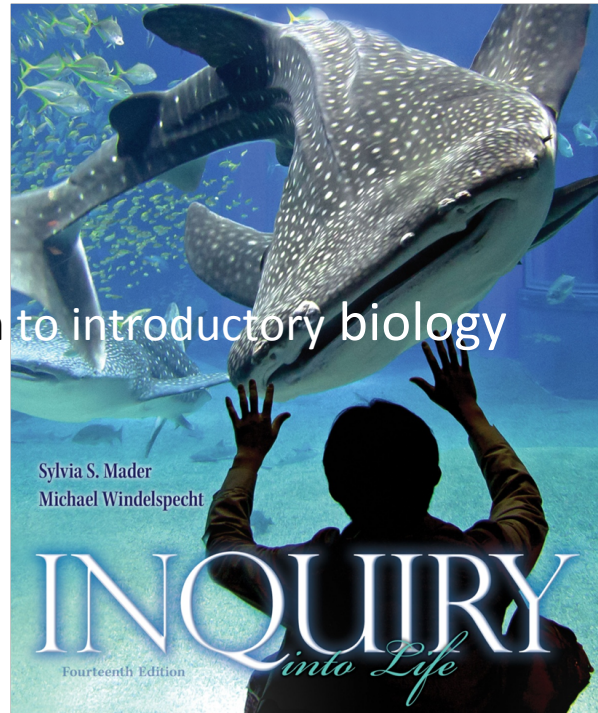


Fundamental Biology

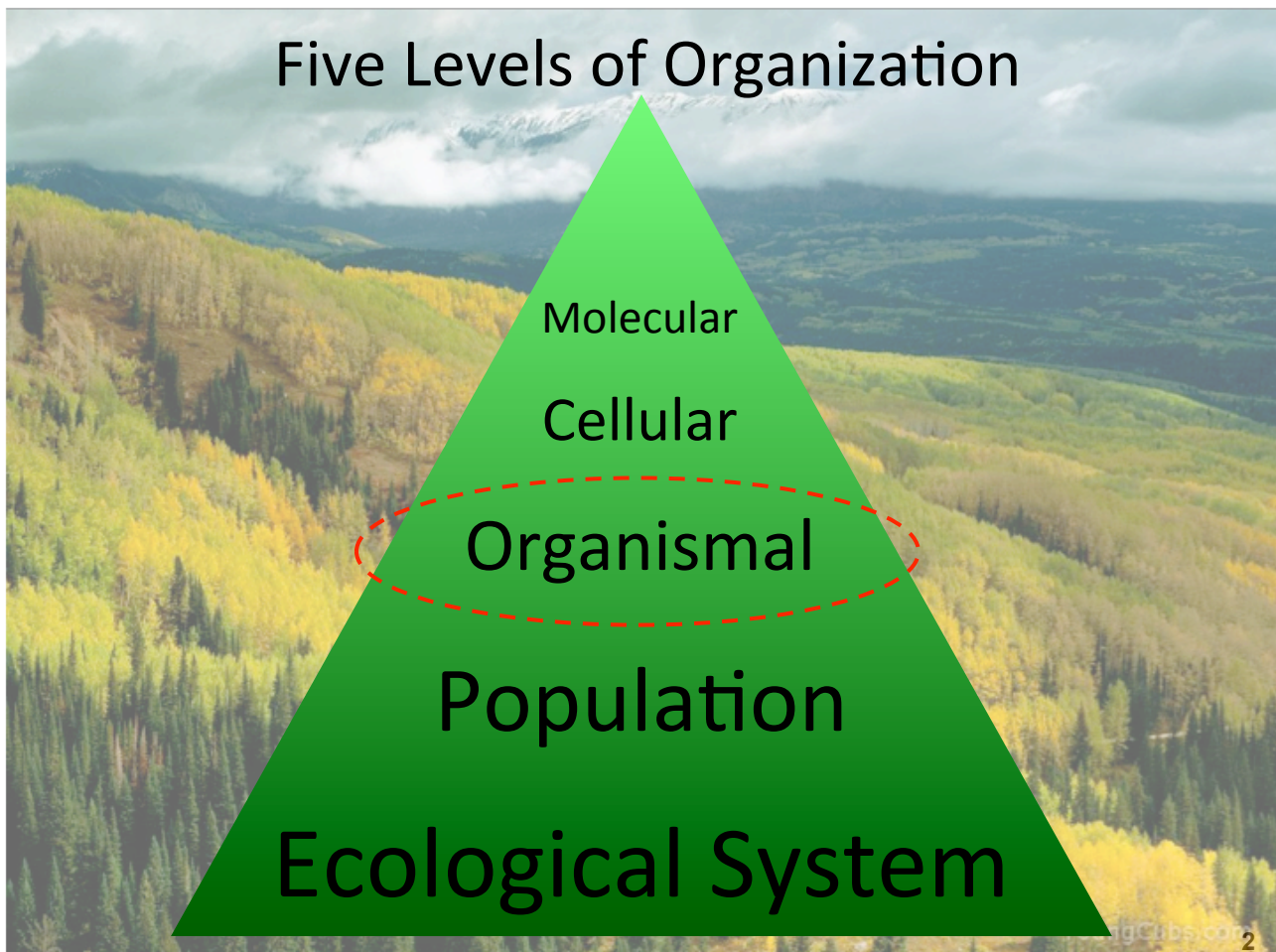
BI 1101

an interdisciplinary approach to introductory biology

Anggraini Barlian,
Iriawati
Tjandra Anggraeni
SITH-ITB



1



Learning outcomes

After this lecture, you should be able to:

1. Describe the structural and functional subdivisions of the nervous system
2. Describe the three parts of a reflex, noting the three types of neurons involved in the reaction
3. Explain how an action potential is produced and the resting membrane potential restored
4. Compare the structures, functions, and locations of electrical and chemical synapses
5. Describe the types and functions of neurotransmitters known in humans
6. Explain how drugs can alter chemical synapses
7. Describe the diversity of animal nervous systems

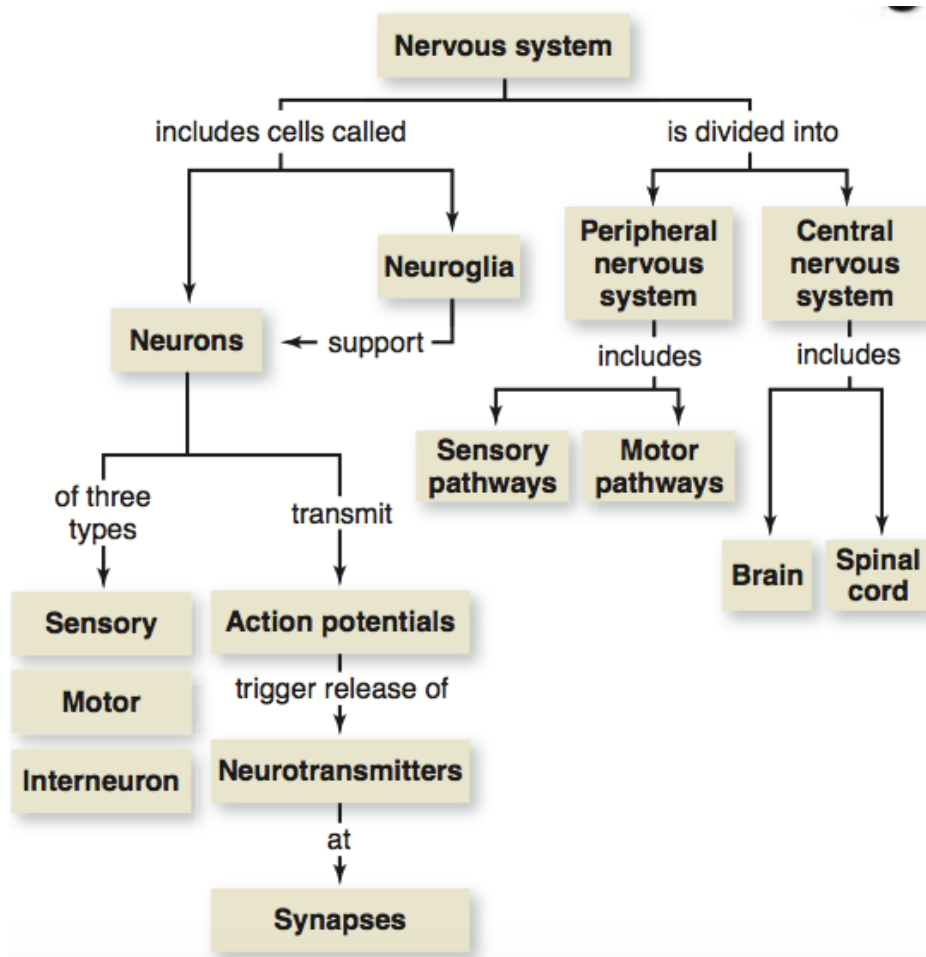
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You should now be able to

8. Describe the general structure of the brain, spinal cord, and associated nerves of vertebrates
9. Compare the functions of the somatic nervous system and autonomic nervous system
10. Describe the parts and functions of the human brain
11. Explain how injuries, illness, and surgery provide insight into the functions of the brain
12. Describe the causes, symptoms, and treatments of schizophrenia, depression, Alzheimer's disease, and Parkinson's disease

NERVOUS SYSTEM

5



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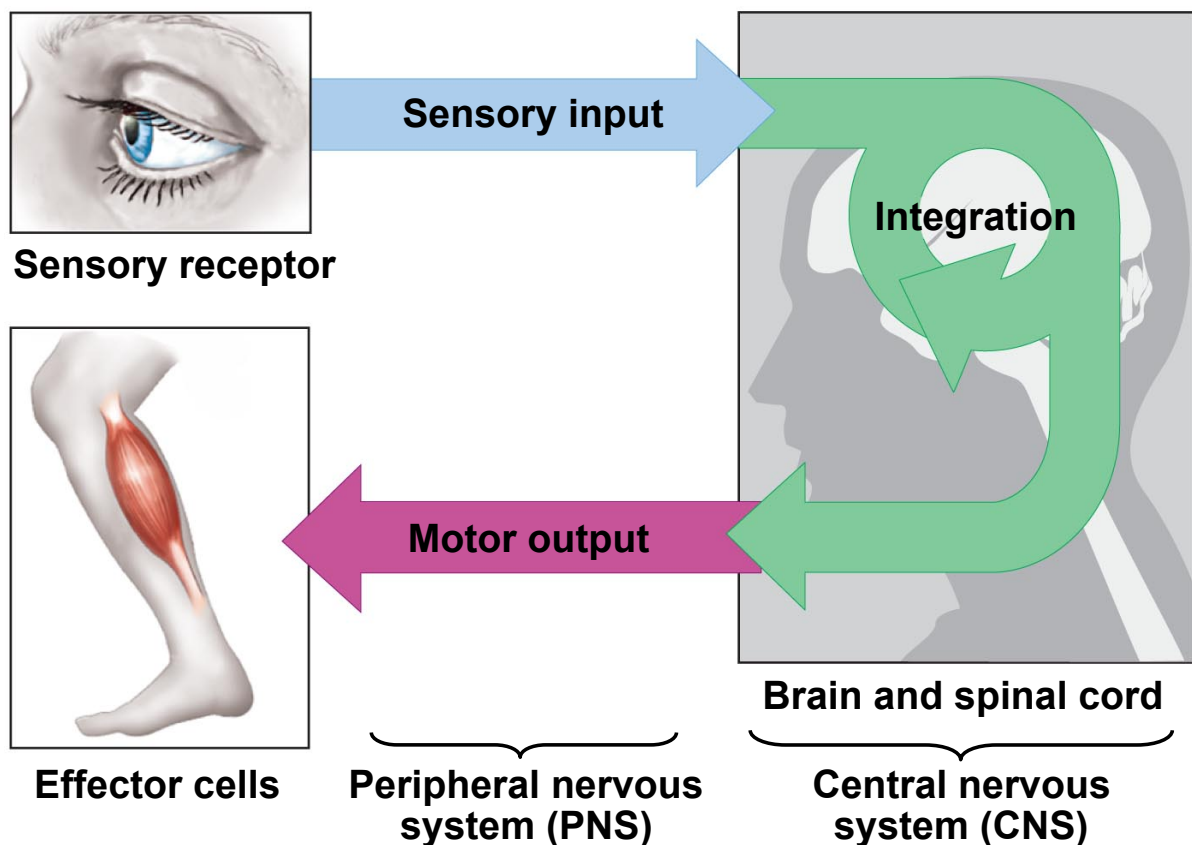
-
- Over 10,000 Americans suffer spinal cord injuries each year
 - Current research shows promise
 - Steroids reduce damage if used within hours of damage
 - Coaxing damaged nerve cells to regenerate
 - Transplants of nerve cells or stem cells

