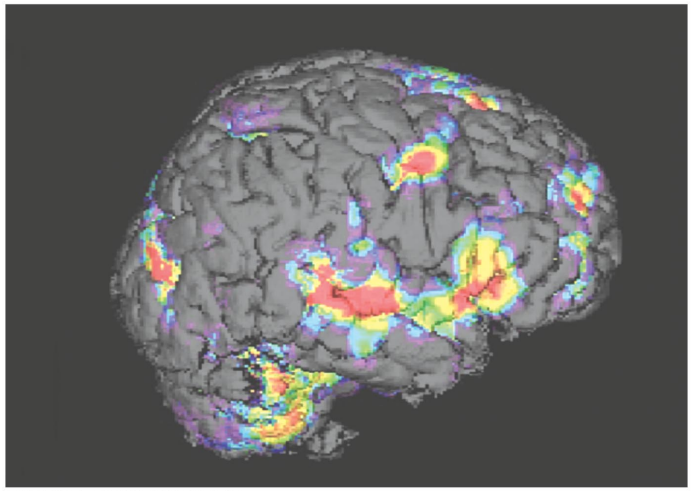
Overview: Command and Control Center

- The circuits in the brain are more complex than the most powerful computers.
- Functional magnetic resonance imaging (MRI) can be used to construct a 3-D map of brain activity.
- *The vertebrate brain is organized into regions with different functions*.

Scientists map activity within the human brain

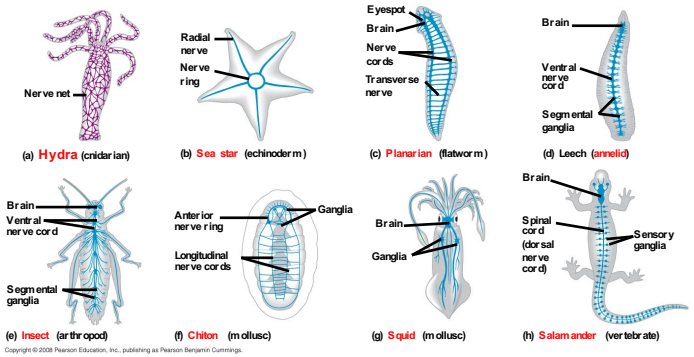


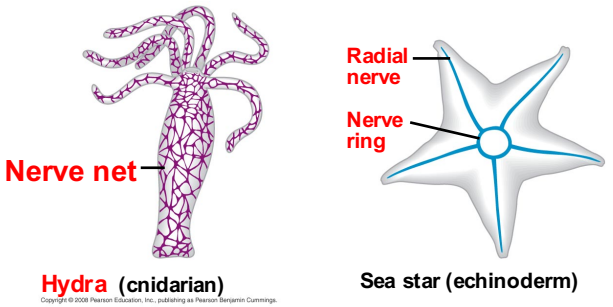
Nervous systems consist of circuits of neurons and supporting cells

- The simplest animals with nervous systems, the cnidarians, have neurons arranged in nerve nets.
- A **nerve net** is a series of interconnected nerve cells. There is no central pathway / or directional organization.
- More complex animals have nerves.

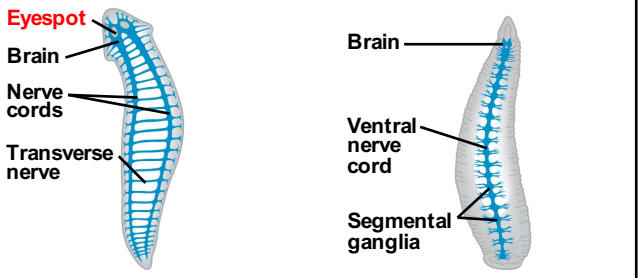
- **Nerves** are bundles that consist of the axons of multiple nerve cells.
- Sea stars have a nerve net in each arm connected by radial nerves to a central nerve ring.

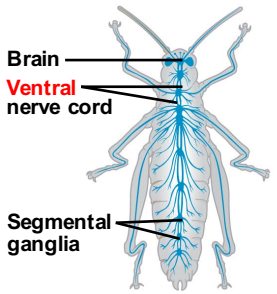
Nervous system organization



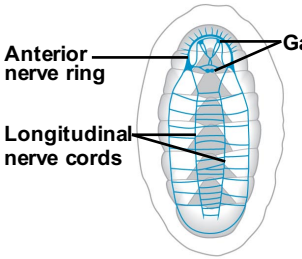


- Bilaterally symmetrical animals exhibit cephalization.
- Cephalization is the clustering of sensory organs at the front end of the body.
- Relatively simple cephalized animals, such as flatworms, have a *central nervous system* (*CNS*).
- The CNS consists of a brain and longitudinal nerve cords.



