Chapter 49

Nervous Systems

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Key concepts

1. Neural network of the brain can do more than the sum of individual neurons.
2. Nervous systems (sensory, CNS, motor) not only make animals respond the environmental changes faster, but also make animals know who they are.

Fig. 49-1

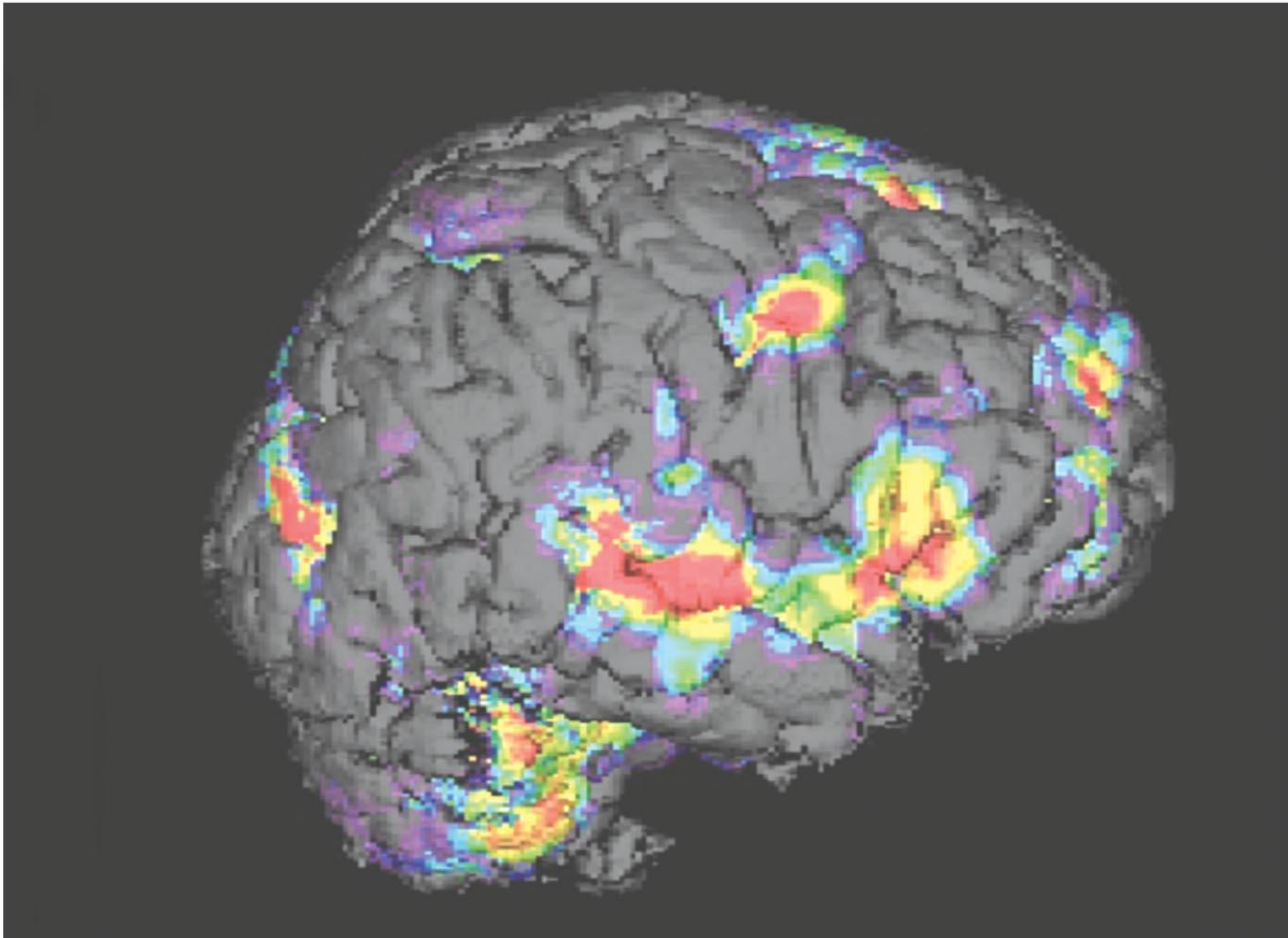