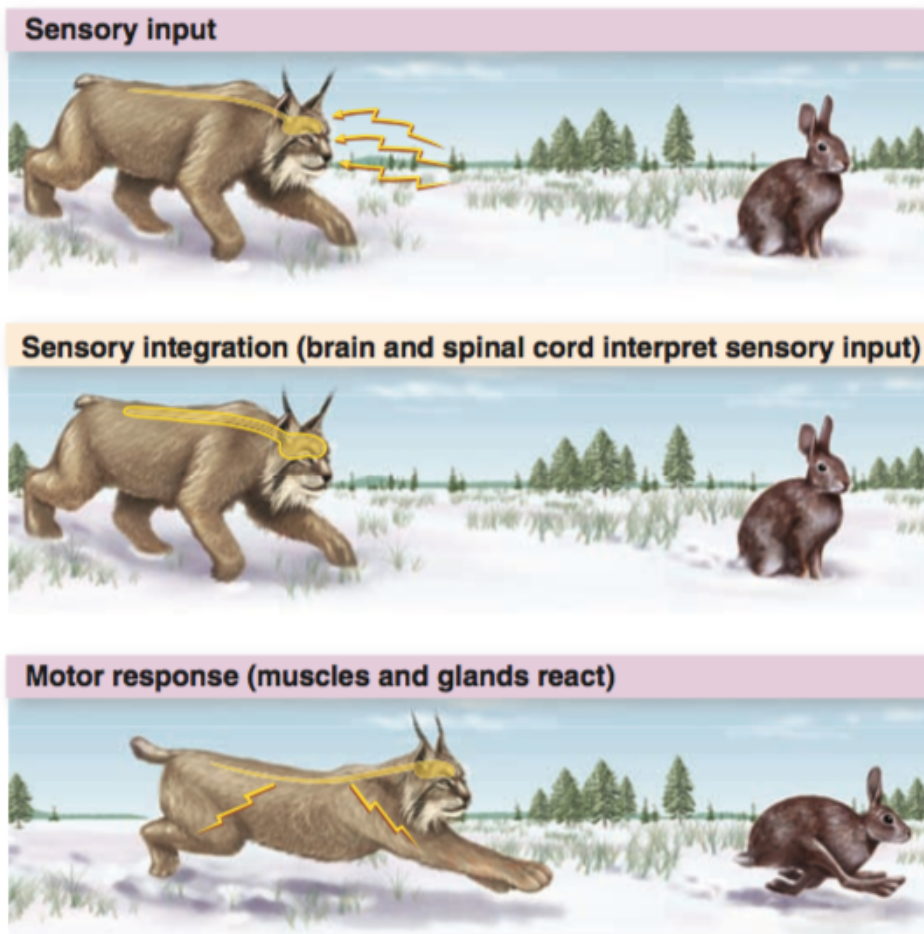
NERVOUS SYSTEM STRUCTURE AND FUNCTION

Nervous systems receive sensory input, interpret it, and send out appropriate commands

The **nervous system**

- Obtains sensory information
- Processes sensory information
- Sends commands to **effector cells** (muscles) that carry out appropriate responses





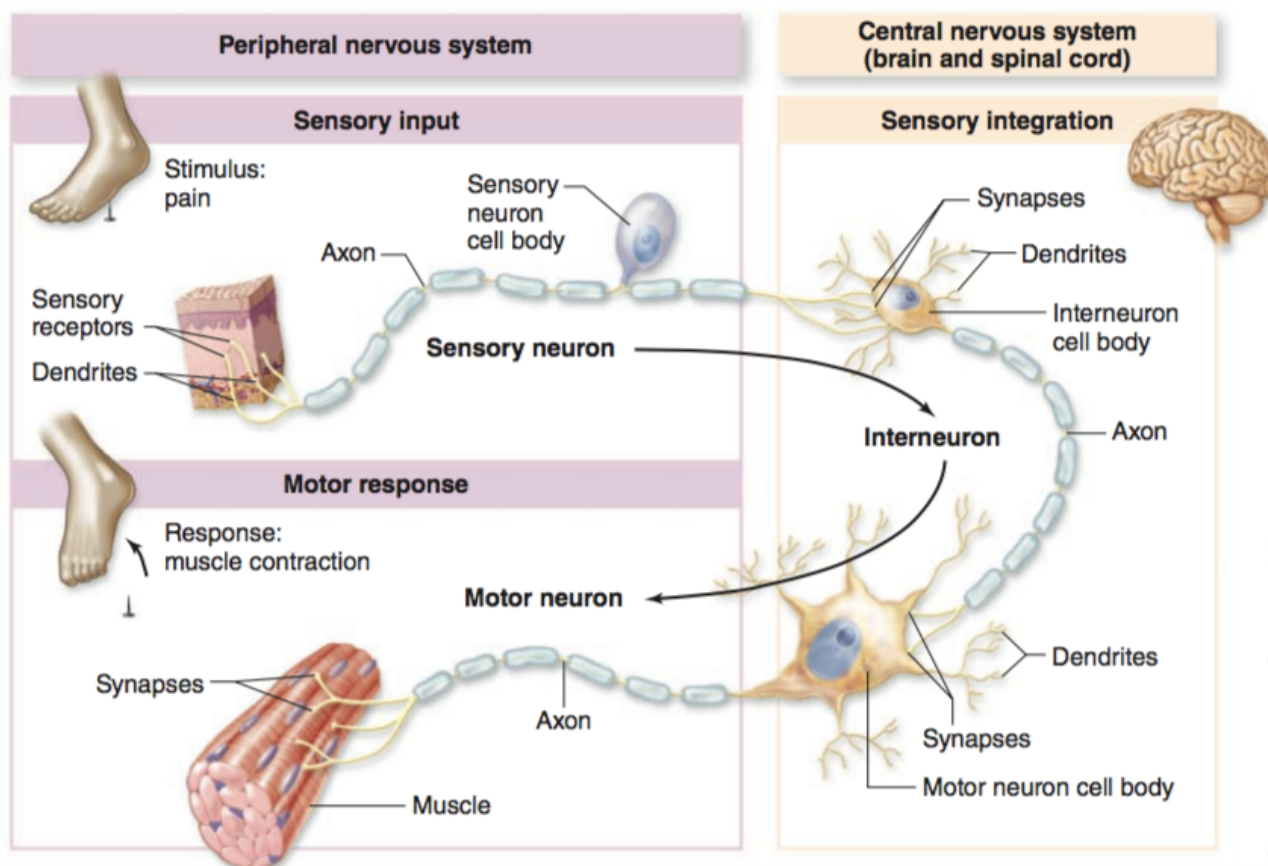
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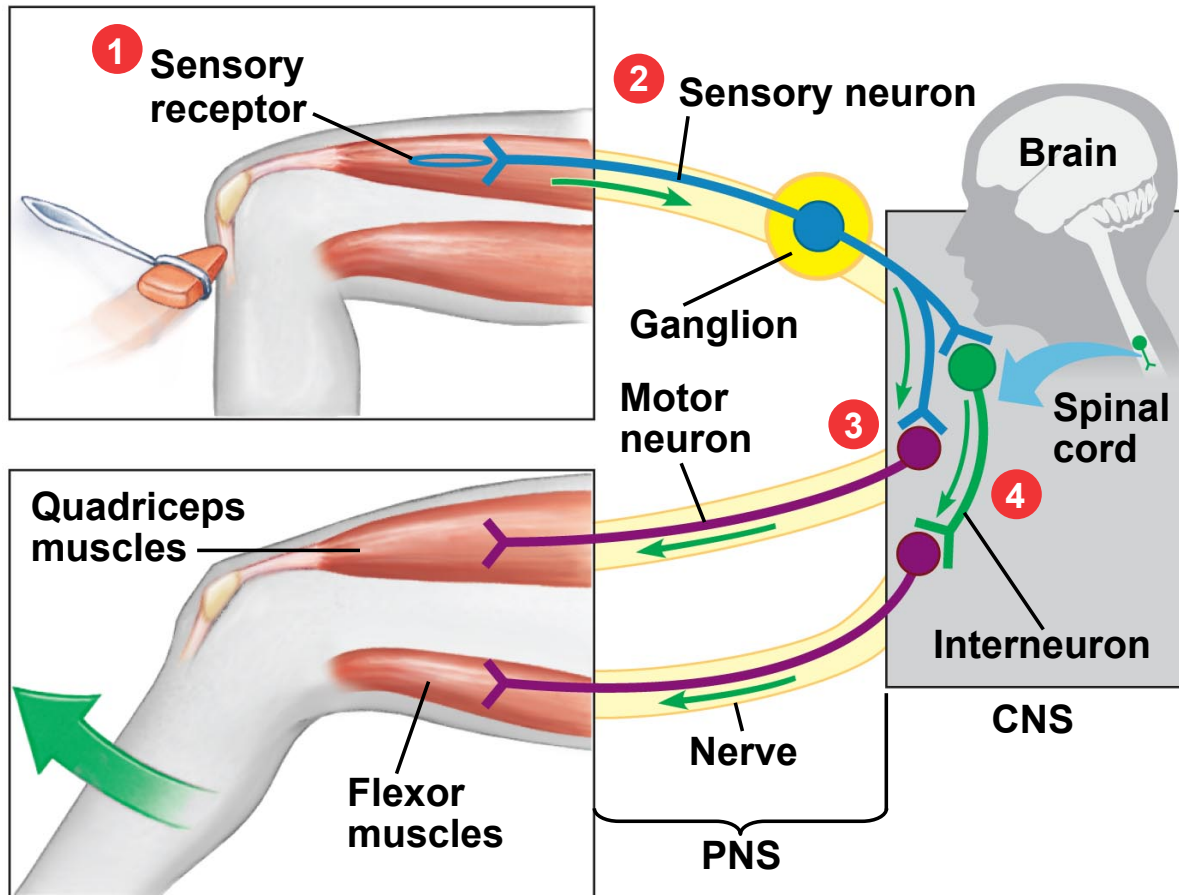
Nervous systems receive sensory input, interpret it, and send out appropriate commands

- The **central nervous system (CNS)** consists of
 - Brain
 - Spinal cord (vertebrates)
- **Peripheral nervous system (PNS)**
 - Located outside the CNS
 - Consists of
 - **Nerves** (bundles of fibers of sensory and motor neurons) and
 - **Ganglia** (clusters of cell bodies of the neurons)

Nervous systems receive sensory input, interpret it, and send out appropriate commands

- **Sensory neurons**
 - Conduct signals from sensory receptors
 - To the CNS
- **Interneurons** in the CNS
 - Integrate information
 - Send it to motor neurons
- **Motor neurons** convey signals to effector cells





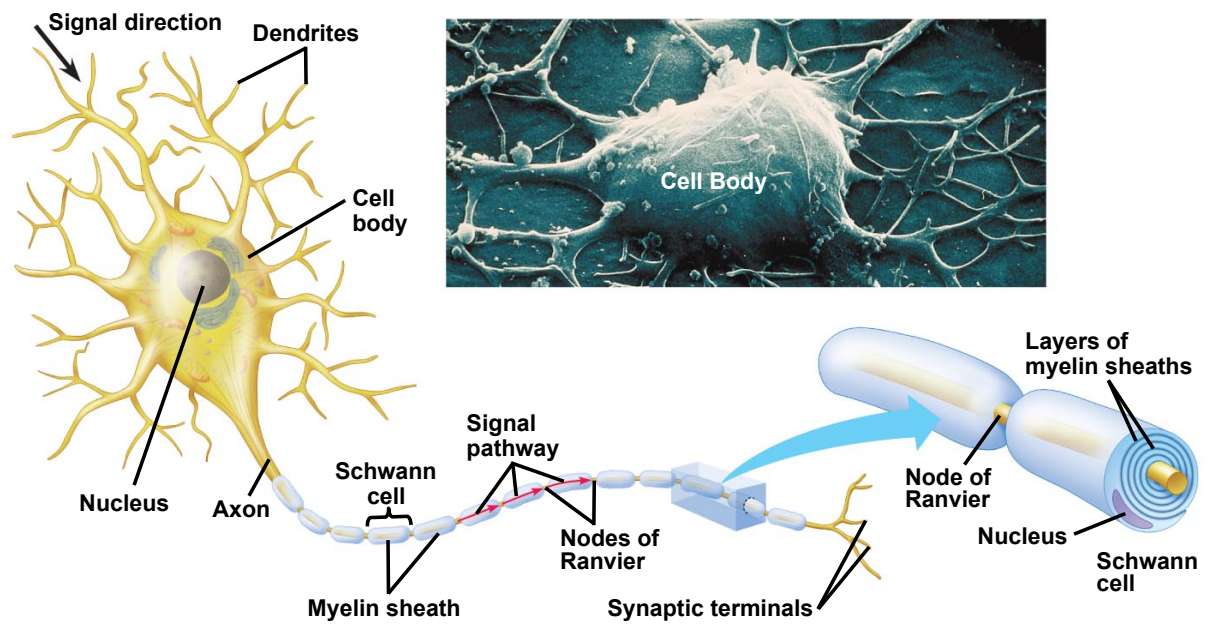
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Neurons are the functional units of nervous systems

- Neurons are
 - Cells specialized for carrying signals
 - The functional units of the nervous system
- A neuron consists of
 - A **cell body**
 - Two types of extensions (fibers) that conduct signals
 - **Dendrites**
 - **Axons**
 - **Myelin sheaths**
 - » Enclose axons
 - » Form a cellular insulation
 - » Speed up signal transmission

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NERVE SIGNALS AND THEIR TRANSMISSION

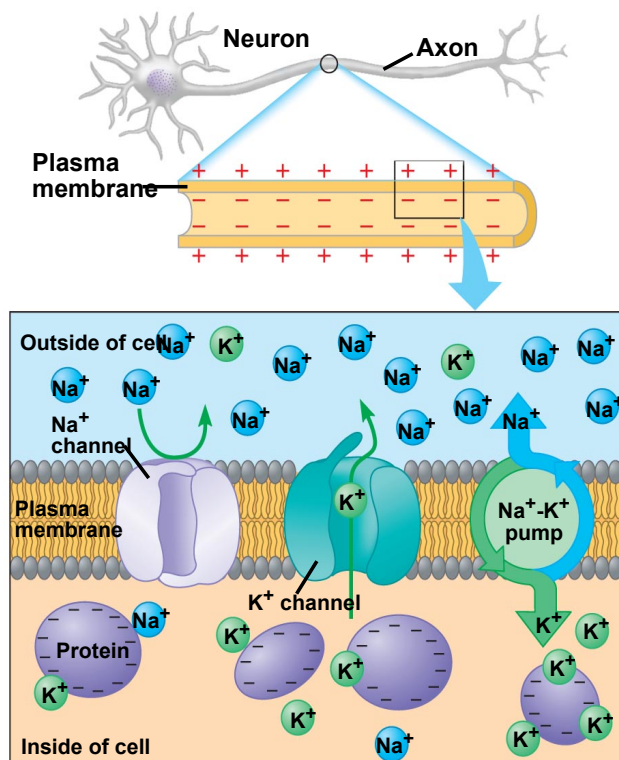
A neuron maintains a membrane potential across its membrane

- At rest, a neuron's plasma membrane
 - Has potential energy—the **membrane potential**
 - Just inside the cell is slightly negative
 - Just outside the cell is slightly positive
 - **Resting potential**—voltage across the plasma membrane

A neuron maintains a membrane potential across its membrane

The resting potential exists because of differences in ion concentration inside and outside a cell