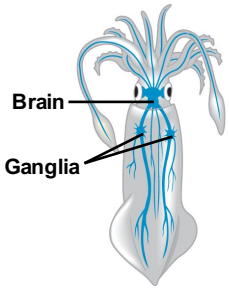


Insect (arthropod)

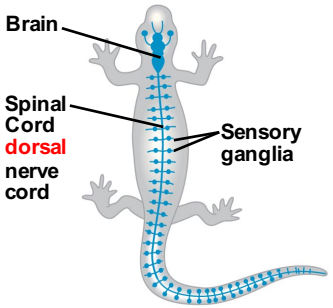


Chiton (mollusc)

- Annelids and arthropods have segmentally arranged clusters of neurons called ganglia.
- *Nervous system organization usually correlates with lifestyle*.
- Sessile molluscs (e.g., clams and chitons) have simple systems, whereas more complex molluscs (e.g., octopuses and squids) have more sophisticated systems.



Squid (mollusc)

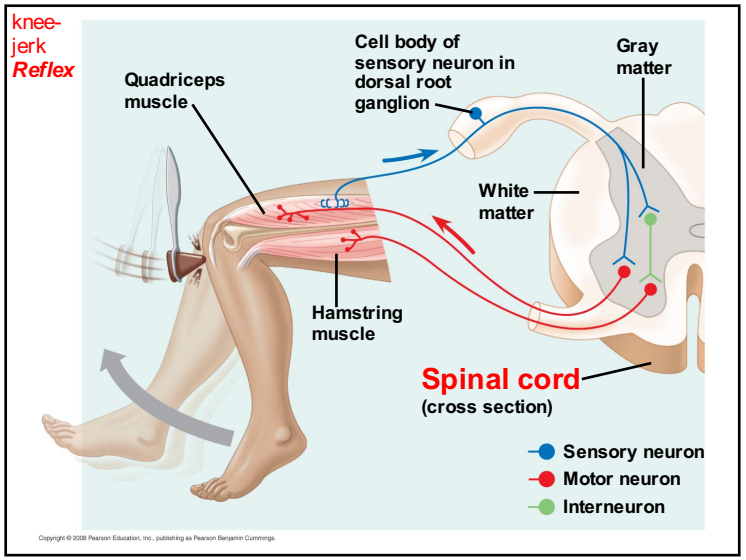


Salamander (vertebrate)

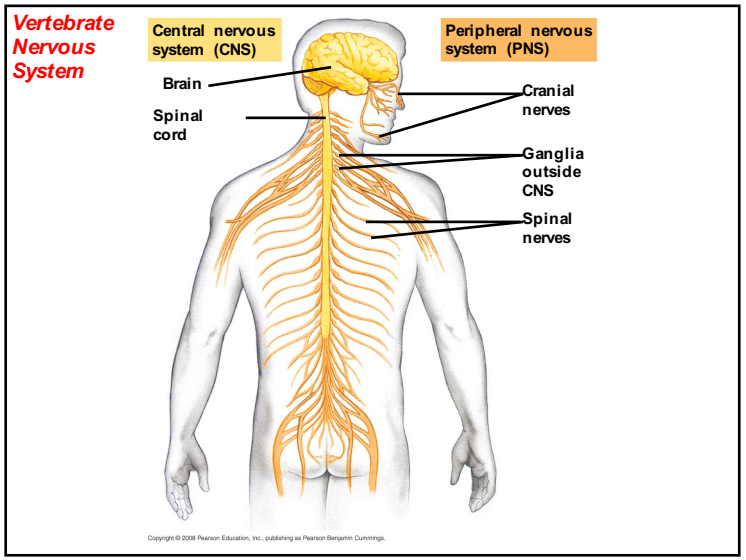
- In vertebrates
  - The CNS is composed of the brain and spinal cord.
  - The *peripheral nervous system* (*PNS*) is composed of nerves and ganglia.

Organization of the Vertebrate Nervous System

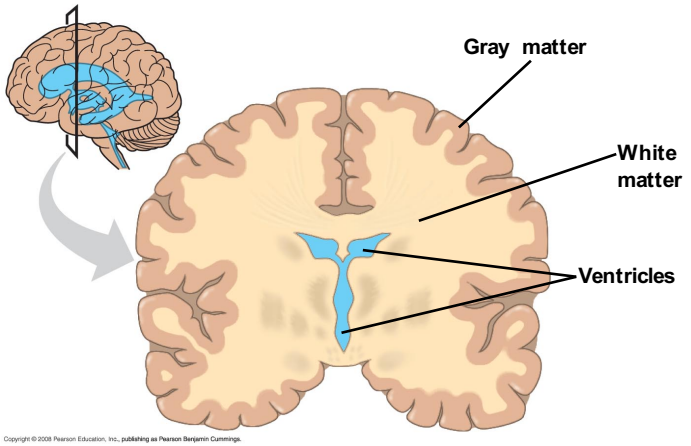
- The spinal cord conveys information from the brain to the PNS.
- The spinal cord also produces reflexes independently of the brain.
- A **reflex** is the body's automatic response to a stimulus.
  - For example, a doctor uses a mallet to trigger a knee-jerk reflex.