Fig. 49-2

Nervous system organization

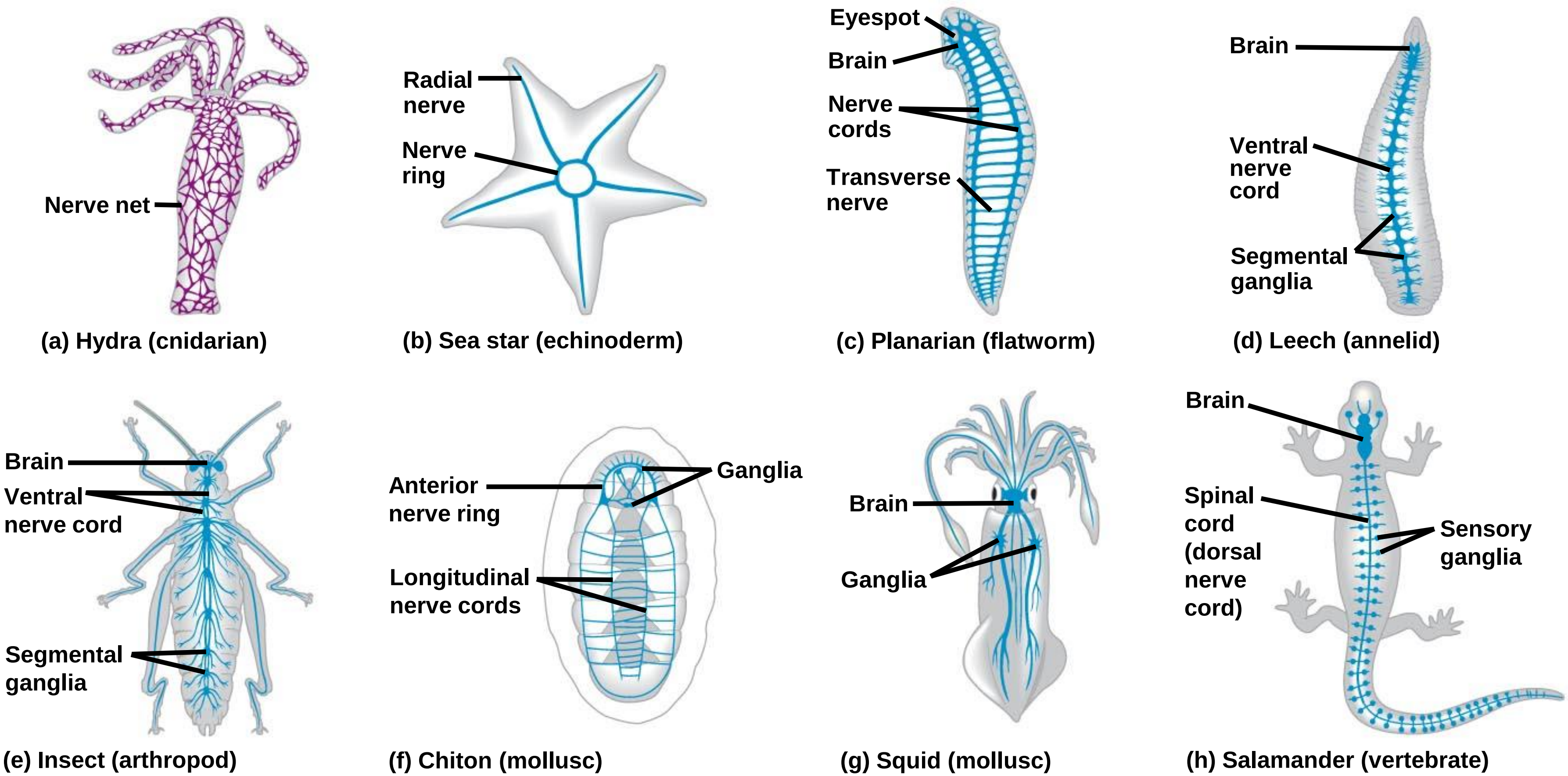


Fig. 49-3

The knee-jerk reflex

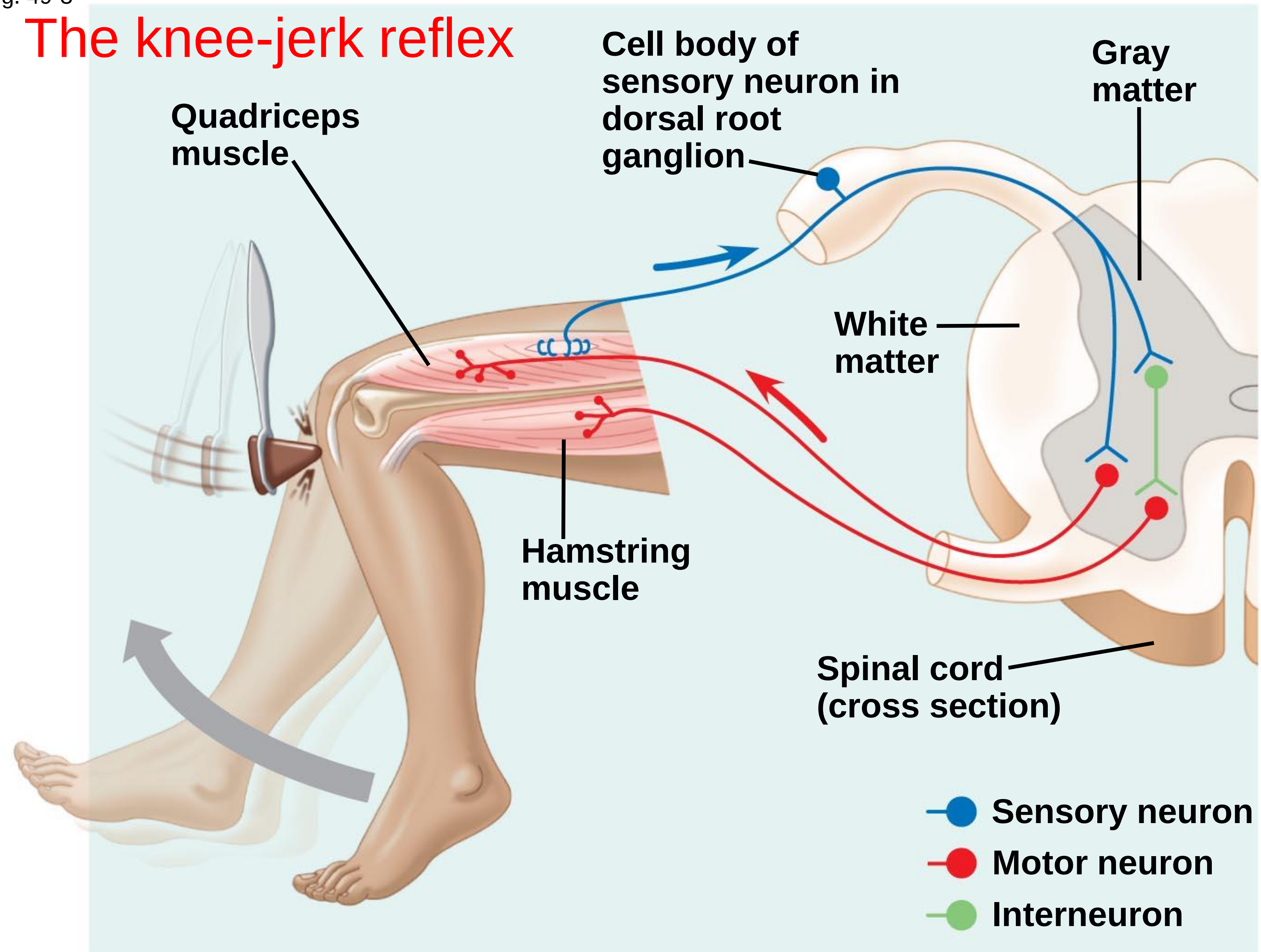
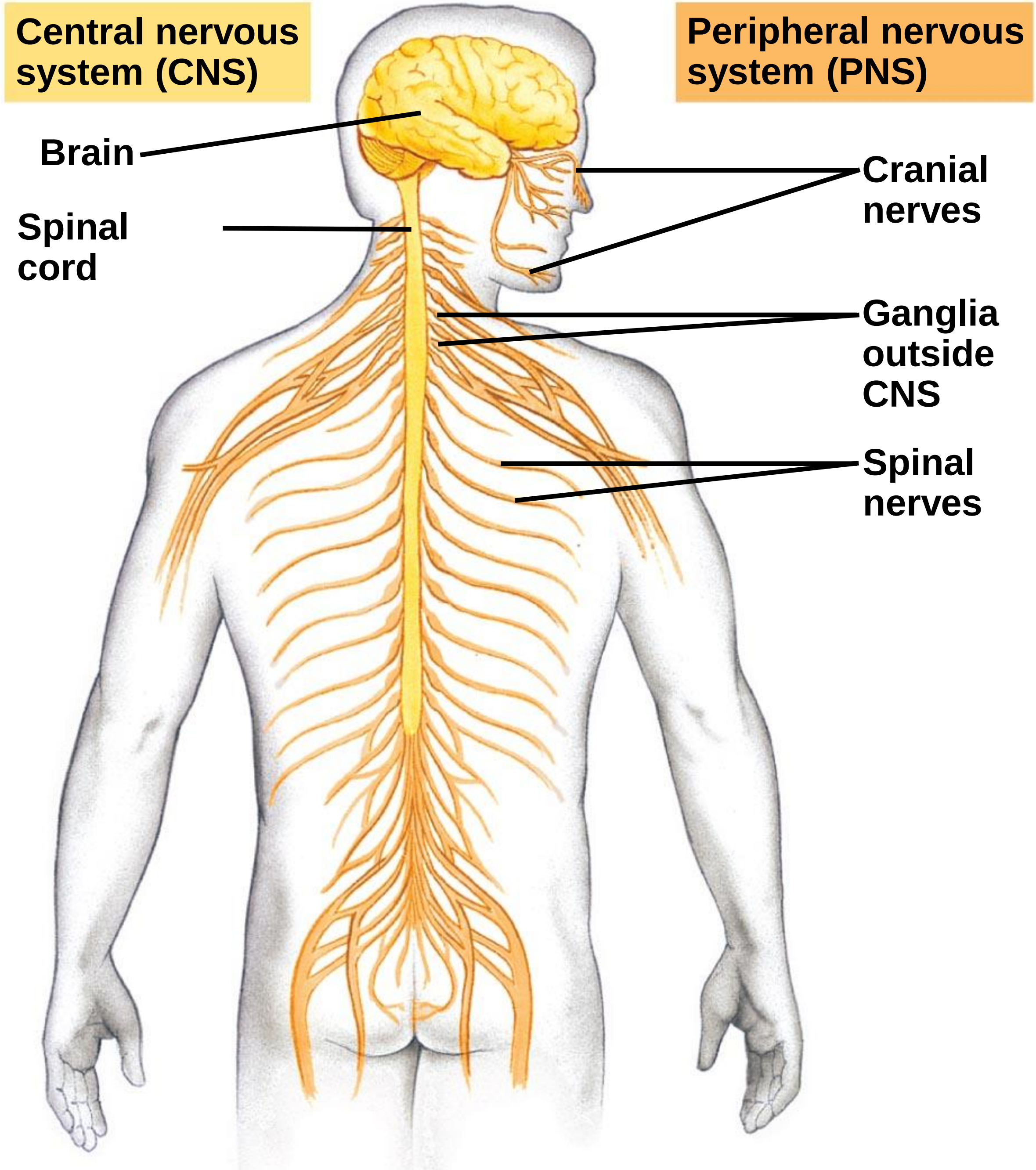


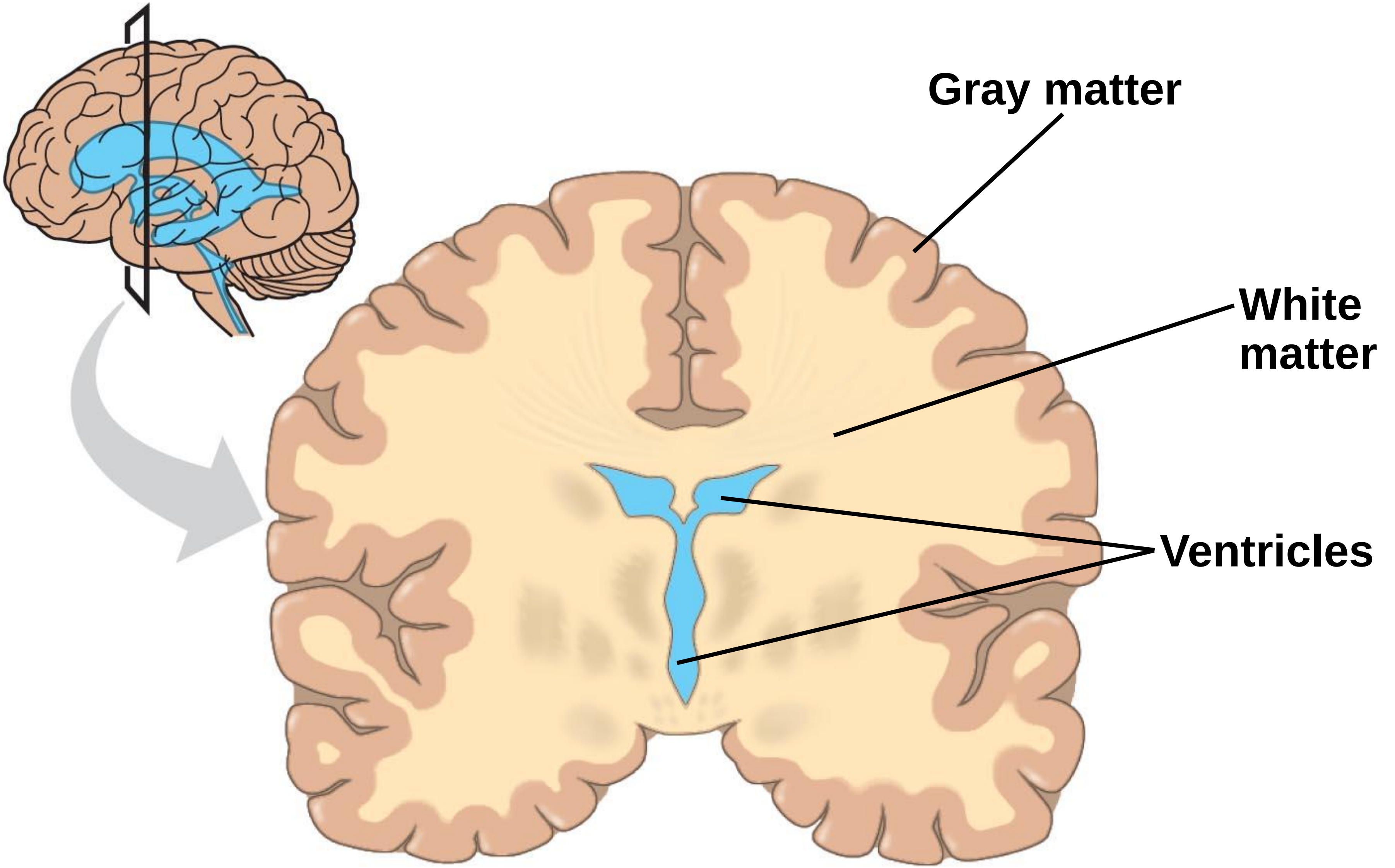
Fig. 49-4



Central nervous system (CNS)
Peripheral nervous system (PNS)
Brain
Spinal cord
Cranial nerves
Ganglia outside CNS
Spinal nerves