- Inside a cell
 - K^+ high
 - Na^+ low
- Outside a cell
 - K^+ low
 - Na^+ high

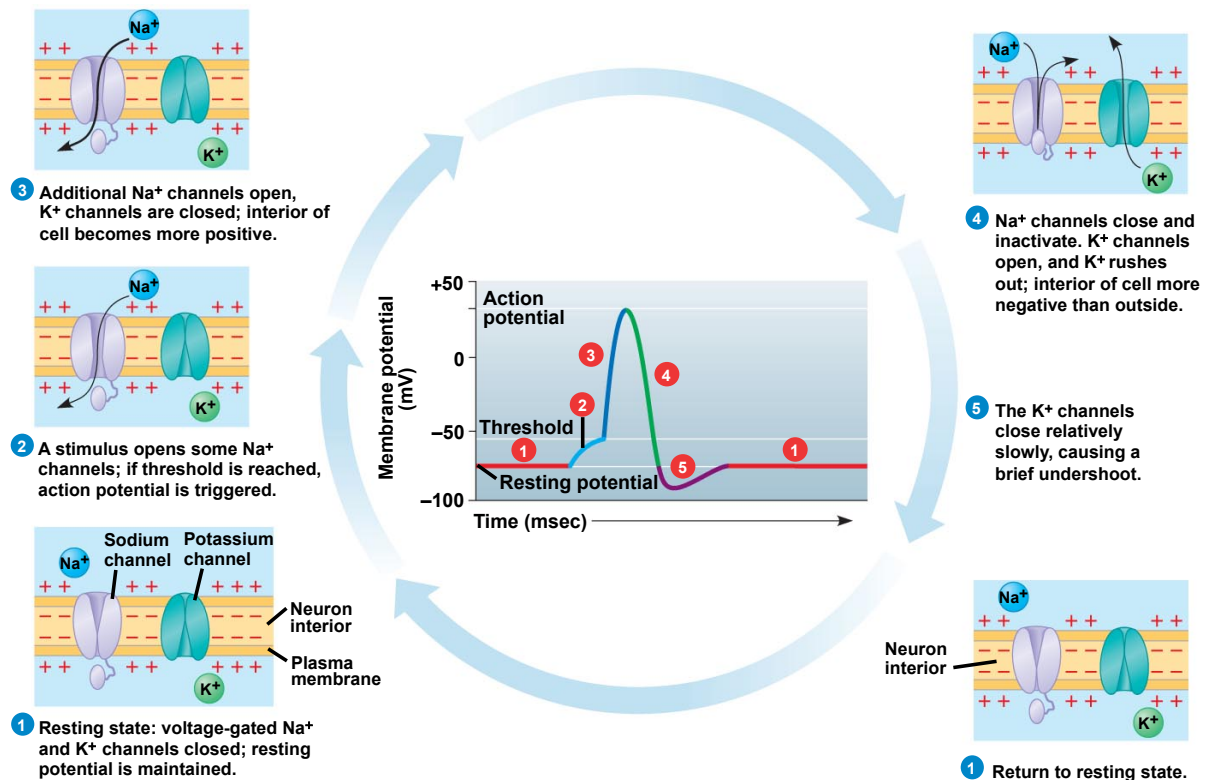


A nerve signal begins as a change in the membrane potential

- **A stimulus**
 - Alters the permeability of a section of membrane
 - Allows ions to pass through
 - Changes the membrane's voltage
- A nerve signal—an **action potential**
 - A change in the membrane voltage
 - From the resting potential
 - To a maximum level
 - And back to the resting potential

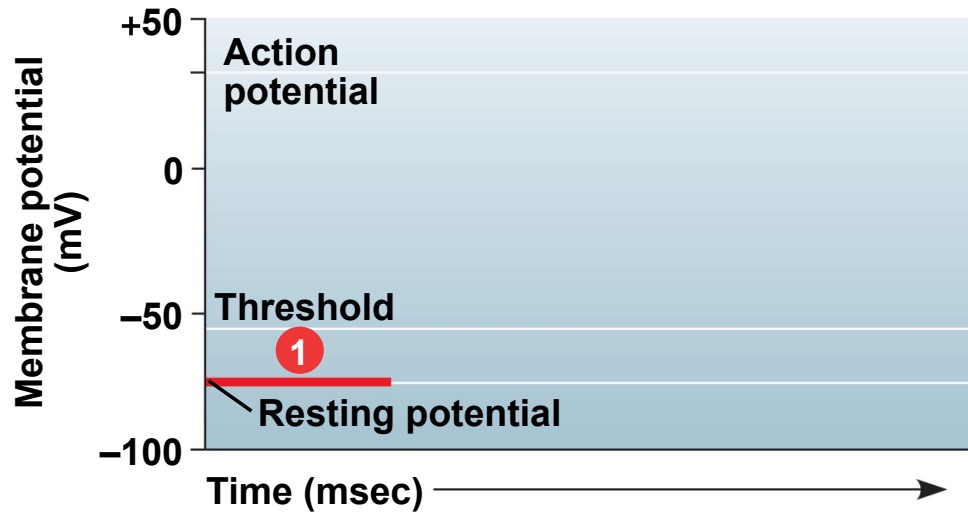
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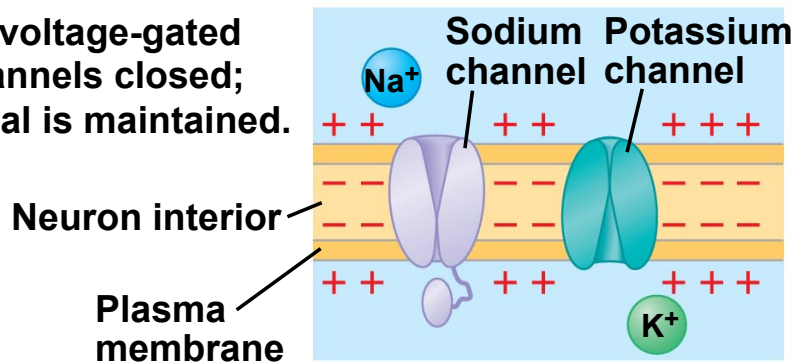


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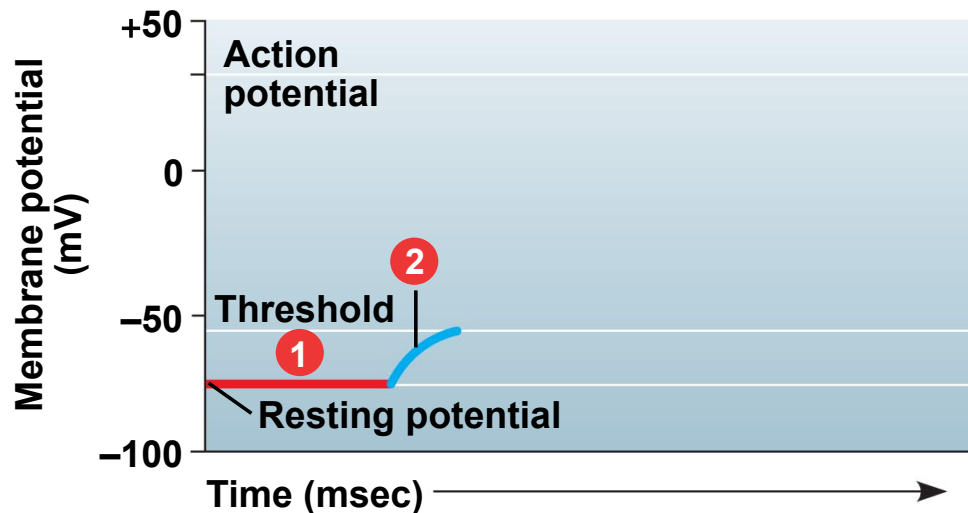


- 1 Resting state: voltage-gated Na^+ and K^+ channels closed; resting potential is maintained.

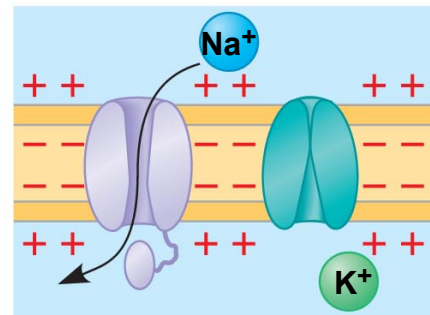


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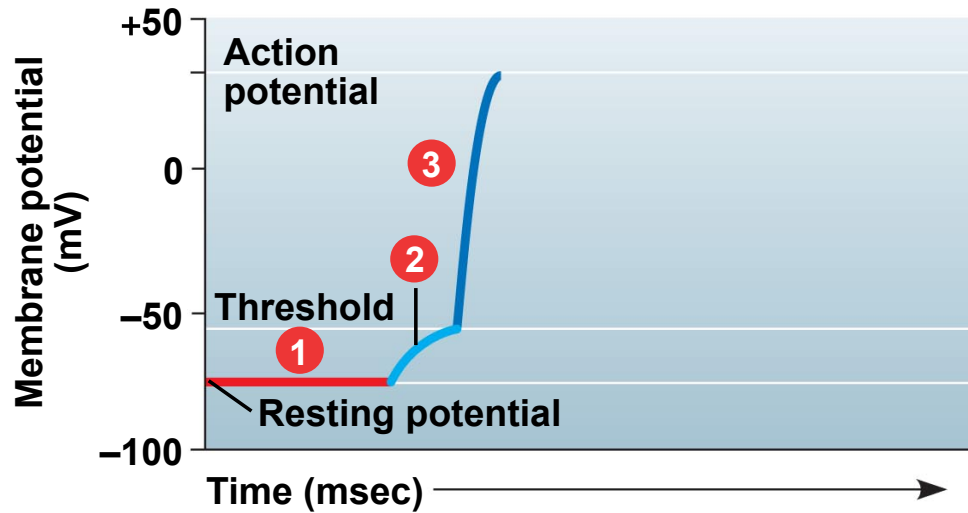


- 2 A stimulus opens some Na^+ channels; if threshold is reached, action potential is triggered.

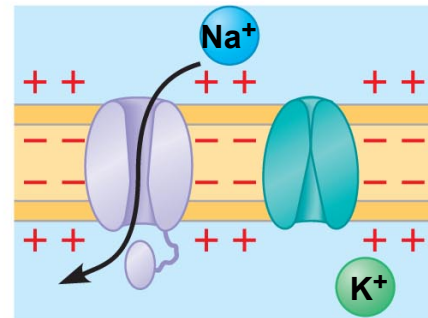


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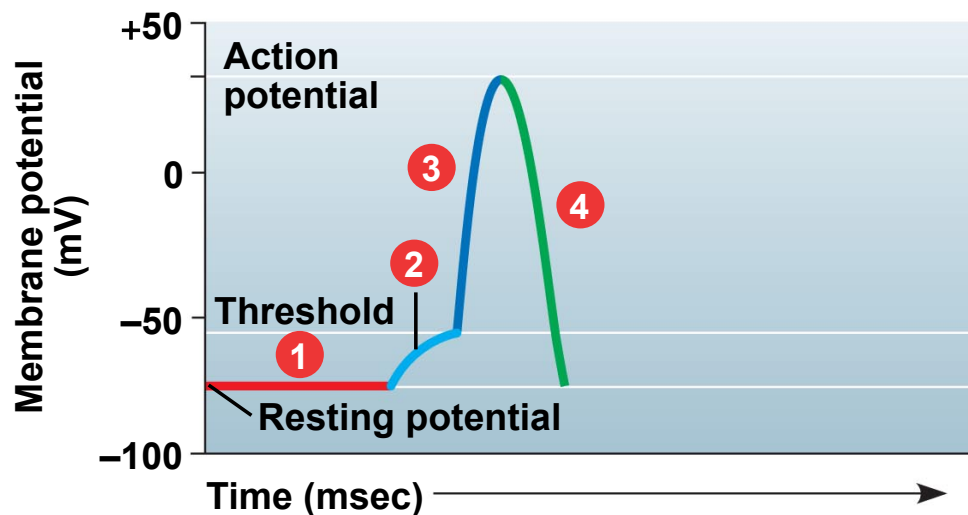


- 3** Additional Na^+ channels open, K^+ channels are closed; interior of cell becomes more positive.

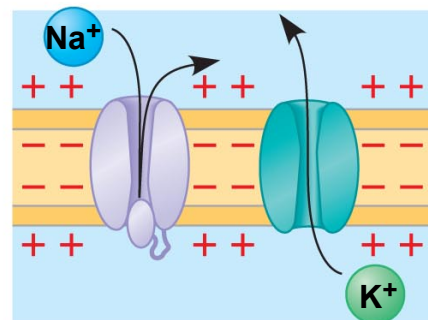


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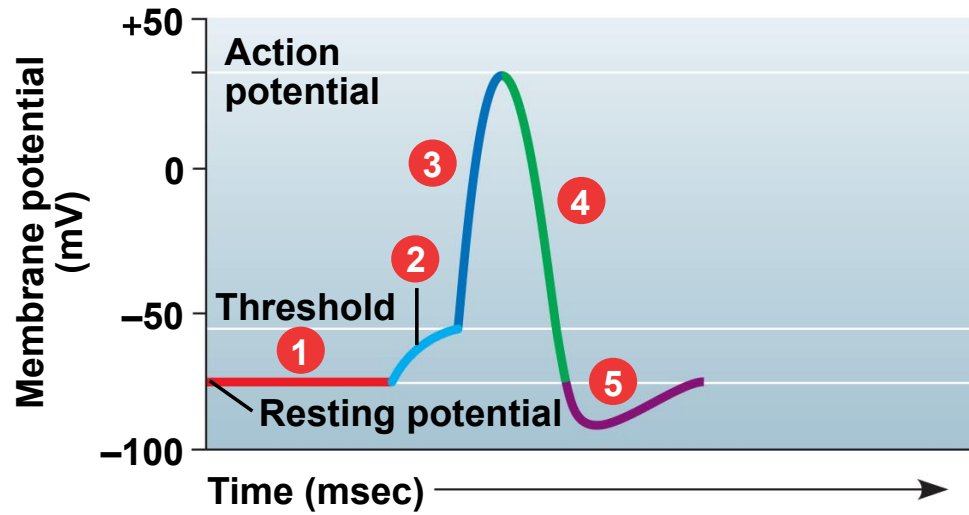


- 4** Na^+ channels close and inactivate. K^+ channels open, and K^+ rushes out; interior of cell more negative than outside.