- Invertebrates usually have a ventral nerve cord while vertebrates have a dorsal spinal cord.
- The spinal cord and brain develop from the embryonic nerve cord.



Ventricles, gray matter, and white matter



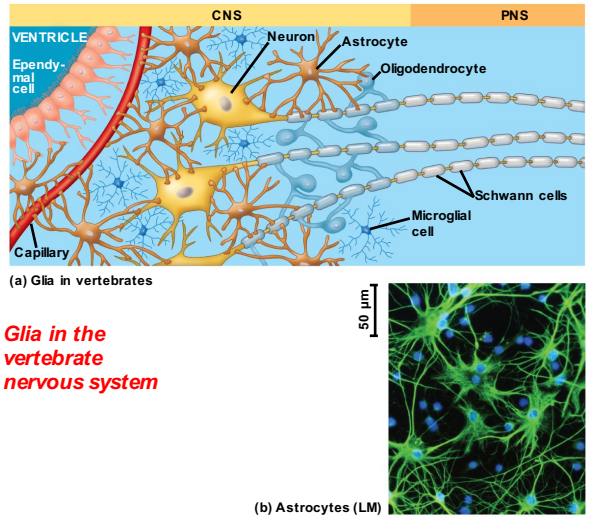
- The ***central canal*** of the *spinal cord* and the ***ventricles*** of the *brain* are hollow and filled with ***cerebrospinal fluid***.
- The cerebrospinal fluid is filtered from blood and functions to cushion the brain and spinal cord.

- The brain and spinal cord contain
  - **Gray matter**, which consists of neuron cell bodies, dendrites, and unmyelinated axons.
  - **White matter**, which consists of bundles of myelinated axons.

Glia in the CNS

- Glia have numerous functions
  - Ependymal cells promote circulation of cerebrospinal fluid.
  - Microglia protect the nervous system from microorganisms.
  - Oligodendrocytes and Schwann cells form the myelin sheaths around axons.

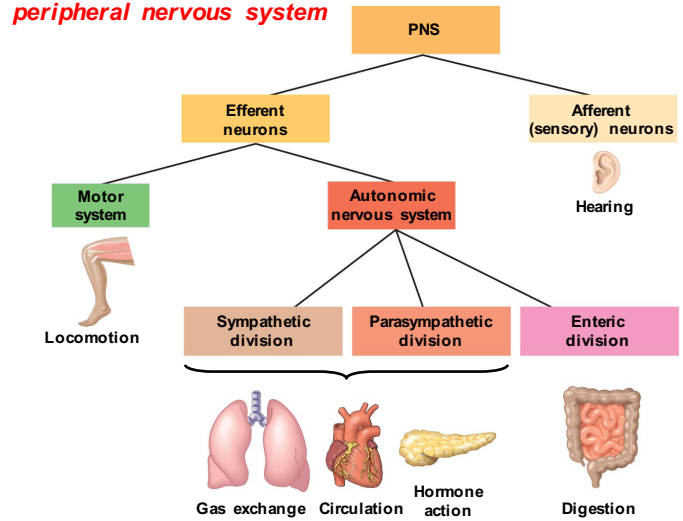
- Glia have numerous functions
  - **Astrocytes** provide *structural support* for neurons, regulate extracellular ions and neurotransmitters, and induce the formation of a ***blood-brain barrier*** that regulates the *chemical environment* of the CNS
  - **Radial glia** play a role in the embryonic development of the nervous system.



Glia in the vertebrate nervous system

The Peripheral Nervous System

- The PNS transmits information to and from the CNS and regulates movement and the internal environment.
- In the PNS, *afferent* neurons transmit information to the CNS and *efferent* neurons transmit information away from the CNS.
- **Cranial nerves** originate in the brain and mostly terminate in organs of the head and upper body.
- **Spinal nerves** originate in the spinal cord and extend to parts of the body below the head.



- The **PNS** has two functional components: the motor system and the autonomic nervous system.
- The **motor system** carries signals to skeletal muscles and is voluntary.
- The **autonomic nervous system** regulates the internal environment in an involuntary manner.

- The PNS autonomic nervous system has sympathetic, parasympathetic, and enteric divisions
- The sympathetic and parasympathetic divisions have antagonistic effects on target organs.

- The **sympathetic division** correlates with the "fight-or-flight" response.
- The **parasympathetic division** promotes a return to "rest and digest."
- The **enteric division** controls activity of the digestive tract, pancreas, and gallbladder.