Fig. 49-5

Ventricles, gray matter, and white matter



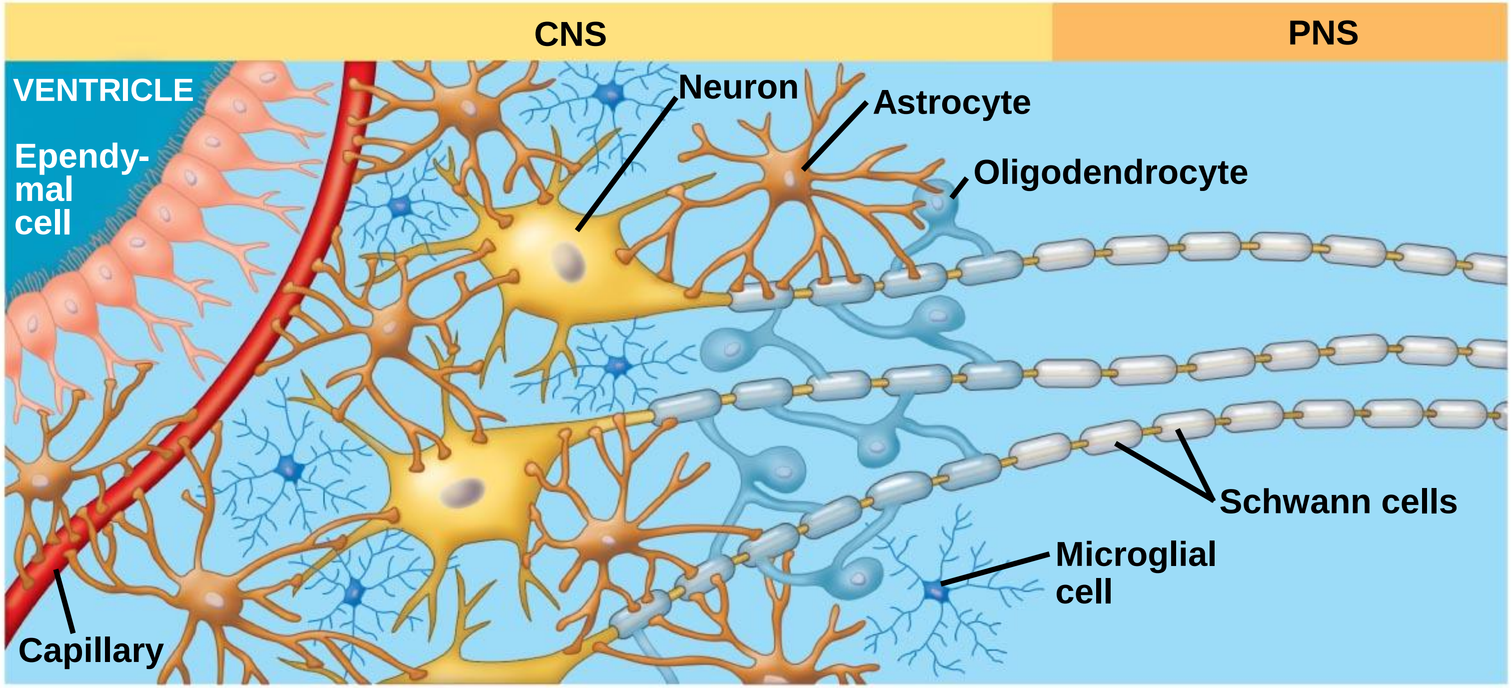
- The **central canal** of the spinal cord and the **ventricles** of the brain are hollow and filled with **cerebrospinal fluid**
- The cerebrospinal fluid is filtered from blood and functions to cushion the brain and spinal cord

Glia in the CNS

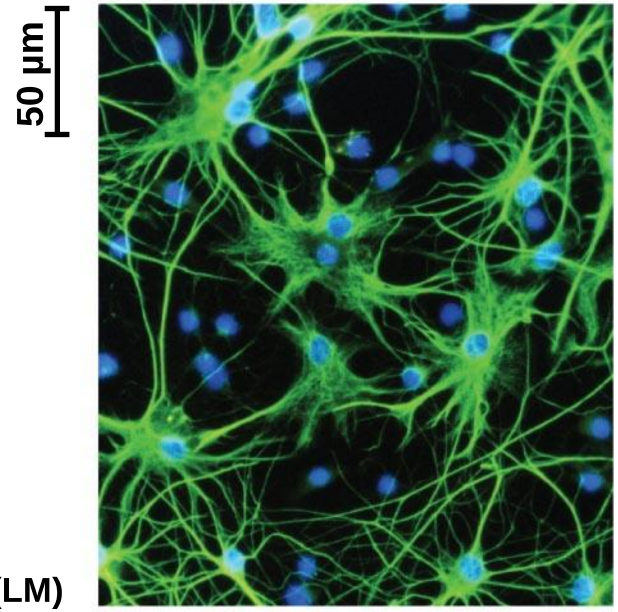
- Glia have numerous functions
  - Ependymal cells promote circulation of cerebrospinal fluid
  - Microglia protect the nervous system from microorganisms
  - Oligodendrocytes and Schwann cells form the myelin sheaths around axons

- 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

Fig. 49-6



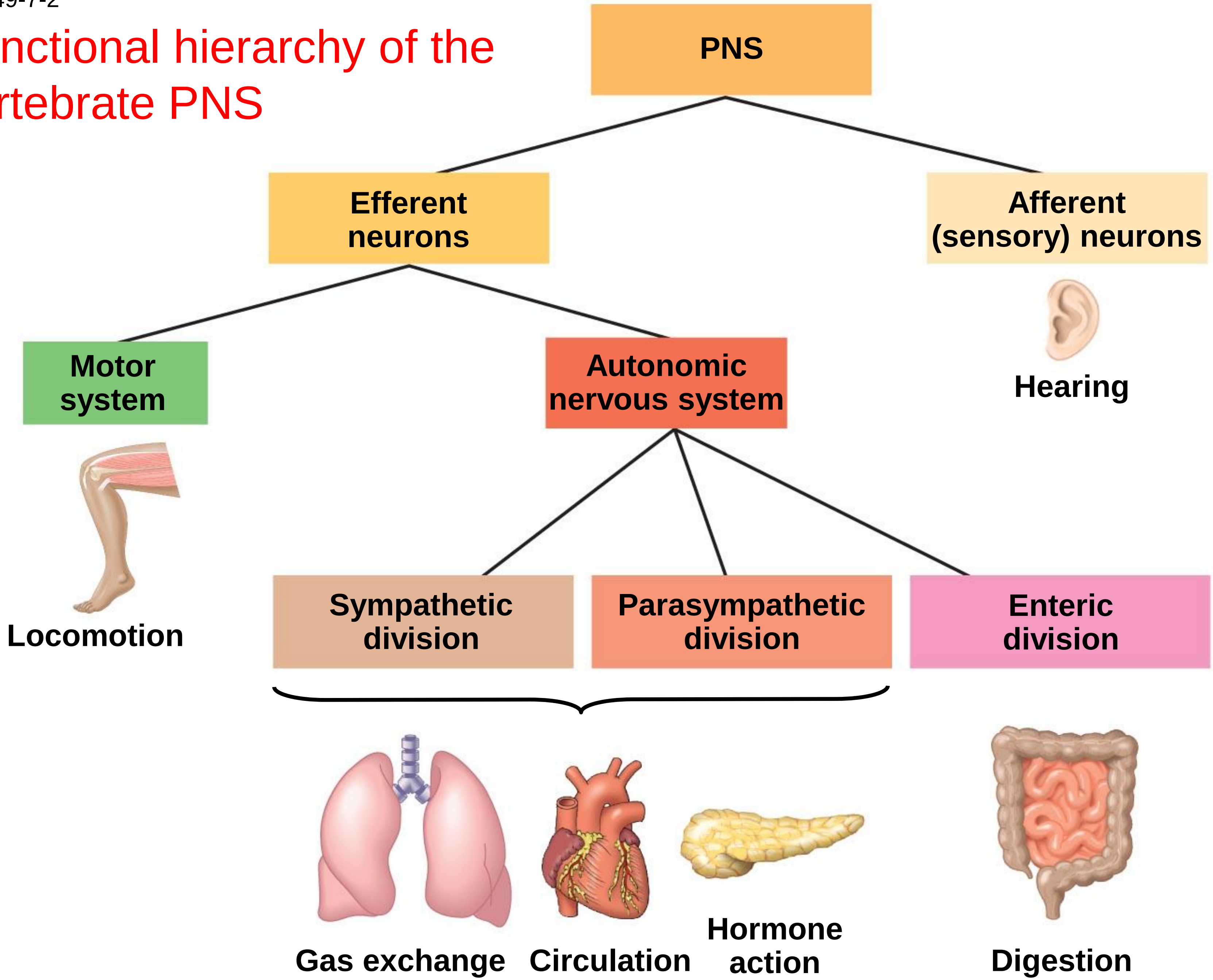
(a) Glia in vertebrates



(b) Astrocytes (LM)