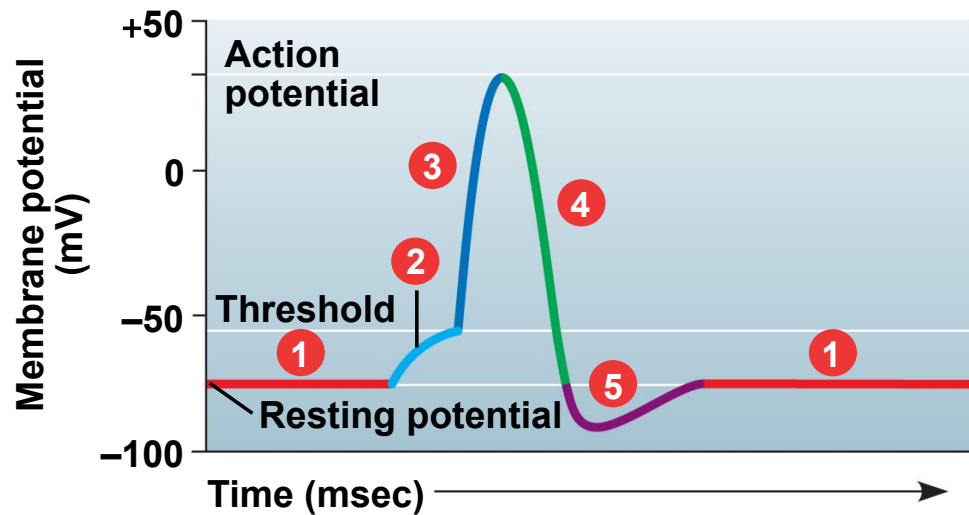


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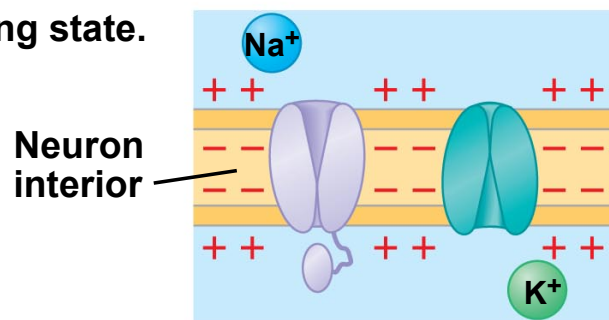
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5 The K^+ channels close relatively slowly, causing a brief undershoot.

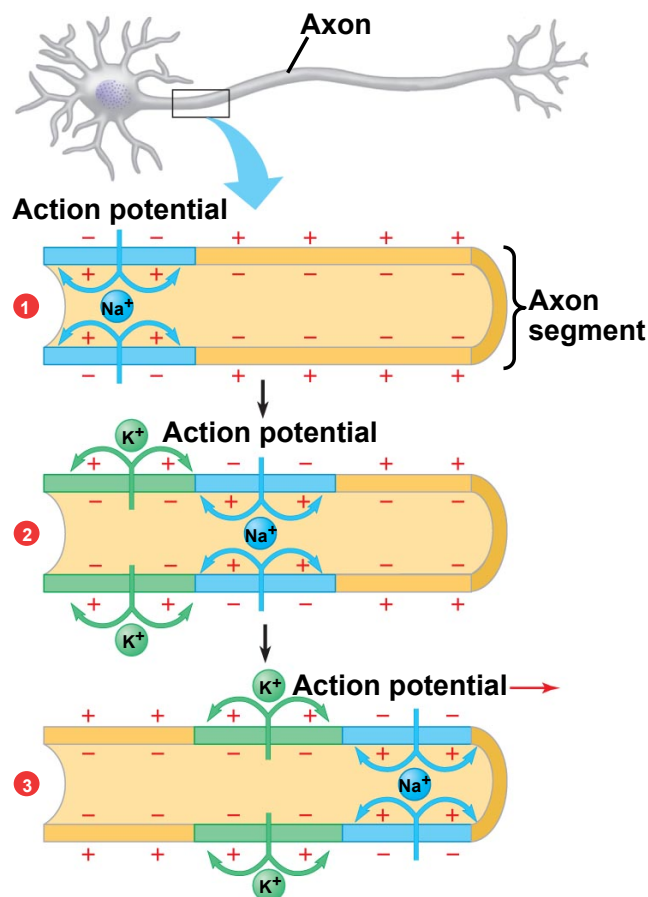


1 Return to resting state.



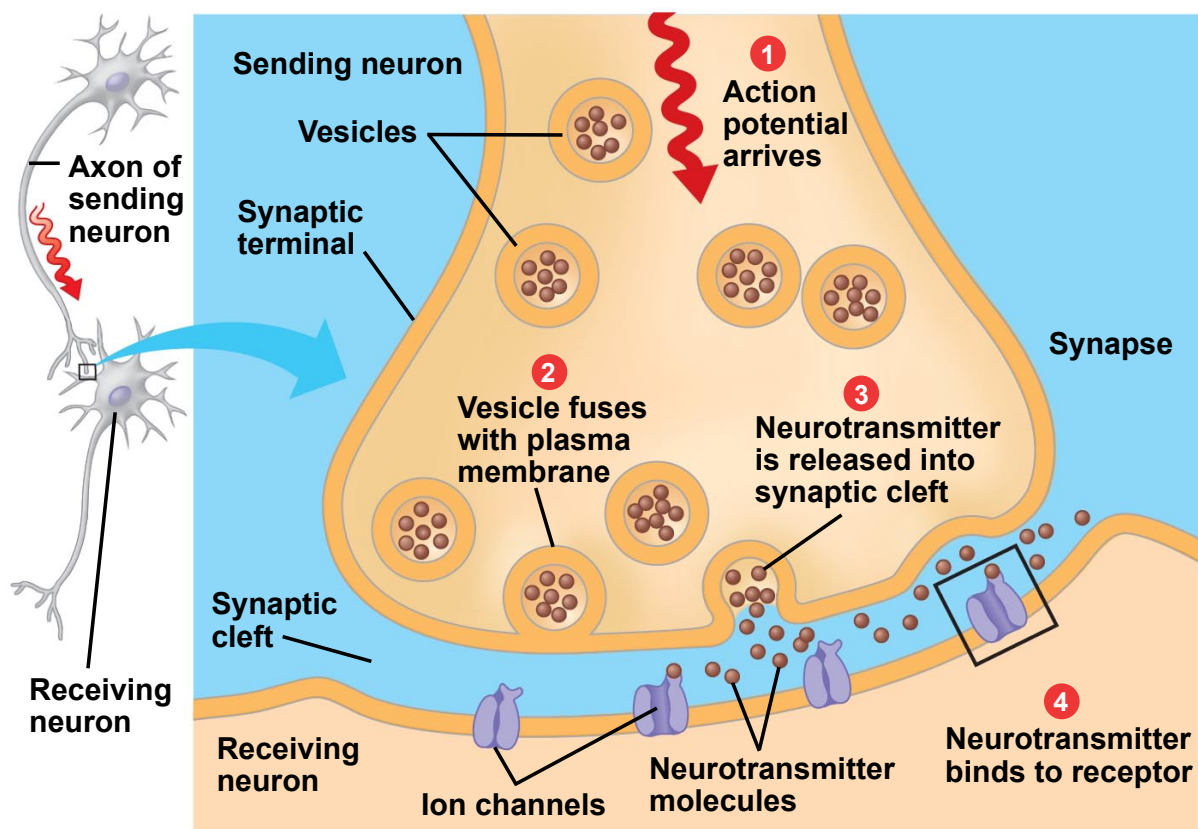
The action potential propagates itself along the neuron

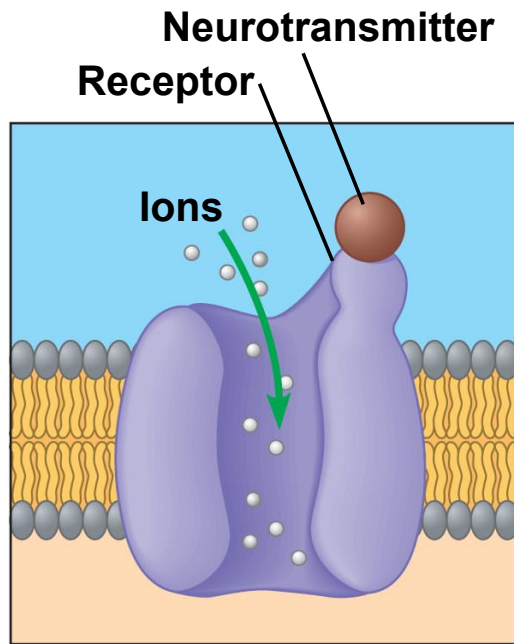
- Action potentials
 - Are self-propagated in a one-way chain reaction along a neuron
 - Are all-or-none events
- The strength of the stimulus changes
 - The frequency of action potentials
 - But not the strength of action potentials



Neurons communicate at synapses

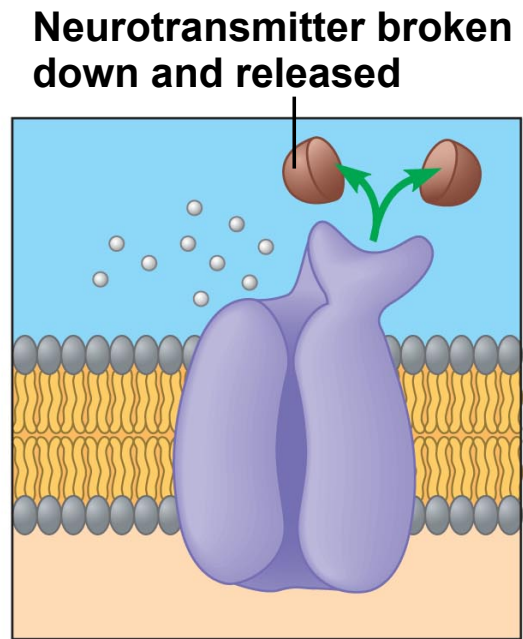
- Synapses are junctions where signals are transmitted between
 - Two neurons
 - Or between neurons and effector cells
- Electrical synapses
 - Electrical signals pass between cells
- Chemical synapses
 - Sending (presynaptic) cell secretes a chemical signal, a **neurotransmitter**
 - The neurotransmitter crosses the **synaptic cleft**
 - The neurotransmitter binds to a receptor on the surface of the receiving (postsynaptic) cell