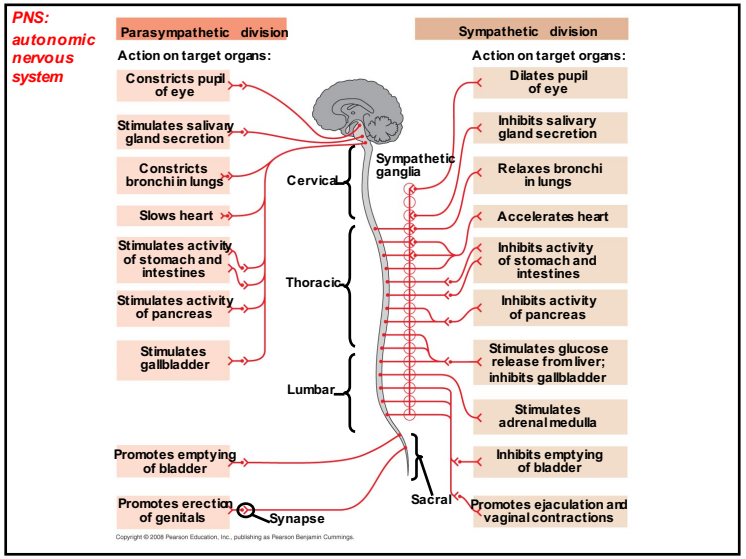


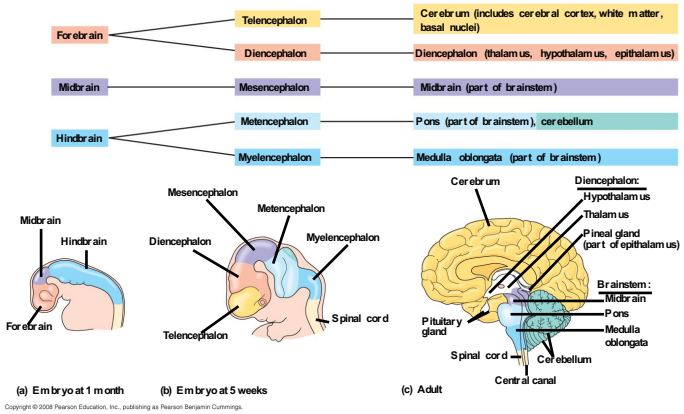
Table 49.1 Properties of Parasympathetic and Sympathetic Neurons

	Parasympathetic Division	Sympathetic Division
Preganglionic Neurons		
Location	Brainstem, sacral segments of spinal cord	Thoracic and lumbar segments of spinal cord
Neurotransmitter released	Acetylcholine	Acetylcholine
Postganglionic Neurons		
Location	Ganglia close to or within target organs	Ganglia close to target organs or chain of ganglia near spinal cord
Neurotransmitter released	Acetylcholine	Norepinephrine

The vertebrate brain is regionally specialized

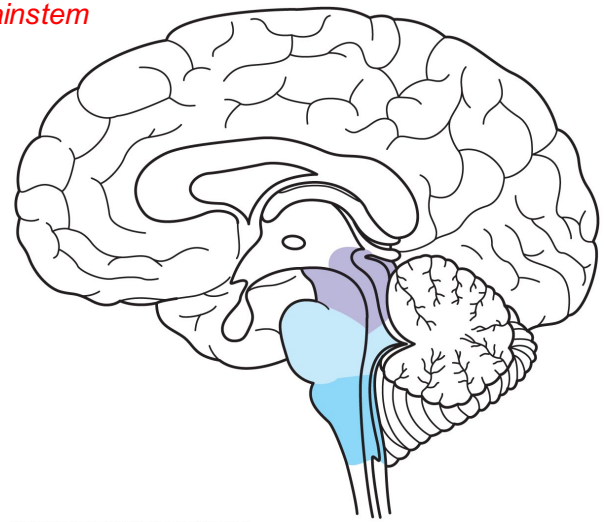
- All vertebrate brains develop from three embryonic regions: **forebrain**, **midbrain**, and **hindbrain.**
- By the fifth week of human embryonic development, five brain regions have formed from the three embryonic regions.

Development of the human brain



- As a human brain develops further, the most profound change occurs in the forebrain, which gives rise to the **cerebrum.**
- The outer portion of the cerebrum called the **cerebral cortex** surrounds much of the brain.

Brainstem



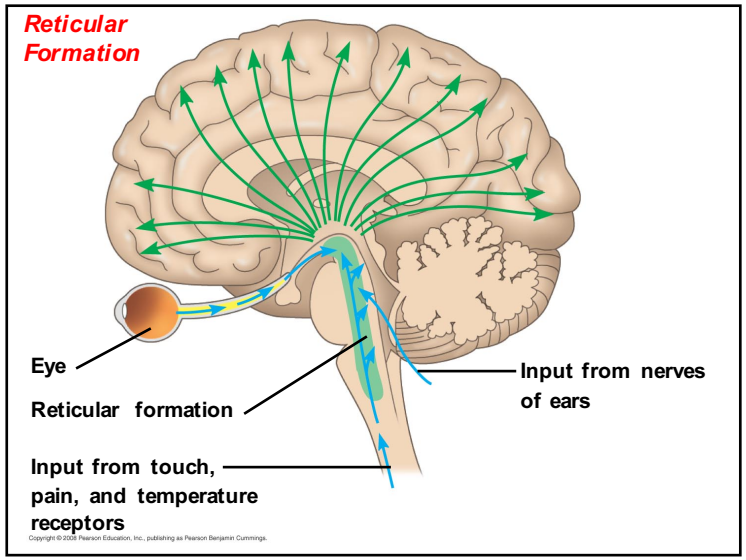
The Brainstem

- *The **brainstem** coordinates and conducts information between brain centers.*
- The brainstem has three parts: the **midbrain**, the **pons**, and the **medulla oblongata.**

- The *midbrain* contains centers for receipt and integration of sensory information.
- The *pons* regulates breathing centers in the medulla.
- The *medulla oblongata* contains centers that control several functions including breathing, cardiovascular activity, swallowing, vomiting, and digestion.