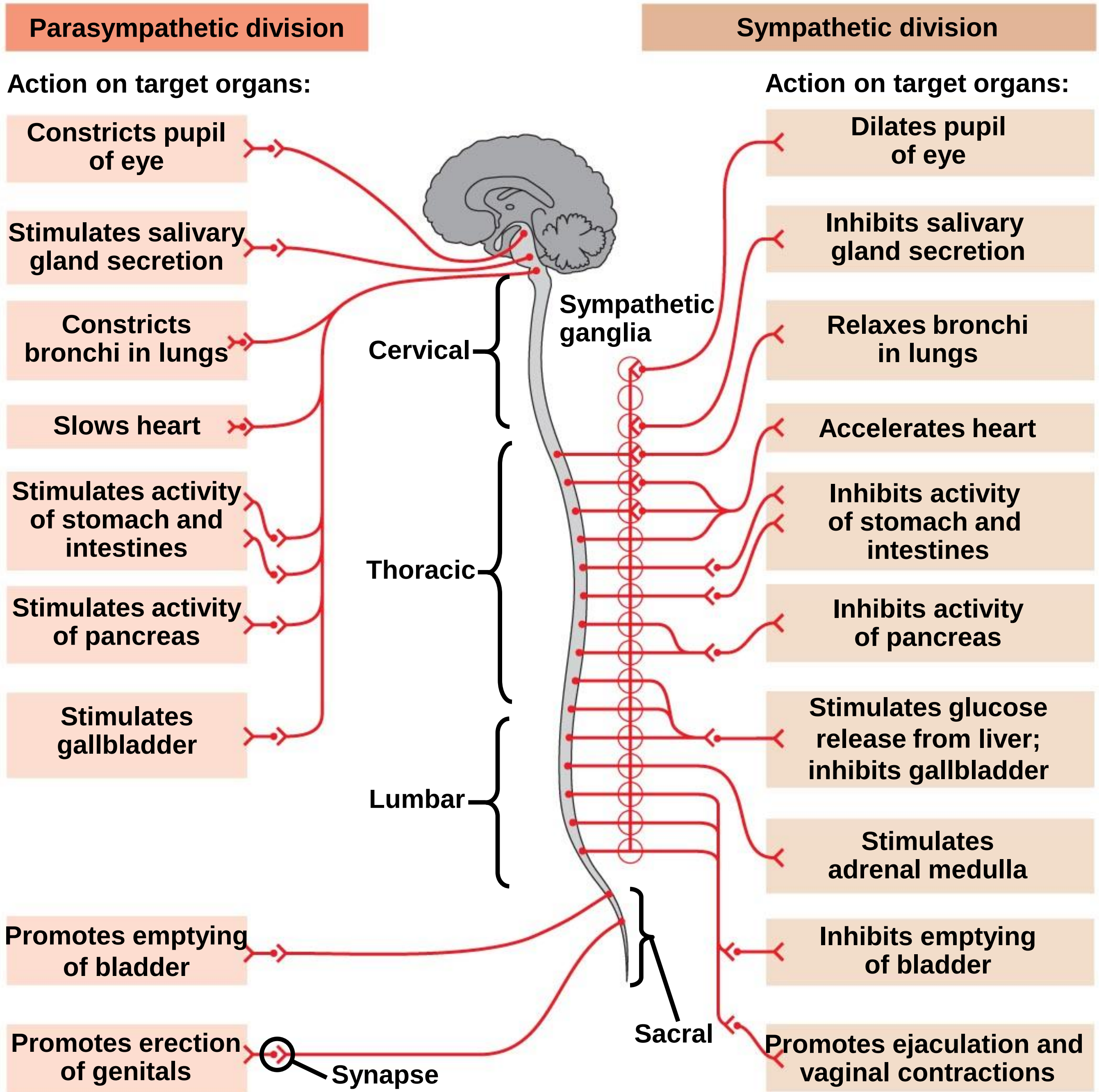
Fig. 49-7-2

Functional hierarchy of the vertebrate PNS



- 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

Fig. 49-8



Parasympathetic division
Sympathetic division
Action on target organs:
Constricts pupil of eye
Stimulates salivary gland secretion
Constricts bronchi in lungs
Slows heart
Stimulates activity of stomach and intestines
Stimulates activity of pancreas
Stimulates gallbladder
Promotes emptying of bladder
Promotes erection of genitals
Synapse
Cervical
Thoracic
Lumbar
Sacral
Sympathetic ganglia
Action on target organs:
Dilates pupil of eye
Inhibits salivary gland secretion
Relaxes bronchi in lungs
Accelerates heart
Inhibits activity of stomach and intestines
Inhibits activity of pancreas
Stimulates glucose release from liver; inhibits gallbladder
Stimulates adrenal medulla
Inhibits emptying of bladder
Promotes ejaculation and vaginal contractions

Table 49-1

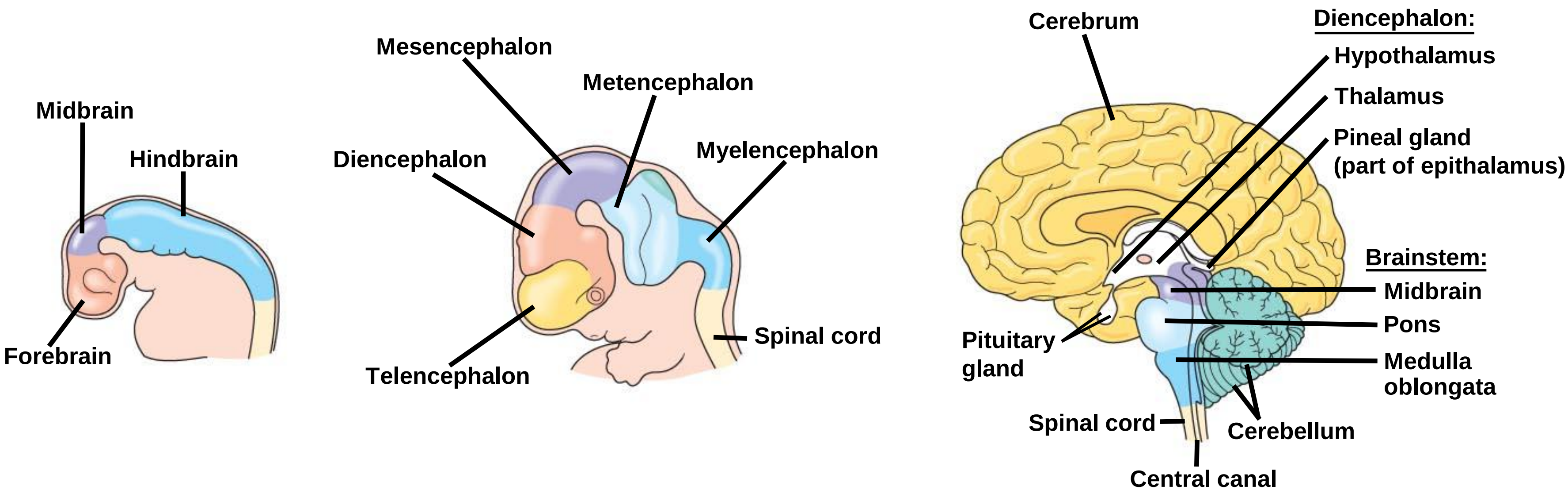
Table 49.1 Properties of Parasympathetic and Sympathetic Neurons

	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

Fig. 49-9

Development of the human brain

Forebrain	Telencephalon	Cerebrum (includes cerebral cortex, white matter, basal nuclei)
	Diencephalon	Diencephalon (thalamus, hypothalamus, epithalamus)
Midbrain	Mesencephalon	Midbrain (part of brainstem)
Hindbrain	Metencephalon	Pons (part of brainstem), cerebellum
	Myelencephalon	Medulla oblongata (part of brainstem)