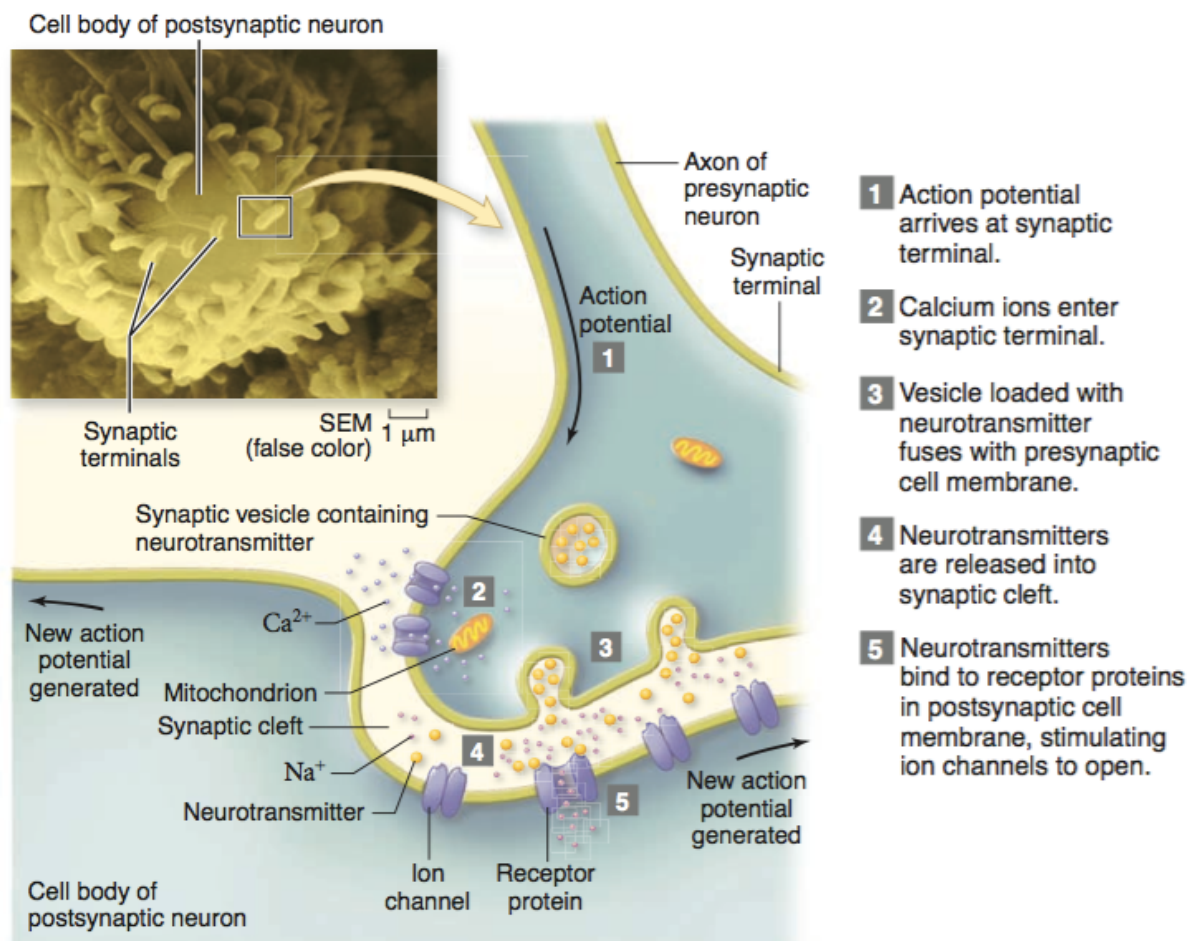
5 Ion channel opens

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6 Ion channel closes

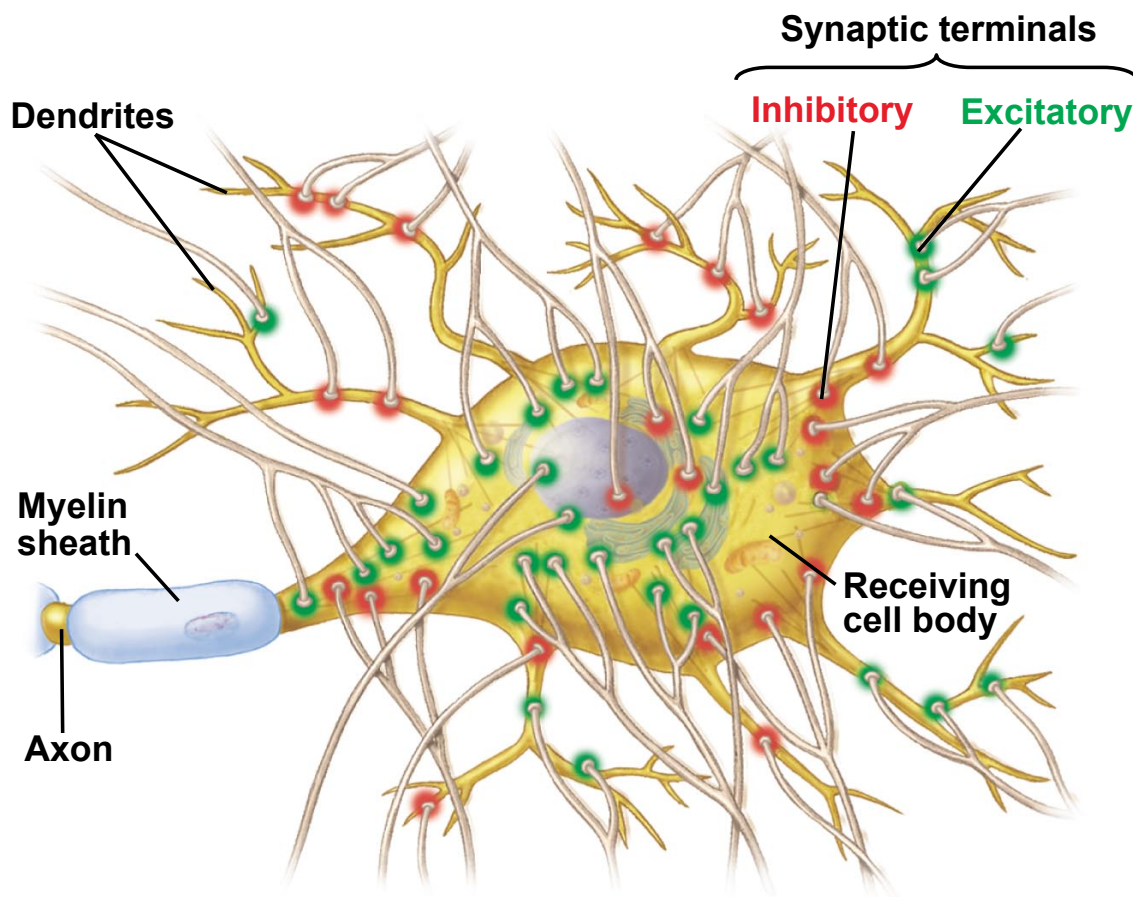
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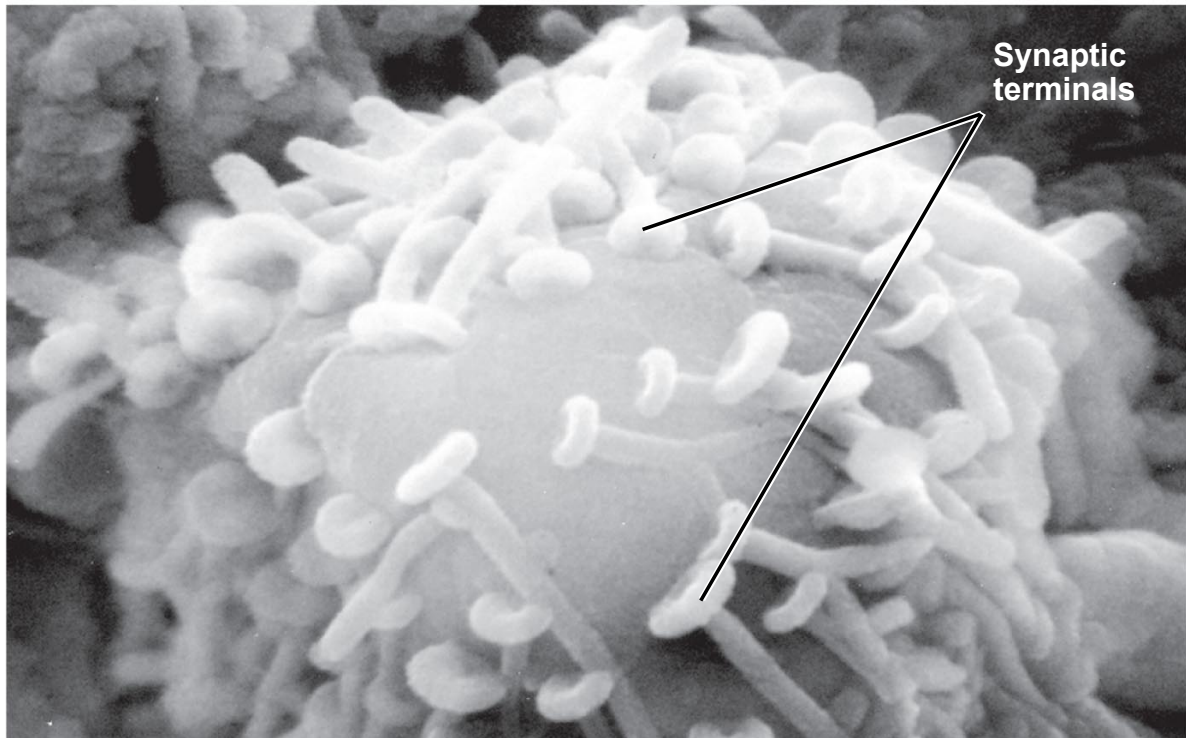


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Chemical synapses make complex information processing possible

- Some neurotransmitters
 - Excite the receiving cell
 - Inhibit the receiving cell's activity by decreasing its ability to develop action potentials
- A neuron may receive information
 - From hundreds of other neurons
 - Via thousands of synaptic terminals
- The summation of excitation and inhibition
 - Determines if a neuron will transmit a nerve signal





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A variety of small molecules function as neurotransmitters

- Many small, nitrogen-containing molecule serve as neurotransmitters
 - **Acetylcholine** is a neurotransmitter
 - In the brain
 - Between neurons and muscle cells
 - **Biogenic amines**
 - Important in the CNS
 - Serotonin and dopamine affect sleep, mood, attention

A variety of small molecules function as neurotransmitters

- Amino acids important in the CNS
 - Some are excitatory
 - Some are inhibitory
- Neuropeptides
 - Substance P mediates perceptions of pain
 - Endorphins decrease perception of pain
- Nitric oxide
 - A dissolved gas
 - Triggers erections

CONNECTION: Many drugs act at chemical synapses

- Many psychoactive drugs
 - Act at synapses
 - Affect neurotransmitter action
- Caffeine counteracts inhibitory neurotransmitters
- Nicotine acts as a stimulant
- Alcohol is a depressant



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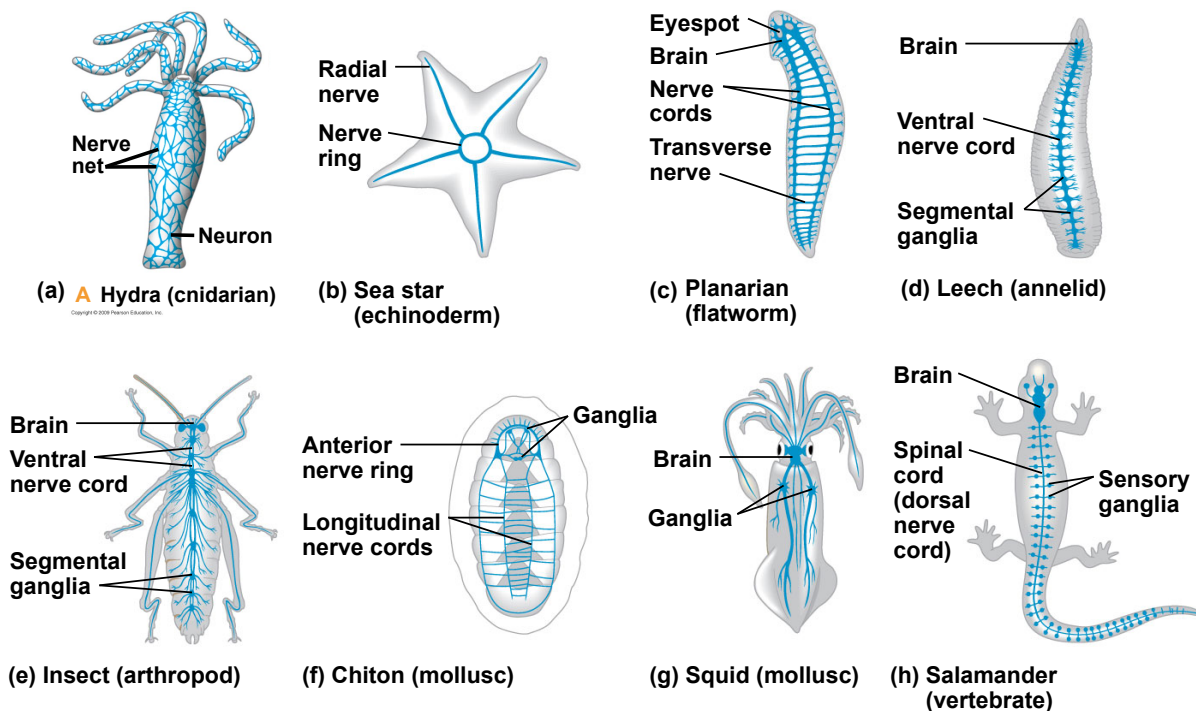
AN OVERVIEW OF ANIMAL NERVOUS SYSTEMS

EVOLUTION CONNECTION: The evolution of animal nervous systems reflects changes in body symmetry

- Radially symmetrical animals
 - Nervous system arranged in a weblike system of neurons
 - **Nerve net**
- Most bilaterally symmetrical animals exhibit
 - **Centralization**—presence of a central nervous system
 - **Cephalization**—concentration of the nervous system in the head region

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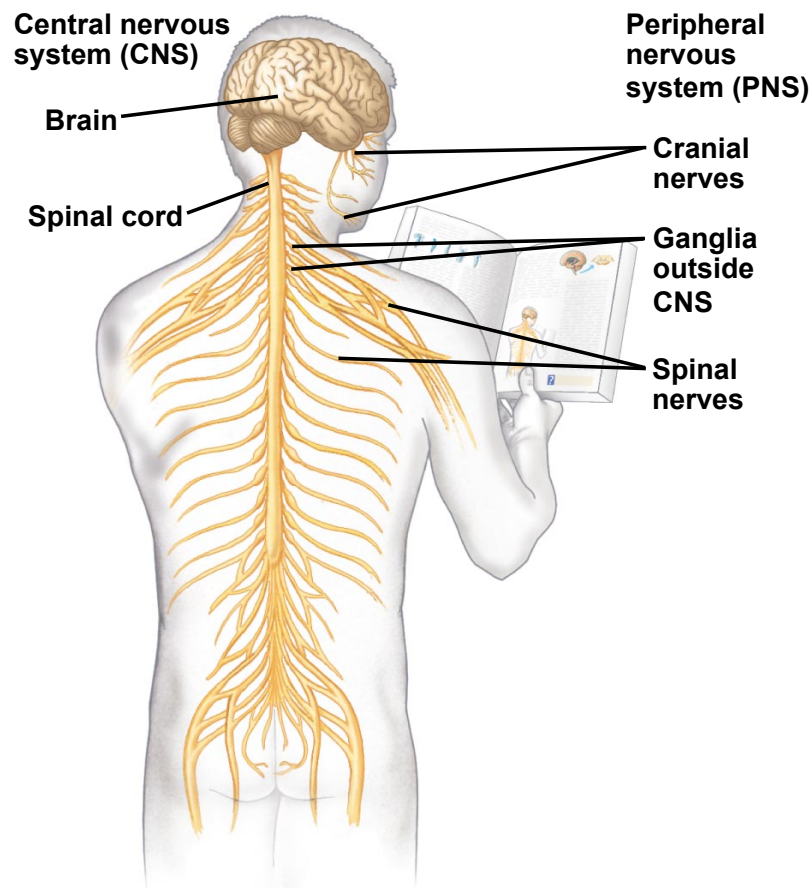
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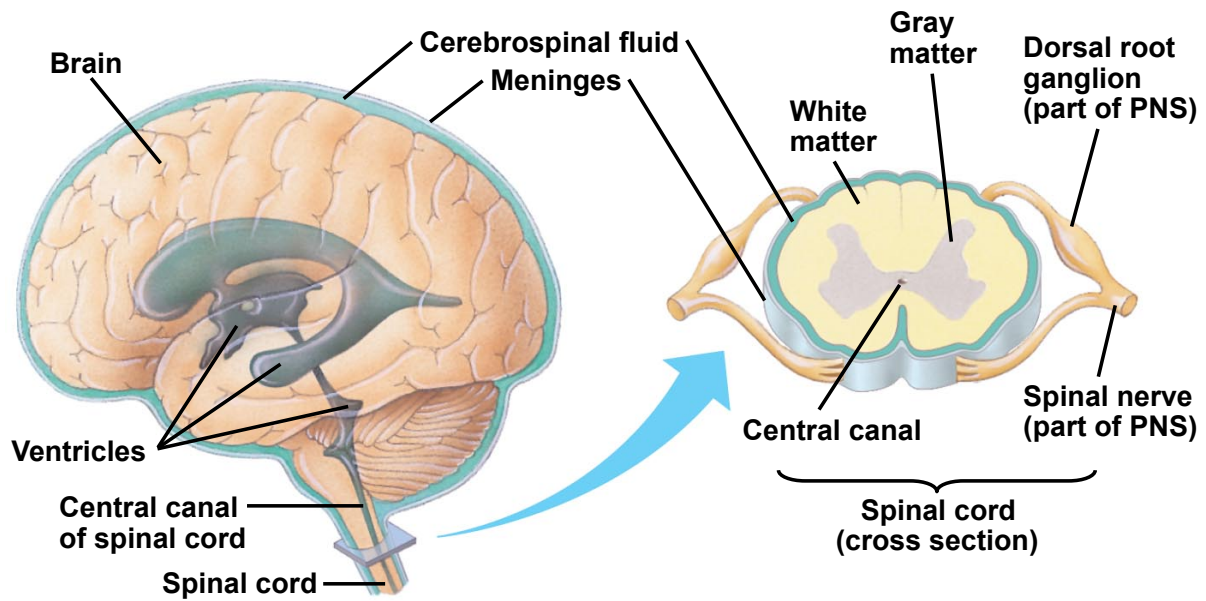