Arousal and Sleep

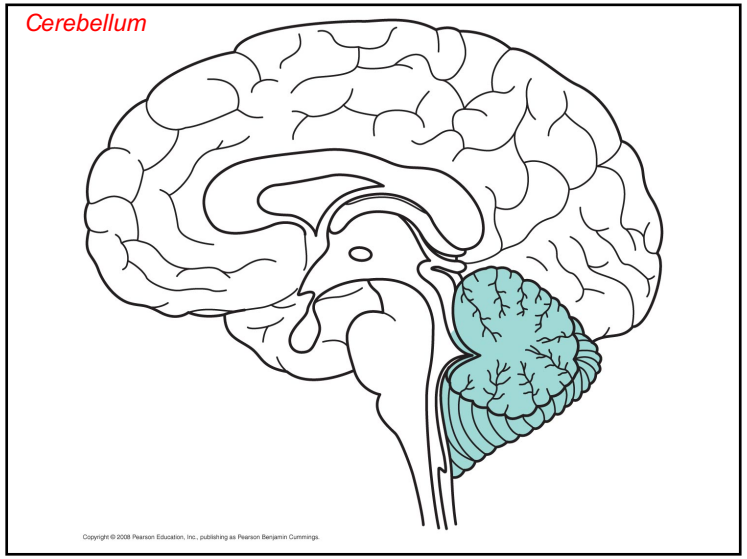
- The brainstem and cerebrum control arousal and sleep.
- The core of the brainstem has a diffuse network of neurons called the **reticular formation.**
- This regulates the amount and type of information that reaches the cerebral cortex and affects alertness.
- The hormone melatonin is released by the pineal gland and plays a role in bird and mammal sleep cycles.



- Sleep is essential and may play a role in the consolidation of learning and memory.
- Dolphins sleep with one brain hemisphere at a time and are therefore able to swim while "asleep."

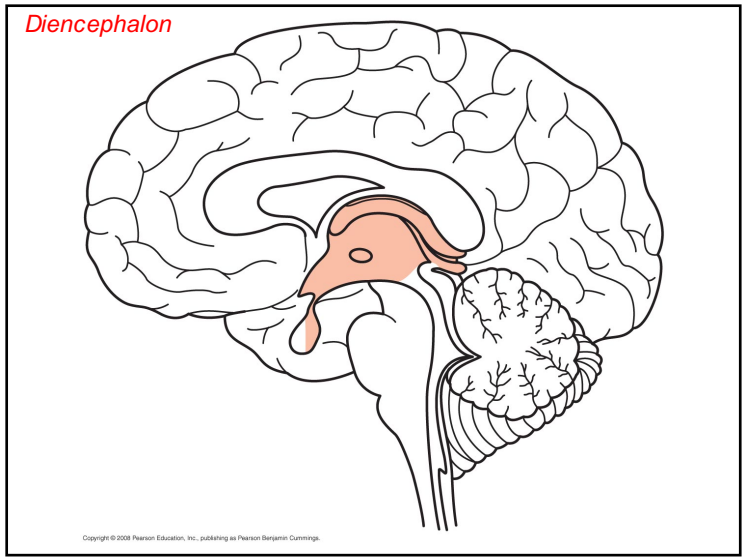
The Cerebellum

- The **cerebellum** is important for coordination and error checking during motor, perceptual, and cognitive functions.
- It is also involved in learning and remembering motor skills.



