex hormones affect development of brain.

Cardiovascular System

Brain controls nerves that regulate the heart and dilation of blood vessels.



Blood vessels deliver nutrients and oxygen to neurons, carry away wastes.

Digestive System

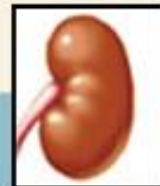
Brain controls nerves that innervate smooth muscle and permit digestive tract movements.



Digestive tract provides nutrients for growth, maintenance, and repair of neurons and neuroglial cells.

Urinary System

Brain controls nerves that innervate muscles that permit urination.



Kidneys maintain blood levels of Na^+ , K^+ , and Ca^{2+} , which are needed for nerve conduction.

Reproductive System

Brain controls onset of puberty; nerves are involved in erection of penis and clitoris, contraction of ducts that carry gametes, and contraction of uterus.



Sex hormones masculinize or feminize the brain, exert feedback control over the hypothalamus, and influence sexual behavior.



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Questions



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<http://www.daytonastate.edu/asc/ascsiencehandouts.html>