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Vertebrate nervous systems are highly centralized and cephalized

- Vertebrate nervous systems are
 - Highly centralized
 - Cephalized
- Central nervous system (CNS)
 - The **brain** and **spinal cord**
 - Contains fluid-filled spaces
 - In ventricles of the brain
 - In the central canal of the spinal cord
 - Surrounding the brain
- Peripheral nervous system (PNS)
 - Nerves—**cranial nerves** and **spinal nerves**
 - Gangli



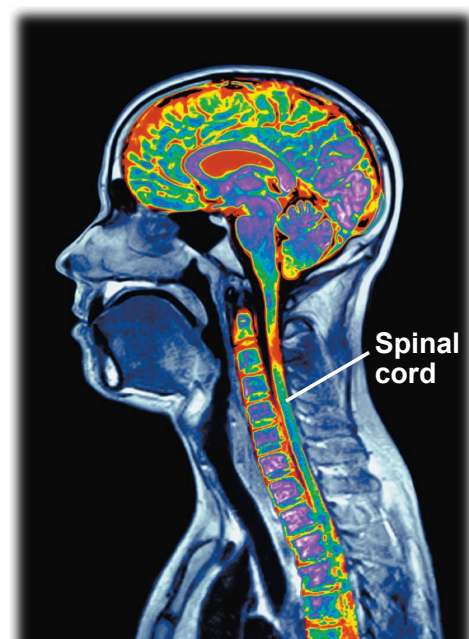


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Can an Injured Spinal Cord Be Fixed?

Spinal cord injuries disrupt communication between

- The central nervous system (brain and spinal cord)
- The rest of the body



Introduction: *Can an Injured Spinal Cord Be Fixed?*

The late actor Christopher Reeve

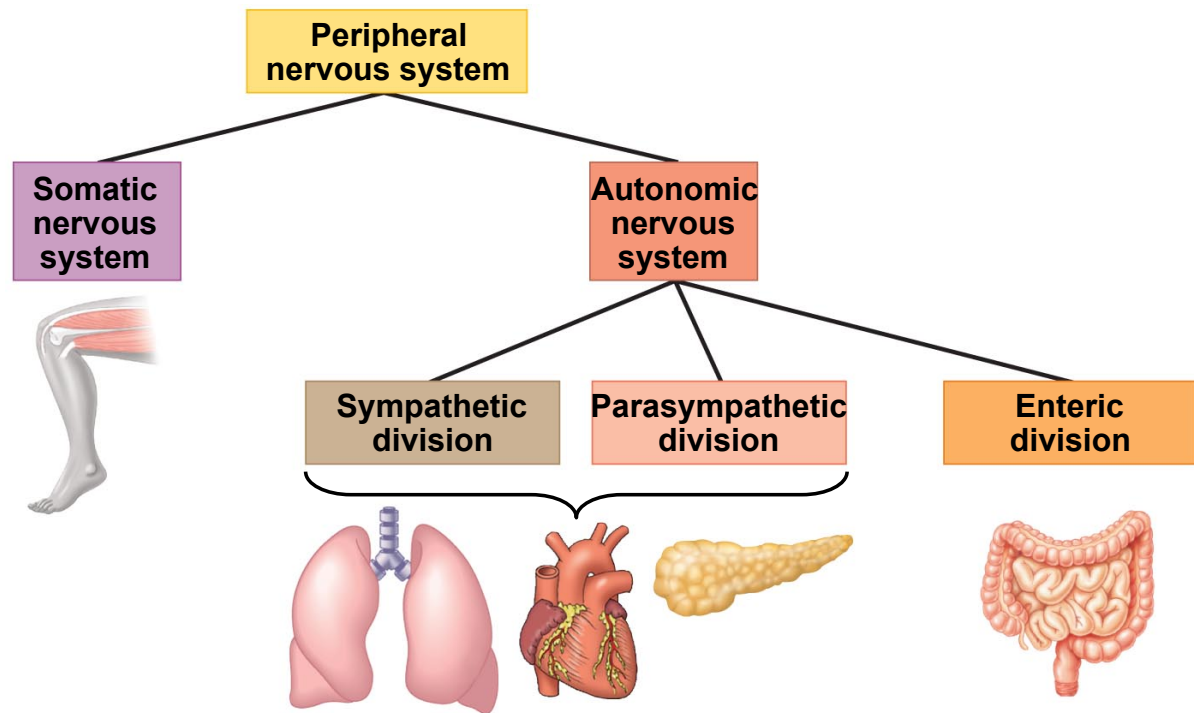
- Suffered a spinal cord injury during an equestrian competition in 1995
- Was an influential advocate for spinal cord research
- Died of complications to the injury in 2004



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The peripheral nervous system of vertebrates is a functional hierarchy

- Two functional components of the PNS
 - **Somatic nervous system**—mostly voluntary
 - **Autonomic nervous system (ANS)**—mostly involuntary
- Somatic nervous system
 - Carries signals to and from skeletal muscles
 - Mainly in response to external stimuli
- Autonomic nervous system
 - Regulates the internal environment
 - Controls
 - Smooth muscle
 - Cardiac muscle
 - Organs of various body systems

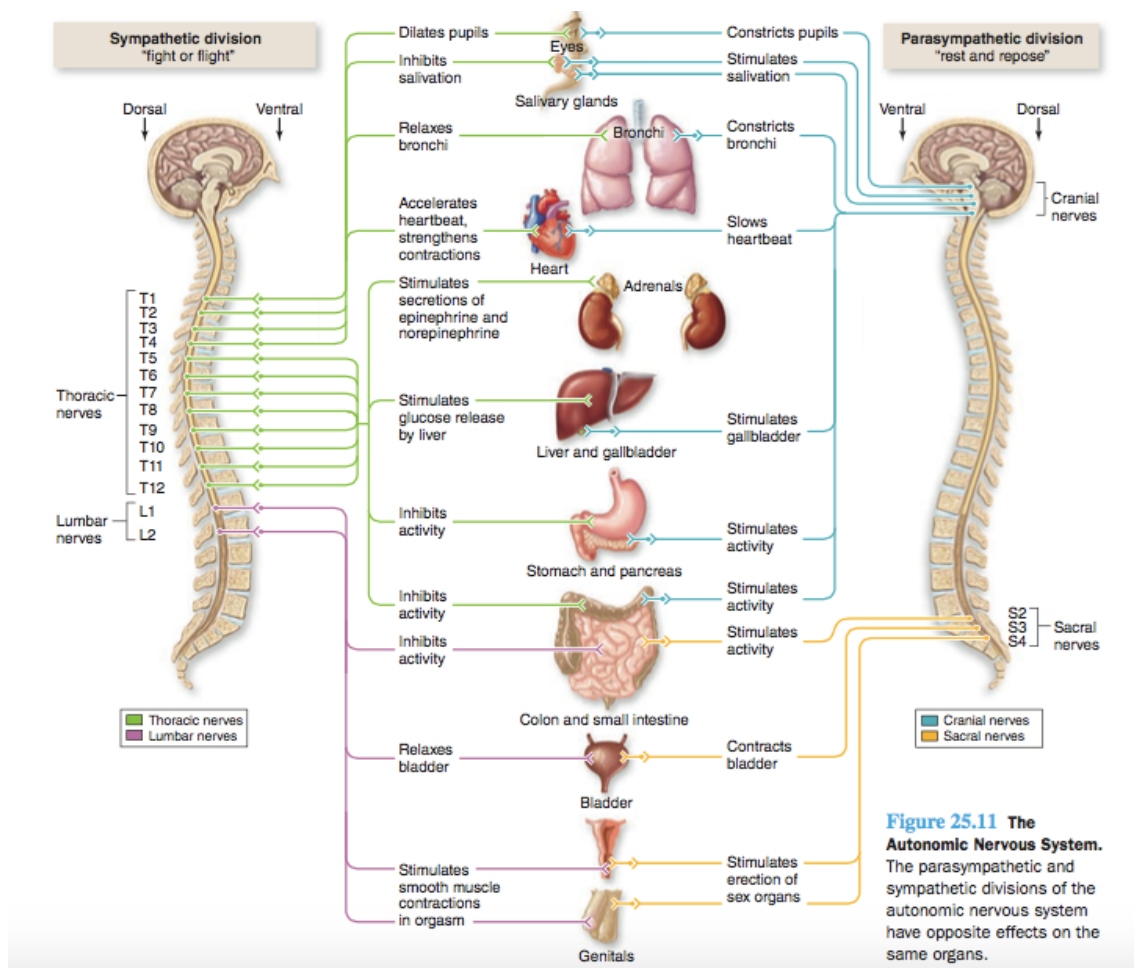


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Opposing actions of sympathetic and parasympathetic neurons regulate the internal environment

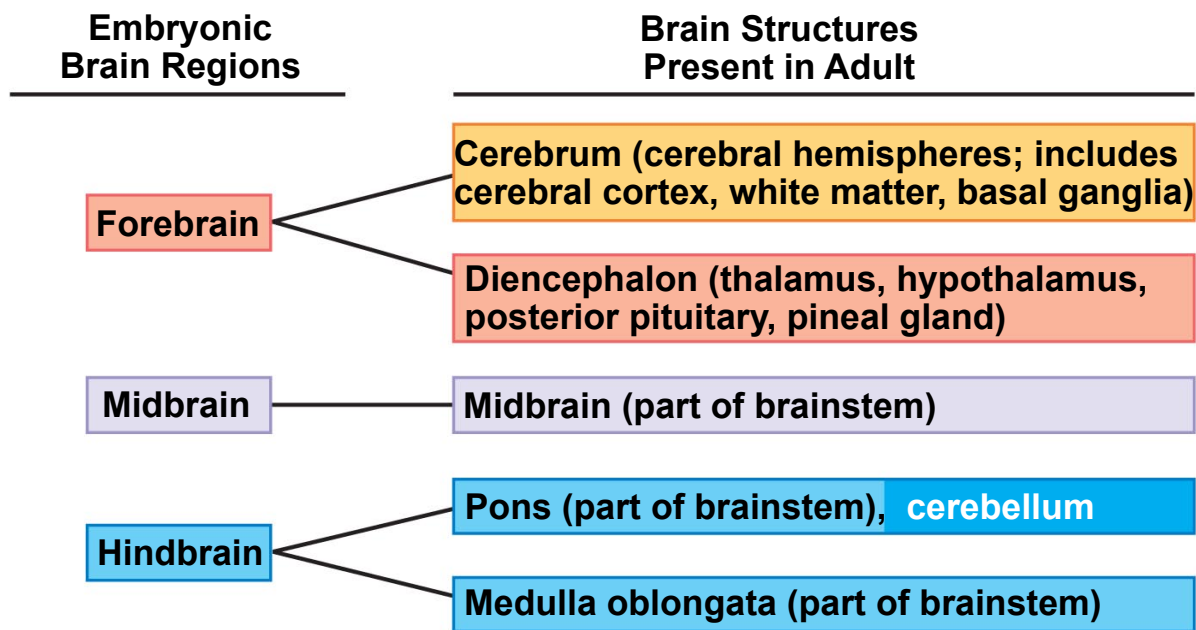
- **Parasympathetic division** of ANS
 - Primes the body for activities that gain and conserve energy for the body
- **Sympathetic division** of ANS
 - Prepares the body for intense, energy-consuming activities



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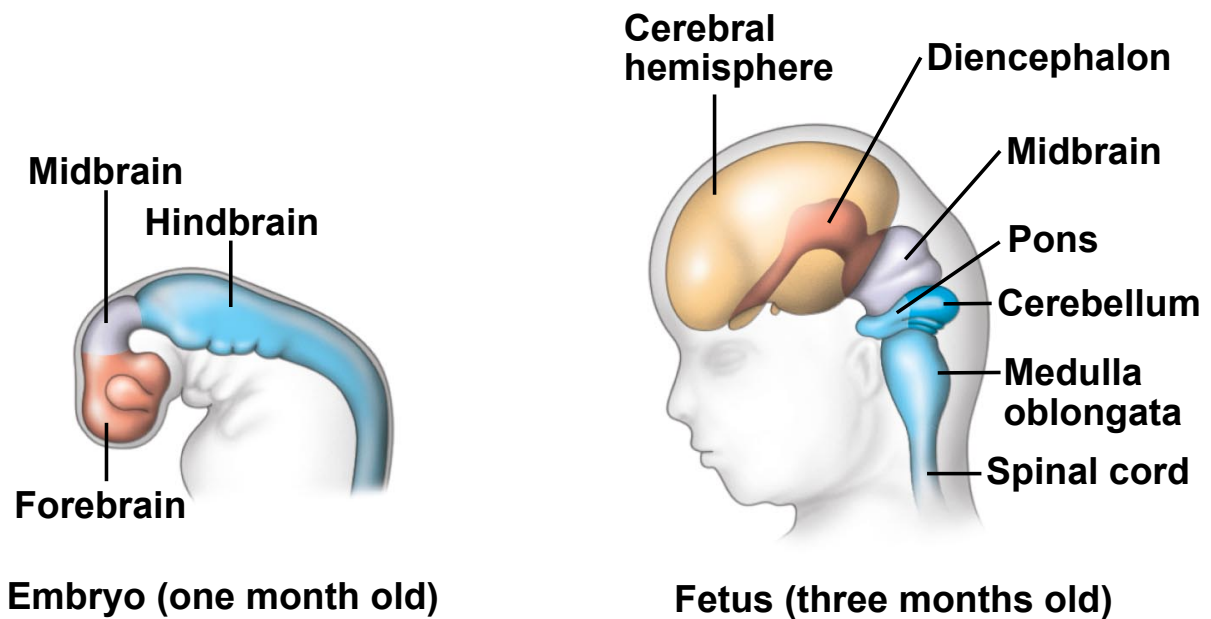
The vertebrate brain develops from three anterior bulges of the neural tube