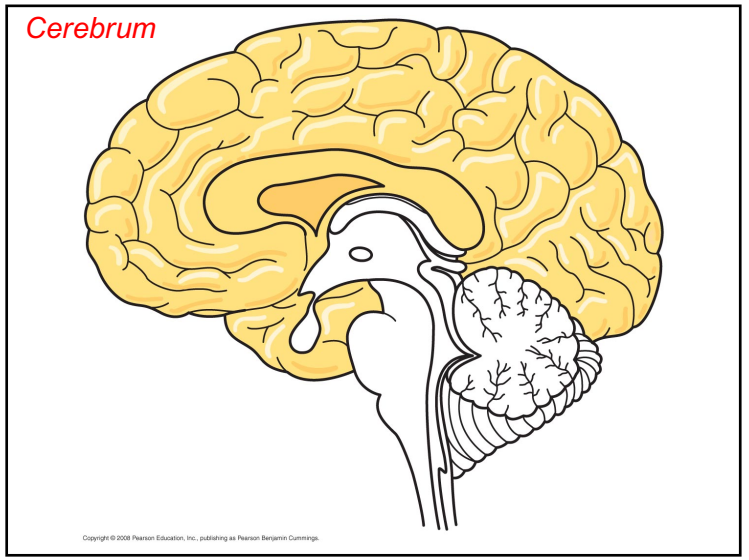
The Diencephalon

- The diencephalon develops into three regions: the epithalamus, thalamus, and hypothalamus.
- The *epithalamus* includes the pineal gland and generates cerebrospinal fluid from blood.
- The **thalamus** is the main input center for sensory information to the cerebrum and the main output center for motor information leaving the cerebrum.
- The **hypothalamus** regulates homeostasis and basic survival behaviors such as feeding, fighting, fleeing, and reproducing.



Biological Clock Regulation by the Hypothalamus

- The hypothalamus also regulates circadian rhythms such as the sleep/wake cycle.
- Mammals usually have a pair of **suprachiasmatic nuclei** (**SCN**) in the hypothalamus that function as a **biological clock.**
- Biological clocks usually require external cues to remain synchronized with environmental cycles.

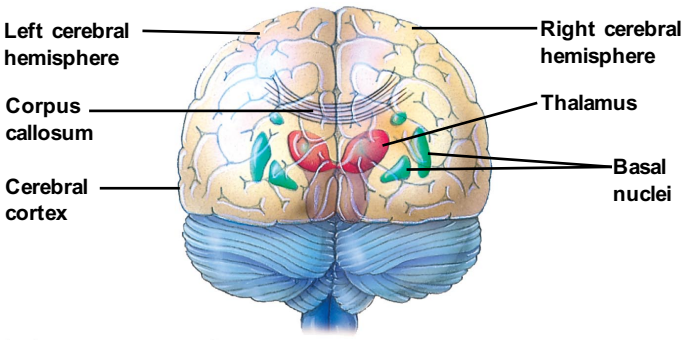


Cerebrum

- The cerebrum has right and left **cerebral hemispheres**.
- Each cerebral hemisphere consists of a cerebral cortex (gray matter) overlying white matter and basal nuclei.
- In humans, the cerebral cortex is the largest and most complex part of the brain.
- The basal nuclei are important centers for planning and learning movement sequences.

- A thick band of axons called the **corpus callosum** provides communication between the right and left cerebral cortices.
- The right half of the cerebral cortex controls the left side of the body, and vice versa.

Human Brain viewed from the rear

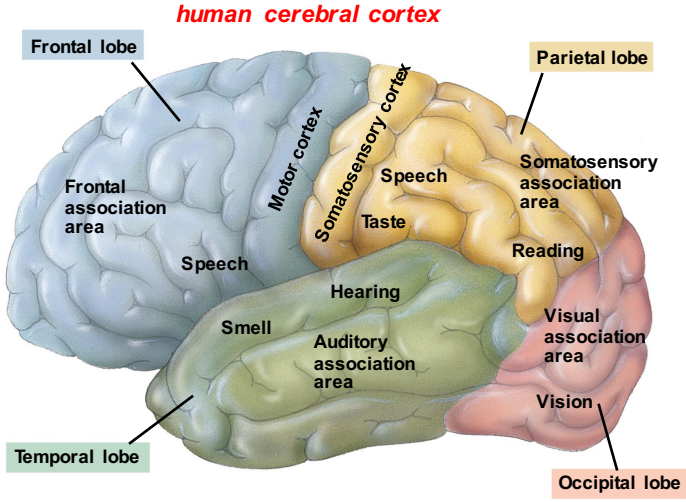


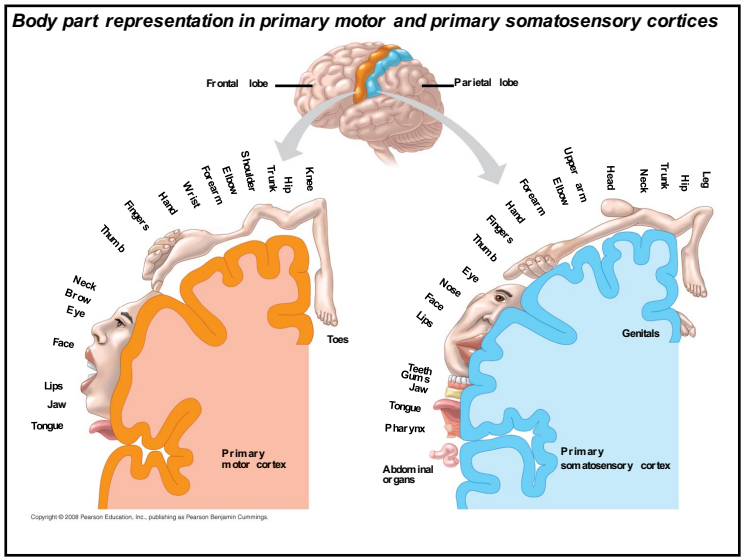
Evolution of Cognition in Vertebrates

- The outermost layer of the cerebral cortex has a different arrangement in birds and mammals.
- In mammals, the cerebral cortex has a convoluted surface called the *neocortex*, which was previously thought to be required for cognition.
- *Cognition is the perception and reasoning that form knowledge*.
- However, it has recently been shown that birds also demonstrate cognition even though they lack a neocortex.