(a) Embryo at 1 month (b) Embryo at 5 weeks (c) Adult

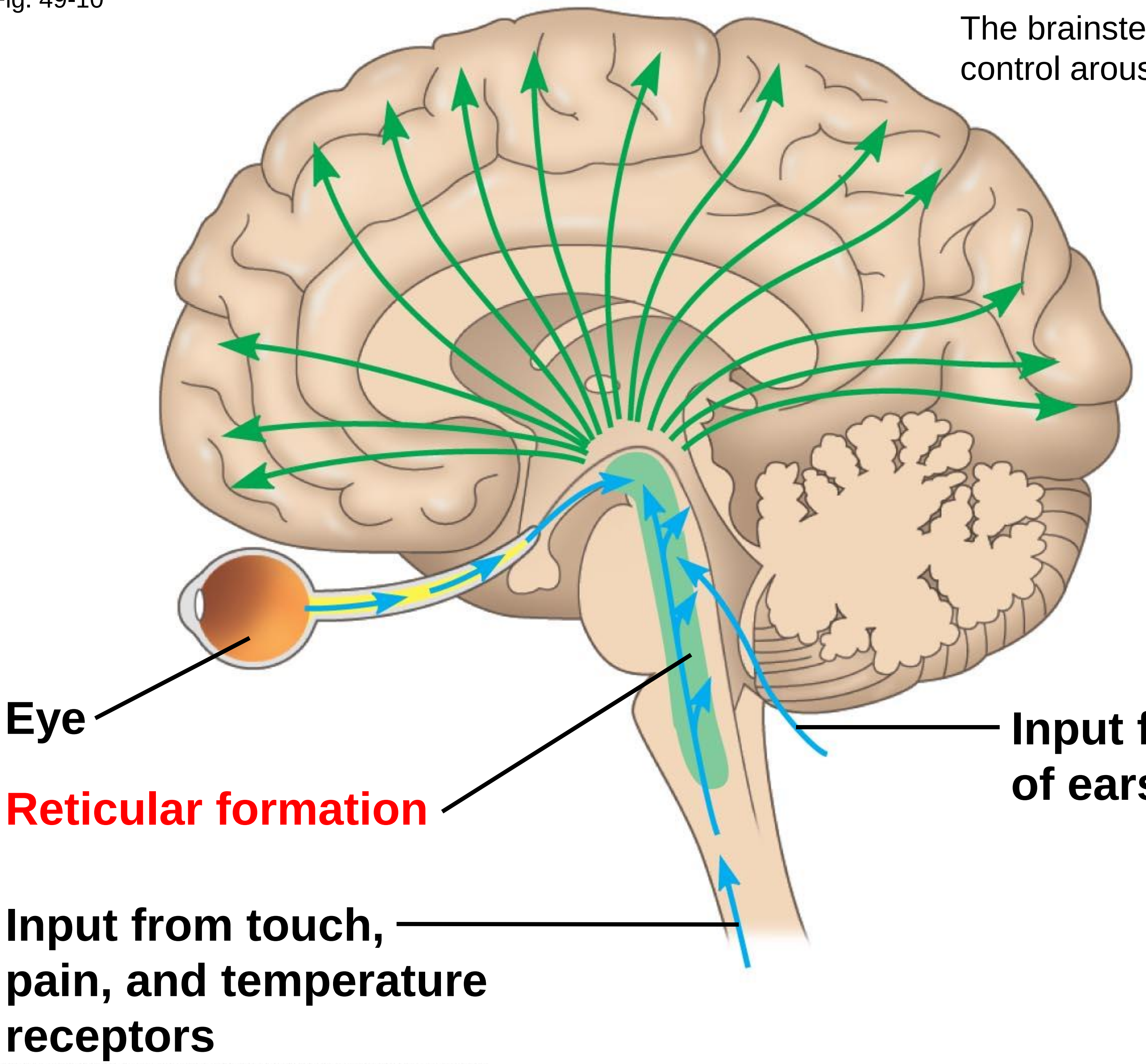
The Brainstem

- 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

Fig. 49-10

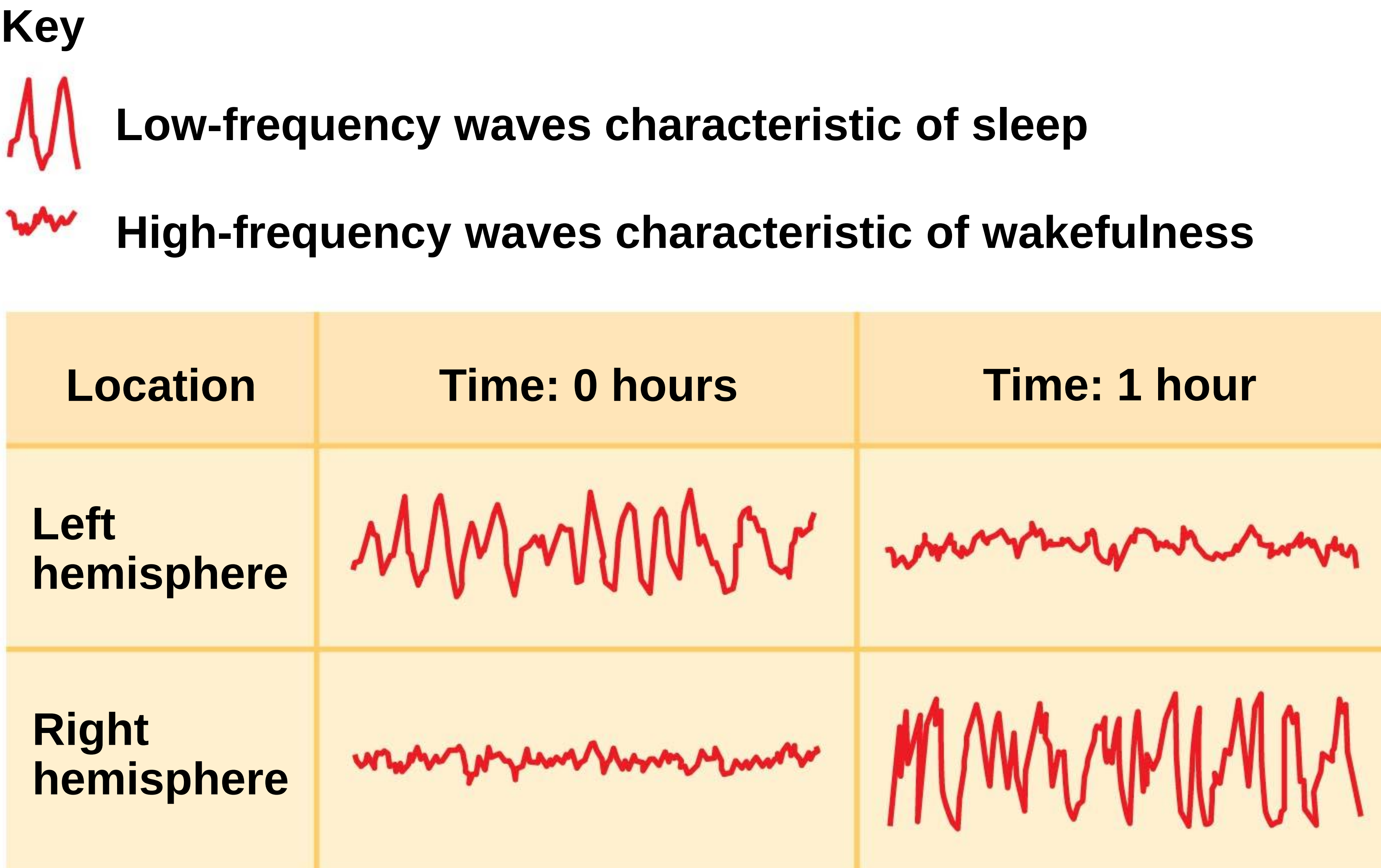
The brainstem and cerebrum control arousal and sleep



- 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”

Fig. 49-11

Dolphins can be asleep and awake at the same time



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

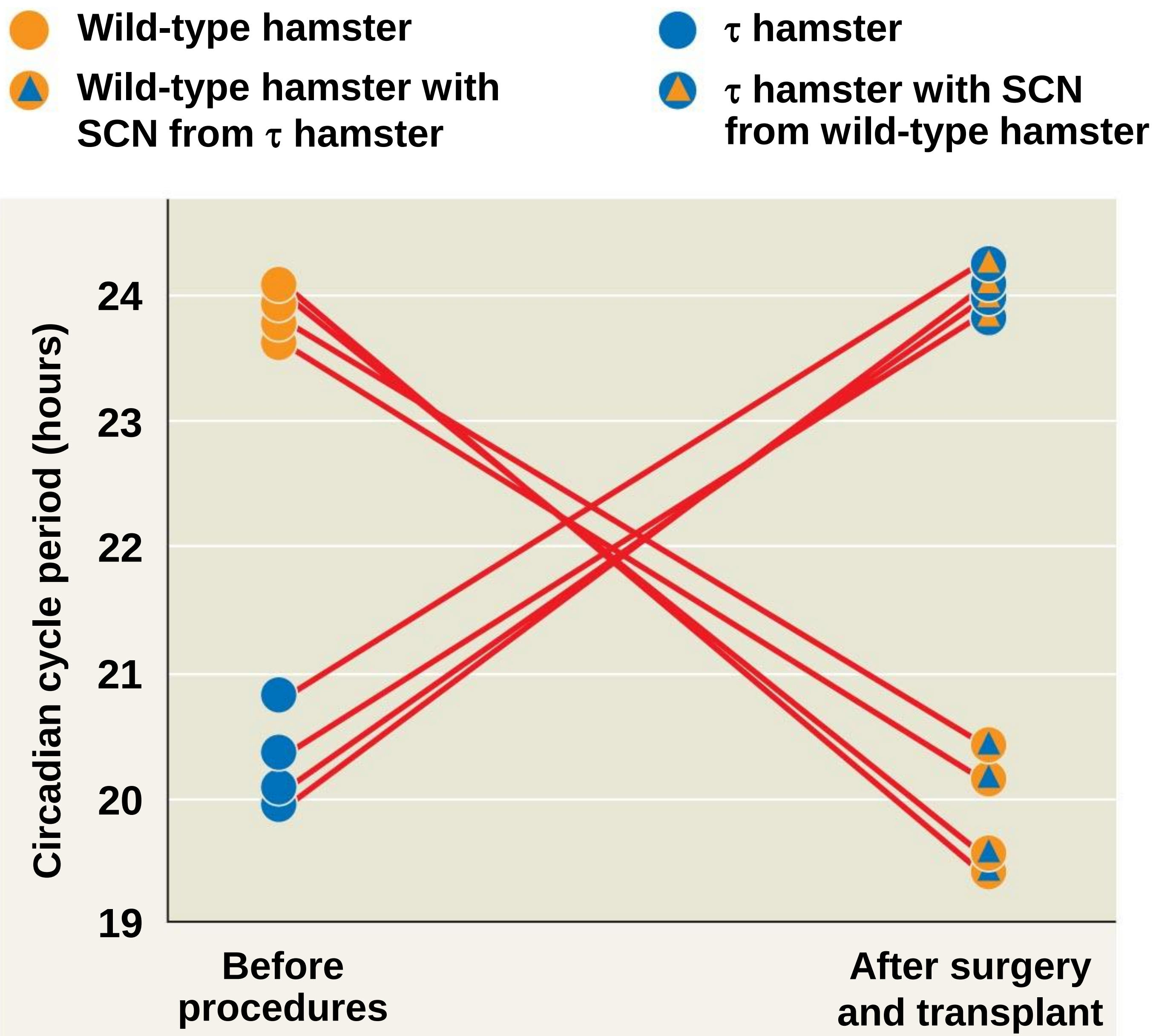
Biological Clock Regulation by the Hypothalamus