- The vertebrate brain evolved by the enlargement and subdivision of the
 - **Forebrain**
 - **Midbrain**
 - **Hindbrain**
- In birds and mammals
 - Size and complexity of the **cerebrum** → Correlates with their sophisticated behavior



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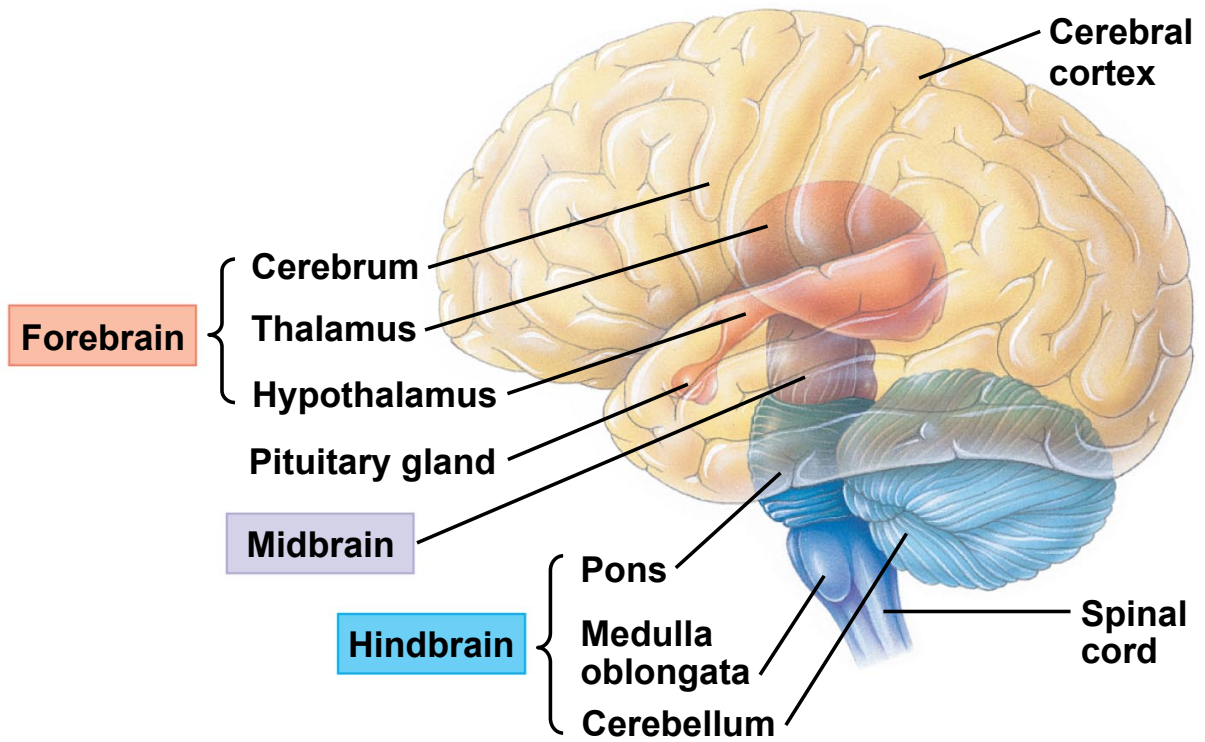
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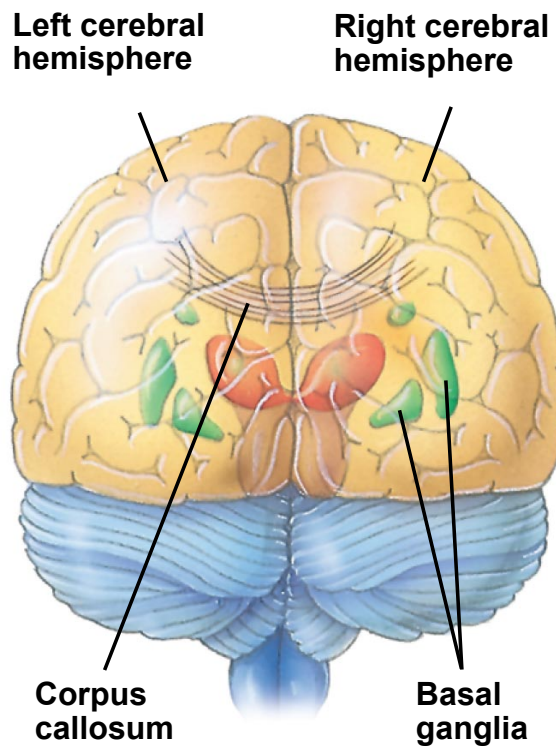
THE HUMAN BRAIN

The structure of a living supercomputer: The human brain

- The human brain
 - More powerful than the most sophisticated computer
 - Composed of three main parts
 - Forebrain
 - Midbrain
 - Hindbrain



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The structure of a living supercomputer: The human brain

- Midbrain, subdivisions of the hindbrain, thalamus, and hypothalamus
 - Conduct information to and from higher brain centers
 - Regulate homeostatic functions
 - Keep track of body position
 - Sort sensory information

The structure of a living supercomputer: The human brain

- Cerebrum
 - Part of the forebrain
 - Largest and most complex part of the brain
 - Most integrative power is in the cerebral cortex

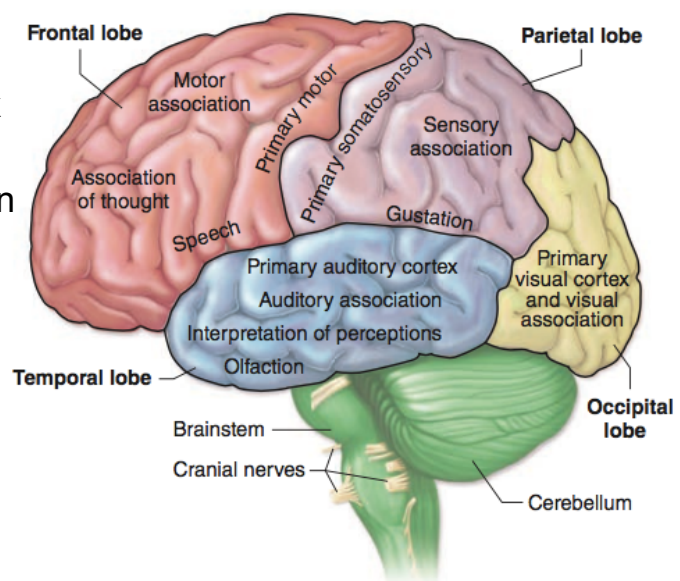


TABLE 28.15 MAJOR STRUCTURES OF THE HUMAN BRAIN	
Brain Structure	Major Functions
Brainstem	Conducts data to and from other brain centers; helps maintain homeostasis; coordinates body movement
{ Medulla oblongata	Controls breathing, circulation, swallowing, digestion
{ Pons	Controls breathing
{ Midbrain	Receives and integrates auditory data; coordinates visual reflexes; sends sensory data to higher brain centers
Cerebellum	Coordinates body movement; plays role in learning and in remembering motor responses
Thalamus	Serves as input center for sensory data going to the cerebrum, output center for motor responses leaving the cerebrum; sorts data
Hypothalamus	Functions as homeostatic control center; controls pituitary gland; serves as biological clock
Cerebrum	Performs sophisticated integration; plays major role in memory, learning, speech, emotions; formulates complex behavioral responses

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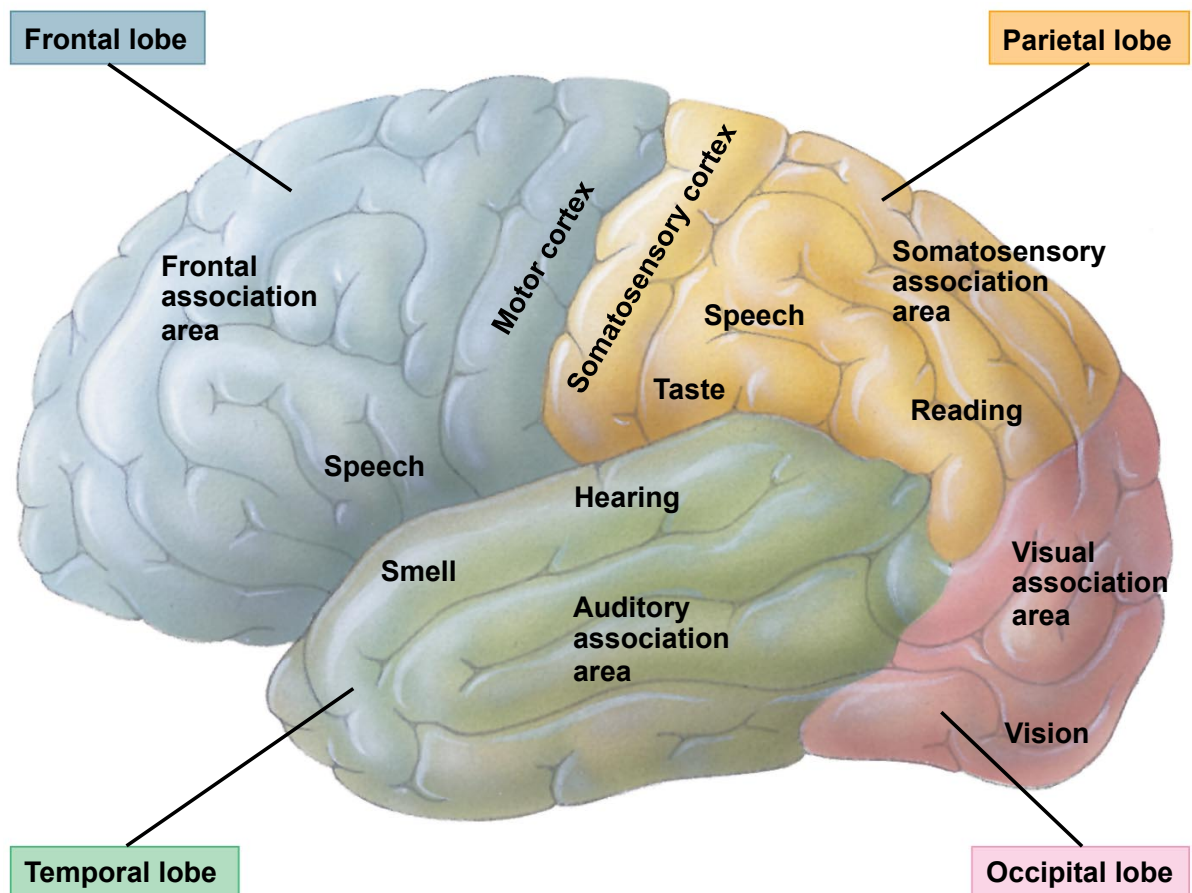
The cerebral cortex is a mosaic of specialized, interactive regions

- **Cerebral cortex**
 - About 5 mm thick
 - Accounts for 80% of brain mass
 - Specialized integrative regions
 - Somatosensory cortex
 - Centers for vision, hearing, taste, and smell

The cerebral cortex is a mosaic of specialized, interactive regions

- Motor cortex—directs responses
- Association areas
 - Make up most of the cerebrum
 - Higher mental activities
 - Reasoning
 - Language
- Right and left cerebral hemispheres
 - Specialize in different mental tasks

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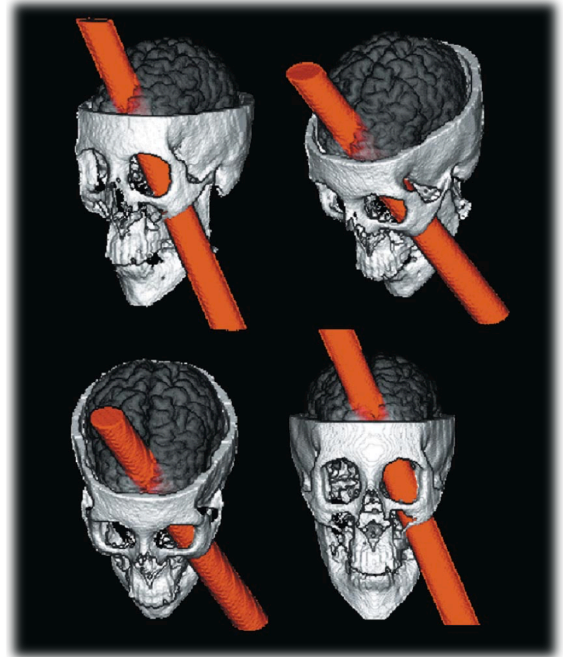