The cerebral cortex controls voluntary movement and cognitive functions

- Each side of the cerebral cortex has four lobes: frontal, temporal, occipital, and parietal.
- Each lobe contains primary sensory areas and association areas where information is integrated.

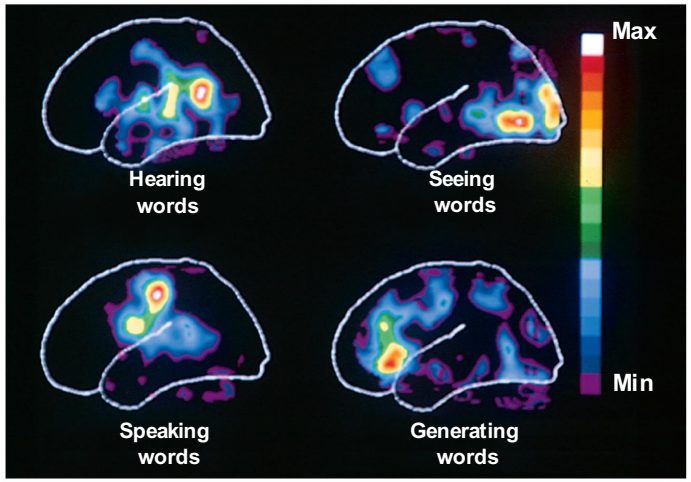




Language and Speech

- Studies of brain activity have mapped areas responsible for language and speech.
- Broca's area in the frontal lobe is active when speech is generated.
- Wernicke's area in the temporal lobe is active when speech is heard.

Mapping language areas in the cerebral cortex



Lateralization of Cortical Function

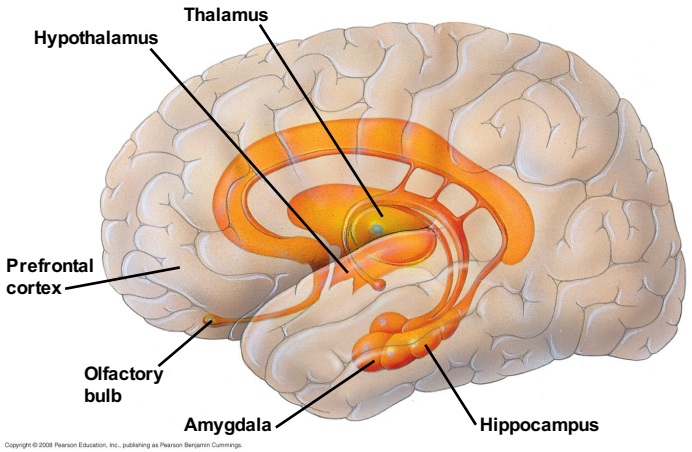
- The corpus callosum transmits information between the two cerebral hemispheres.
- The left hemisphere is more adept at language, math, logic, and processing of serial sequences.
- The right hemisphere is stronger at pattern recognition, nonverbal thinking, and emotional processing.

- The differences in hemisphere function are called **lateralization**.
- Lateralization is linked to handedness.

Emotions

- Emotions are generated and experienced by the ***limbic system*** and other parts of the brain including the sensory areas.
- The *limbic system* is a ring of structures around the *brainstem* that includes the amygdala, hippocampus, and parts of the thalamus.
- The **amygdala** is located in the temporal lobe and helps store an emotional experience as an emotional memory.

The limbic system



Neural Plasticity

- **Neural plasticity** describes the ability of the nervous system to be modified after birth.
- Changes can strengthen or weaken signaling at a synapse.

Memory and Learning

- Learning can occur when neurons make new connections or when the strength of existing neural connections changes.
- **Short-term memory** is accessed via the hippocampus.
- The hippocampus also plays a role in forming **long-term memory**, which is stored in the cerebral cortex.

Nervous system disorders can be explained in molecular terms

- Disorders of the nervous system include schizophrenia, depression, Alzheimer's disease, and Parkinson's disease.
- Genetic and environmental factors contribute to diseases of the nervous system.

Schizophrenia

- About 1% of the world's population suffers from **schizophrenia.**
- Schizophrenia is characterized by hallucinations, delusions, blunted emotions, and other symptoms.
- Available treatments focus on brain pathways that use dopamine as a neurotransmitter.