- 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 (intrinsic photosensitive retinal ganglion cells, ipRGCs)

Fig. 49-12

RESULTS

Which cells control the circadian rhythm in mammals?



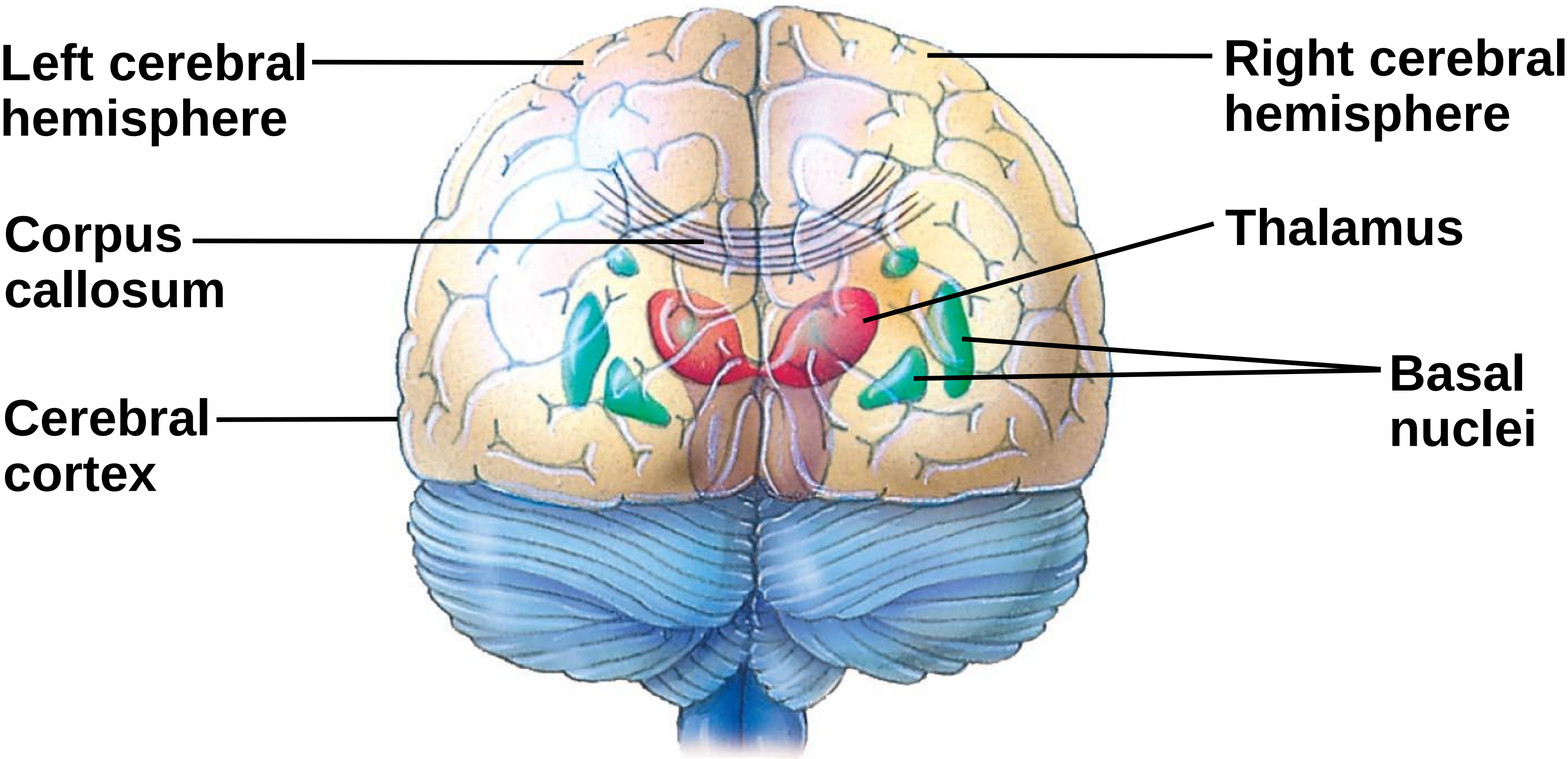
The cerebrum develops from the embryonic telencephalon