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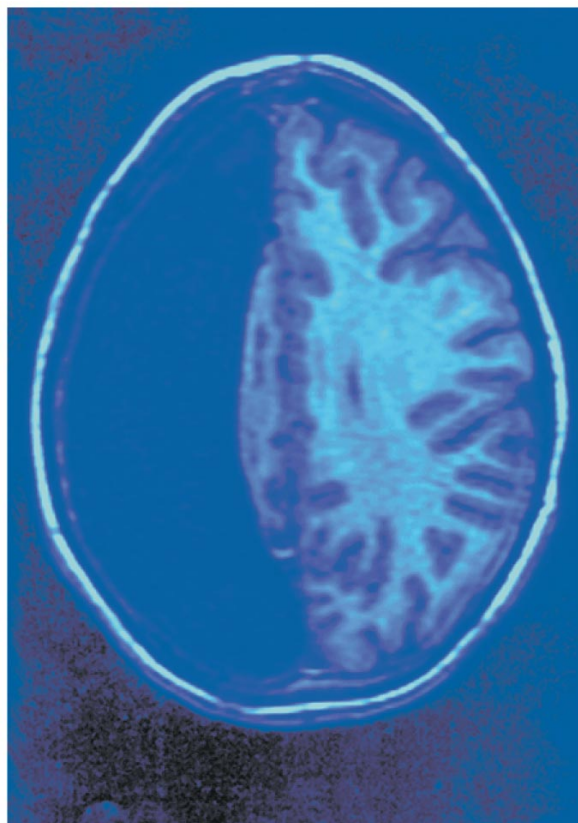
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Injuries and brain operations provide insight into brain function

- Brain injuries and surgeries reveal brain functions
 - The case of Phineas Gage
 - Stimulation of the cerebral cortex during surgery



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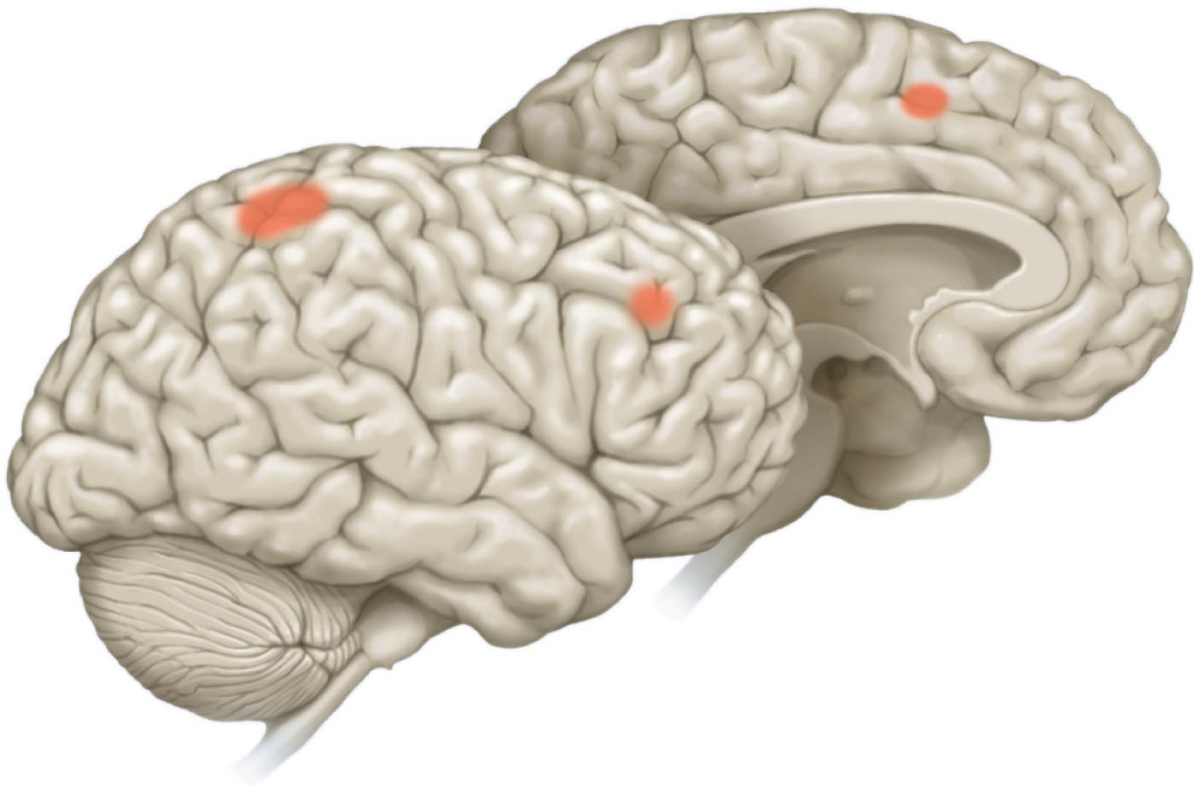


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fMRI scans can provide insight into brain structure and function

- fMRI
 - A scanning and imaging technology used to study brain functions
 - Used on conscious patients
 - Monitors changes in blood oxygen usage in the brain
 - Correlates to regions of intense brain function



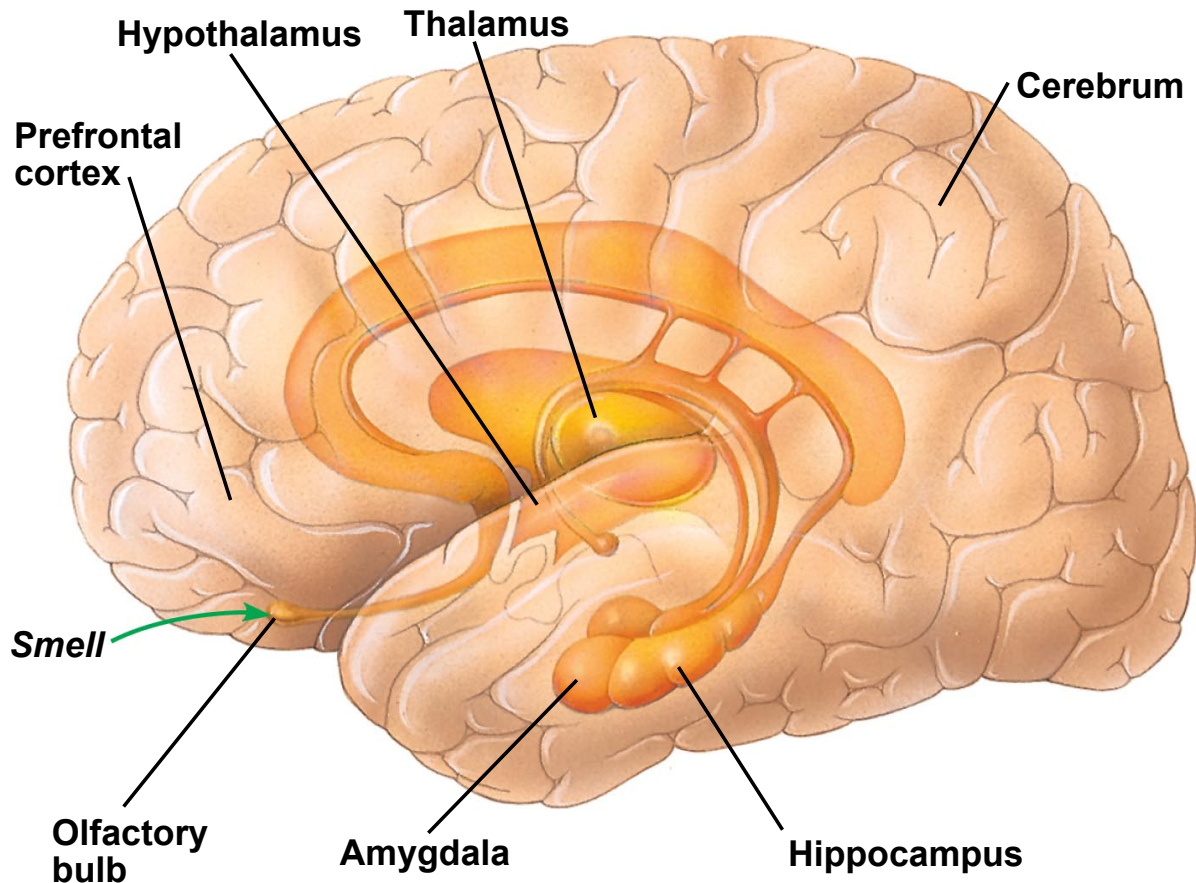
Several parts of the brain regulate sleep and arousal

- Sleep and arousal involve activity by the
 - Hypothalamus
 - Medulla oblongata
 - Pons
 - Neurons of the reticular formation
- Sleep
 - Is essential for survival
 - Sleep is an active state
 - Sleep may be involved in consolidating learning and memory

The limbic system is involved in emotions, memory, and learning

The limbic system

- Is a functional group of integrating centers in
 - Cerebral cortex
 - Thalamus
 - Hypothalamus
- Is involved in
 - Emotions
 - Memory
 - Learning



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Changes in brain physiology can produce neurological disorders

- Many neurological disorders can be linked to changes in brain physiology
 - Schizophrenia
 - Depression
 - Alzheimer's disease
 - Parkinson's disease

Changes in brain physiology can produce neurological disorders

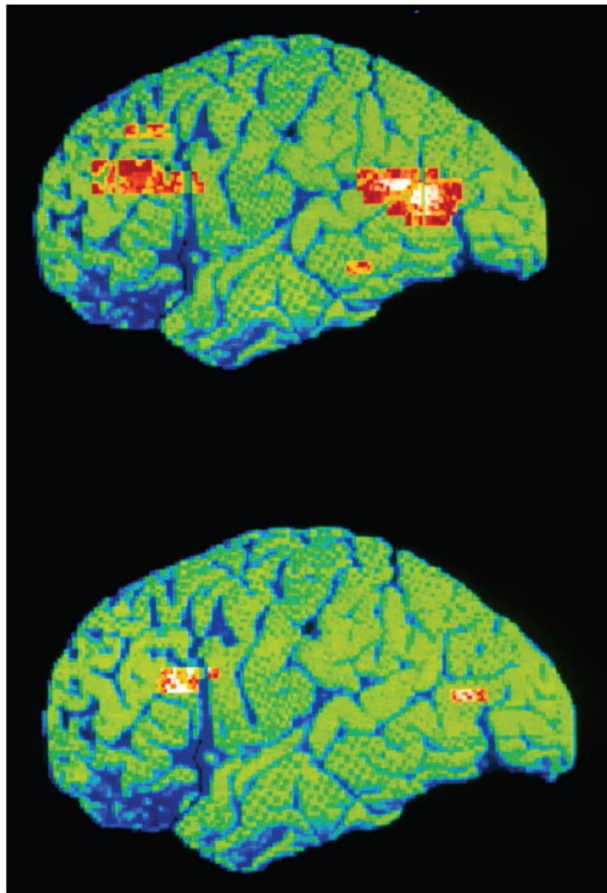
■ Schizophrenia

- A severe mental disturbance
- Characterized by psychotic episodes in which patients lose the ability to distinguish reality

Changes in brain physiology can produce neurological disorders

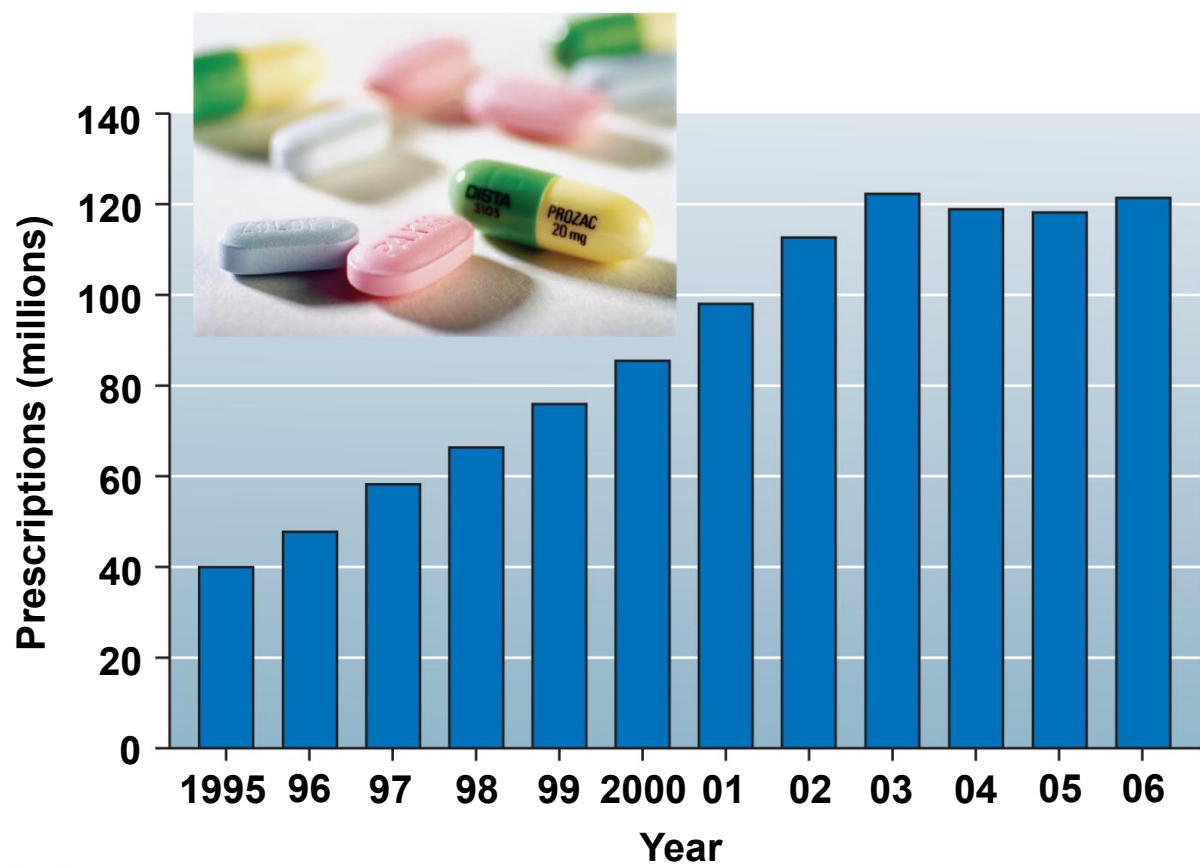
■ Depression

- Two broad forms of depressive illness have been identified
 - **Major depression**
 - **Bipolar disorder**—manic-depressive disorder
- Treatments may include selective serotonin reuptake inhibitors (SSRIs)



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Changes in brain physiology can produce neurological disorders

- **Alzheimer's disease** is characterized by
 - Confusion
 - Memory loss
 - A firm diagnosis is difficult to make
- **Parkinson's disease**
 - Motor disorder
 - Characterized by
 - Difficulty in initiating movements
 - Slowness of movement
 - Rigidity