Depression

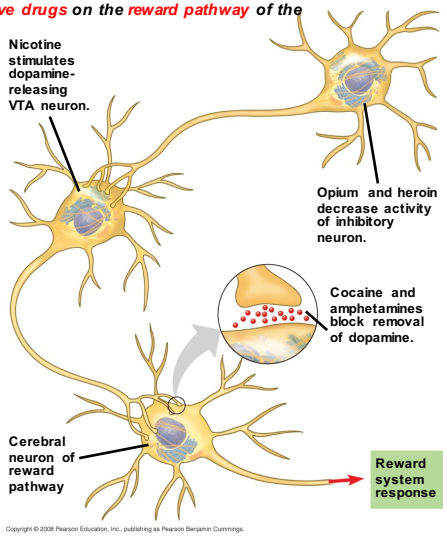
- Two broad forms of depressive illness are known major depressive disorder and bipolar disorder.
- In **major depressive disorder**, patients have a persistent lack of interest or pleasure in most activities.
- **Bipolar disorder** is characterized by manic (high-mood) and depressive (low-mood) phases.
- Treatments for these types of depression include drugs such as Prozac and lithium.

Drug Addiction and the *Brain Reward System*

- The brain's reward system rewards motivation with pleasure.
- Some drugs are addictive because they increase activity of the brain's reward system.
- These drugs include cocaine, amphetamine, heroin, alcohol, and tobacco.
- Drug addiction is characterized by compulsive consumption and an inability to control intake.

- Addictive drugs enhance the activity of the dopamine pathway.
- Drug addiction leads to long-lasting changes in the reward circuitry that cause craving for the drug.

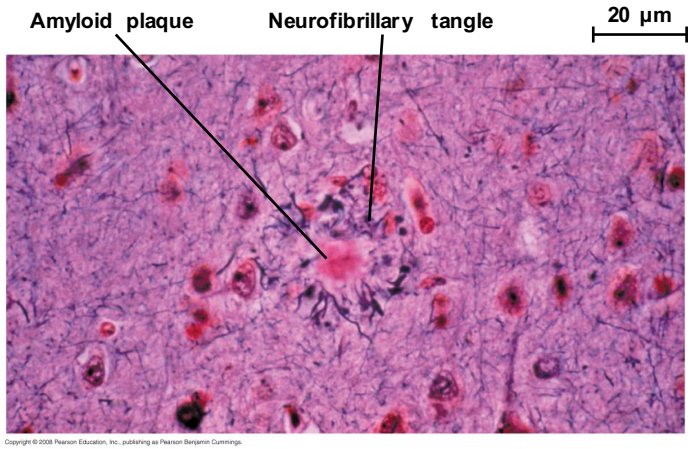
Effects of addictive drugs on the reward pathway of the mammalian brain



Alzheimer's Disease

- **Alzheimer's disease** is a mental deterioration characterized by confusion, memory loss, and other symptoms.
- Alzheimer's disease is caused by the formation of neurofibrillary tangles and amyloid plaques in the brain.
- A successful treatment in humans may hinge on early detection of amyloid plaques.
- There is no cure for this disease though some drugs are effective at relieving symptoms.

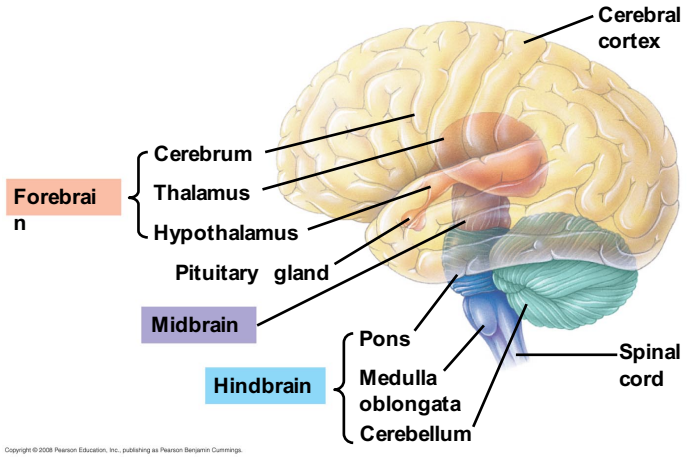
Microscopic signs of Alzheimer's disease



Stem Cell–Based Therapy

- Unlike the PNS, the CNS cannot fully repair itself.
- However, it was recently discovered that the adult human brain contains stem cells that can differentiate into mature neurons.
- Induction of stem cell differentiation and transplantation of cultured stem cells are potential methods for replacing neurons lost to trauma or disease.

Human Brain



You should now be able to:

1. Compare and contrast the nervous systems of: hydra, sea star, planarian, nematode, clam, squid, and vertebrate.
2. Distinguish between the following pairs of terms: central nervous system, peripheral nervous system; white matter, gray matter; bipolar disorder and major depression.
3. List the types of glia and their functions.
4. Compare the three divisions of the autonomic nervous system.

5. Describe the structures and functions of the following brain regions: medulla oblongata, pons, midbrain, cerebellum, thalamus, epithalamus, hypothalamus, and cerebrum.
6. Describe the specific functions of the brain regions associated with language, speech, emotions, memory, and learning.

8. Describe the symptoms and causes of schizophrenia, Alzheimer's disease, and Parkinson's disease
9. Explain how drug addiction affects the brain reward system