- 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

Fig. 49-13

The 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

Fig. 49-14

Comparison of regions for higher cognition in avian and human brains

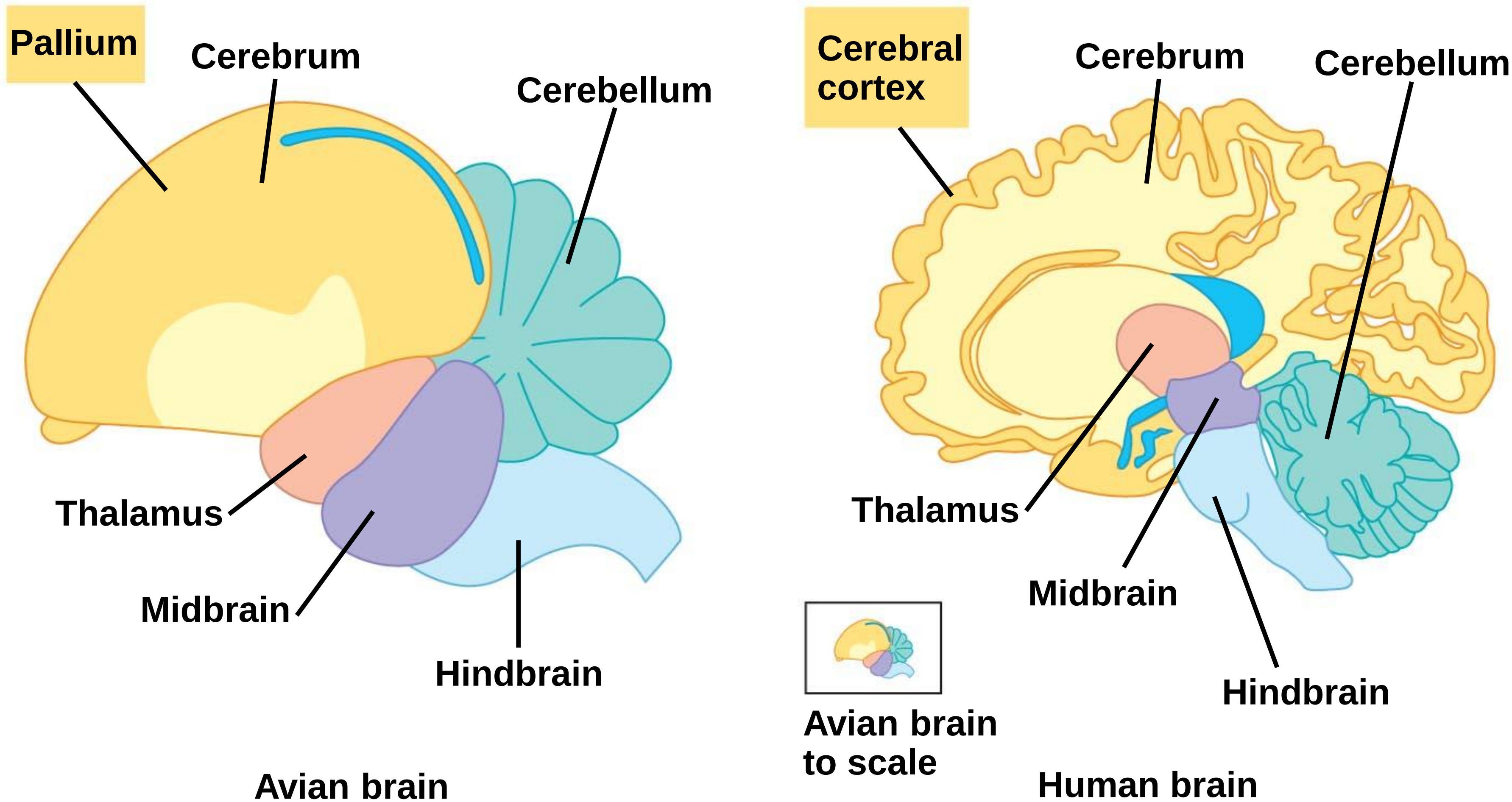


Fig. 49-15

The human cerebral cortex

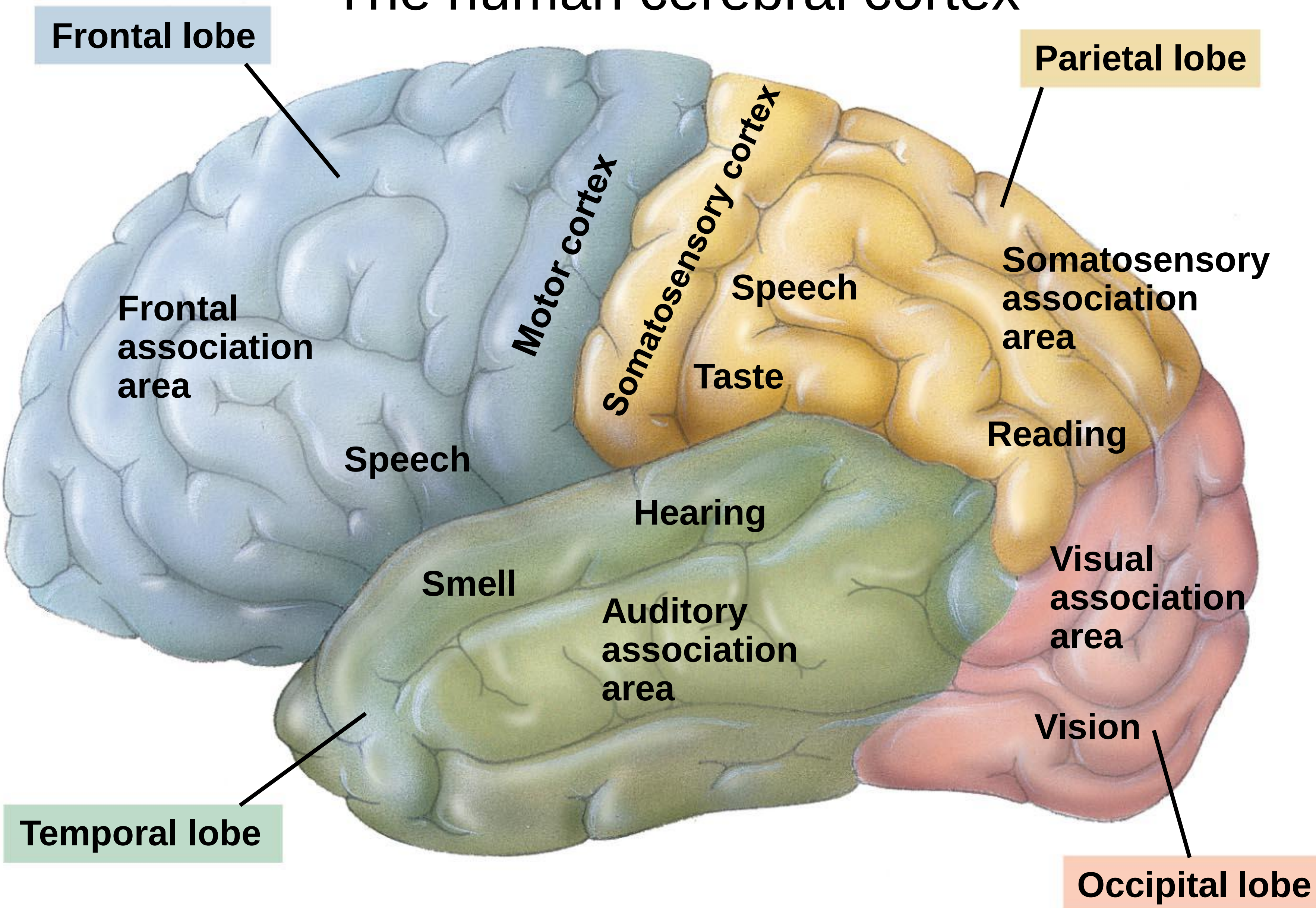
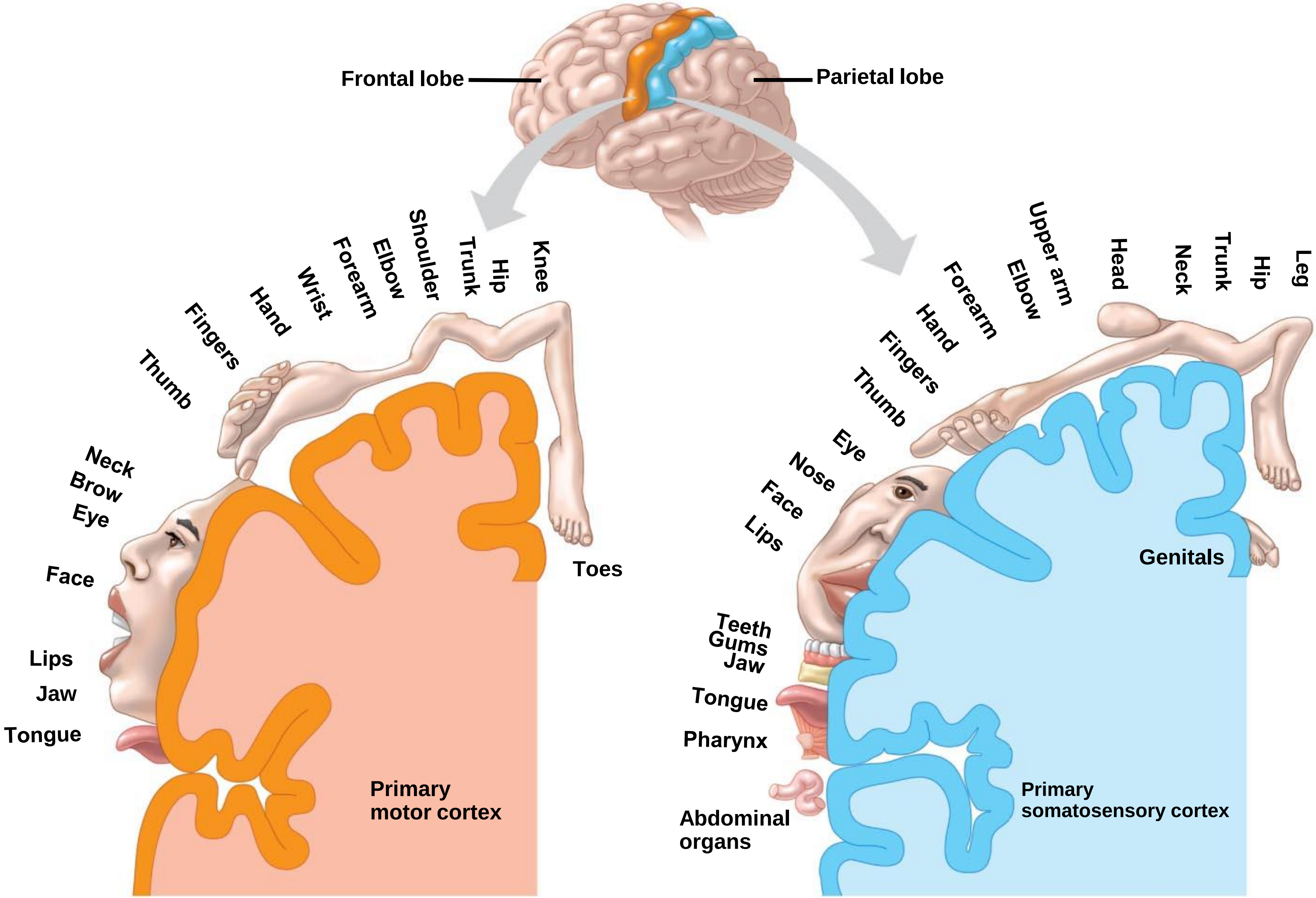


Fig. 49-16

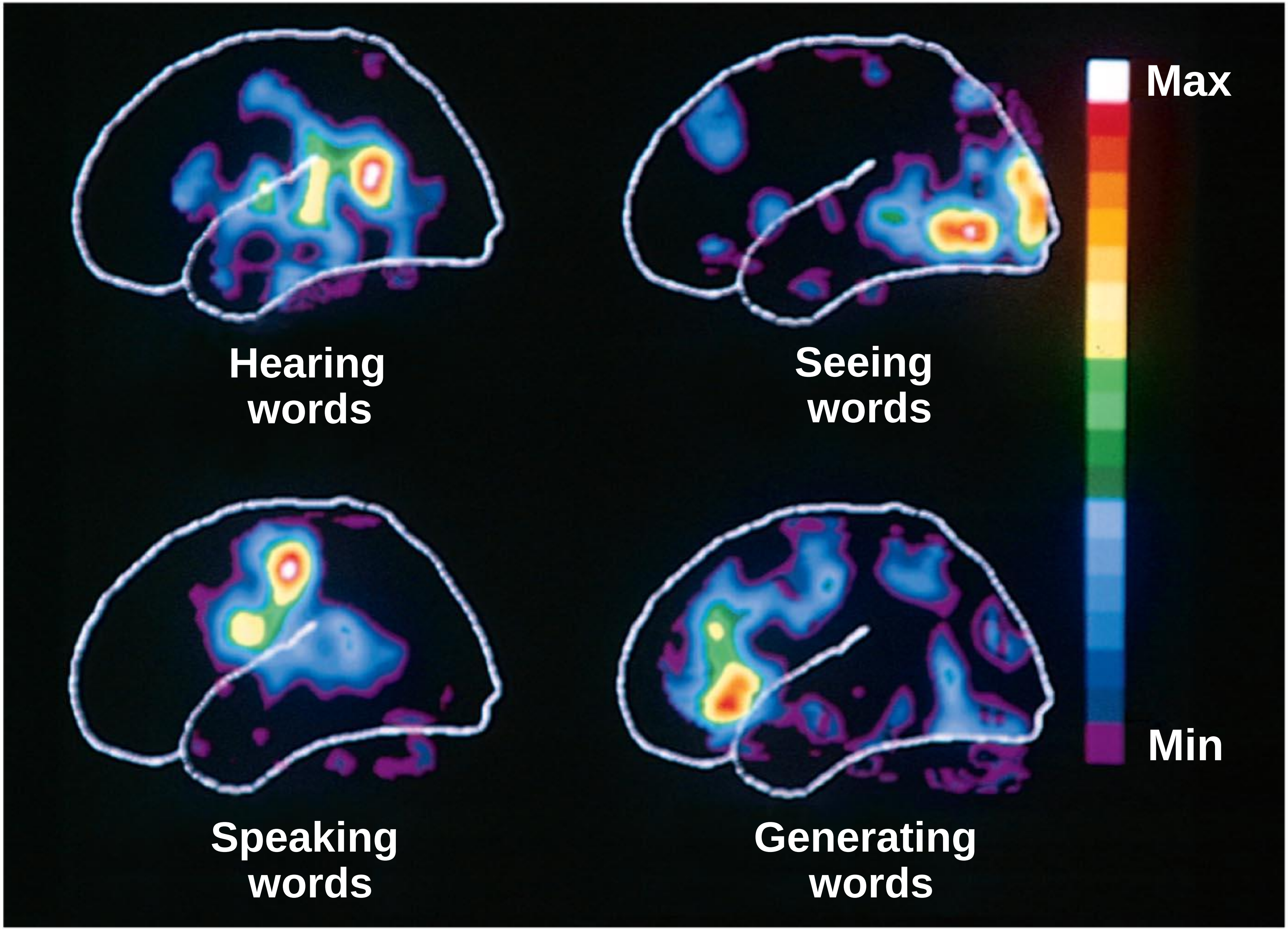
Body part representation in the primary motor and primary somatosensory cortices



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

Fig. 49-17


Max
Hearing words
Seeing words
Speaking words
Generating words
Min

Lateralization of Cortical Function

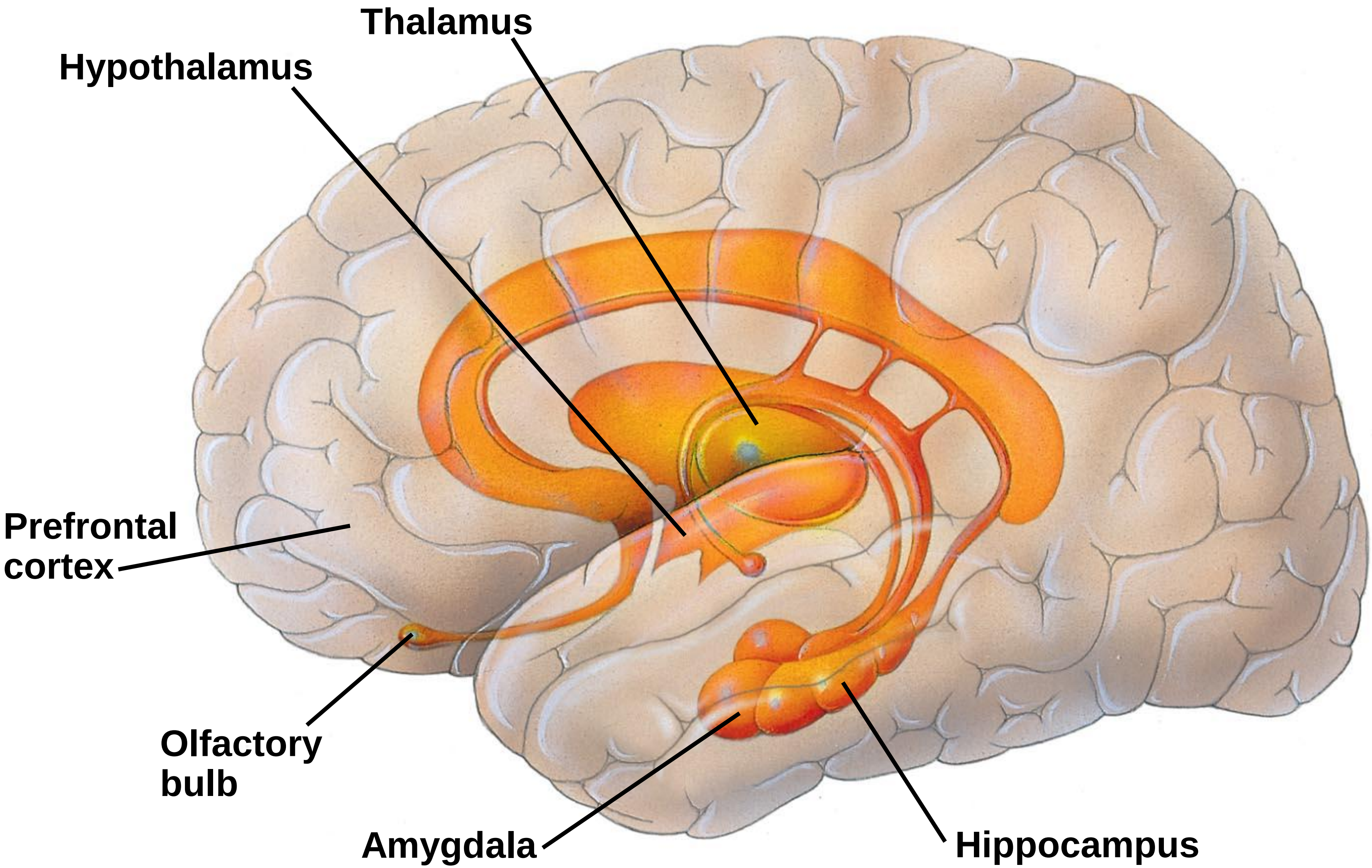
- The corpus callosum transmits information between the two cerebral hemispheres
- The left hemisphere is more adept at language, math, logic, and processing of serial sequences
- The right hemisphere is stronger at pattern recognition, nonverbal thinking, and emotional processing

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

Fig. 49-18

The limbic system



Consciousness

- Modern brain-imaging techniques suggest that consciousness is an emergent property of the brain based on activity in many areas of the cortex

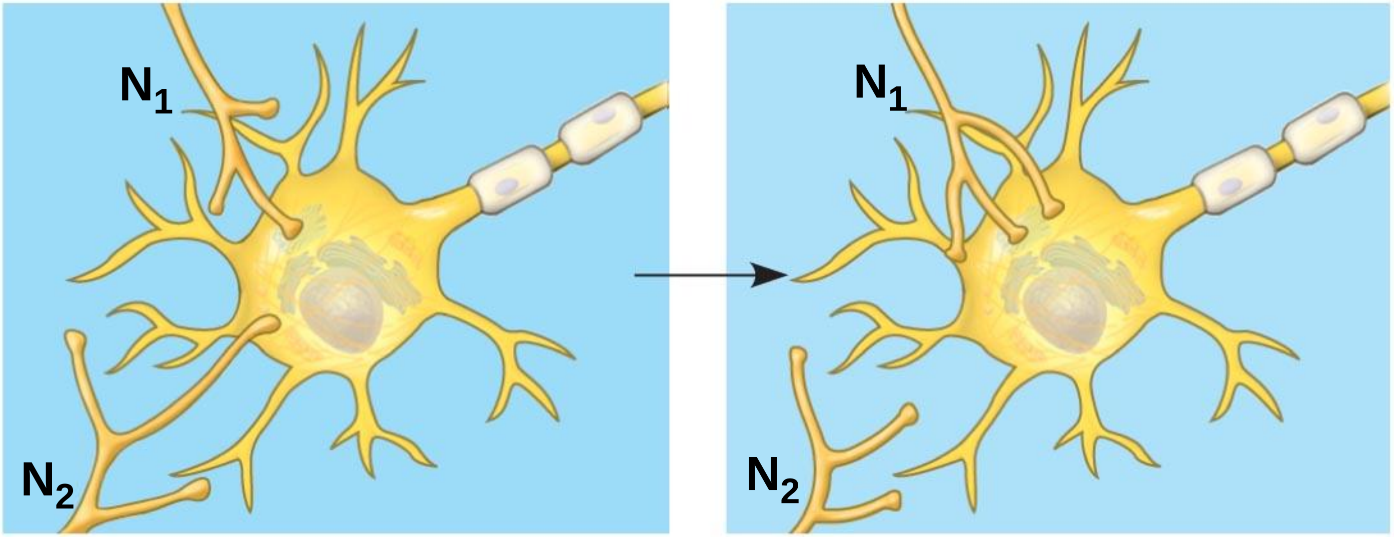
Concept 49.4 Changes in synaptic connections underlie memory and learning

- Two processes dominate embryonic development of the nervous system
  - Neurons compete for growth-supporting factors in order to survive
  - Only half the synapses that form during embryo development survive into adulthood

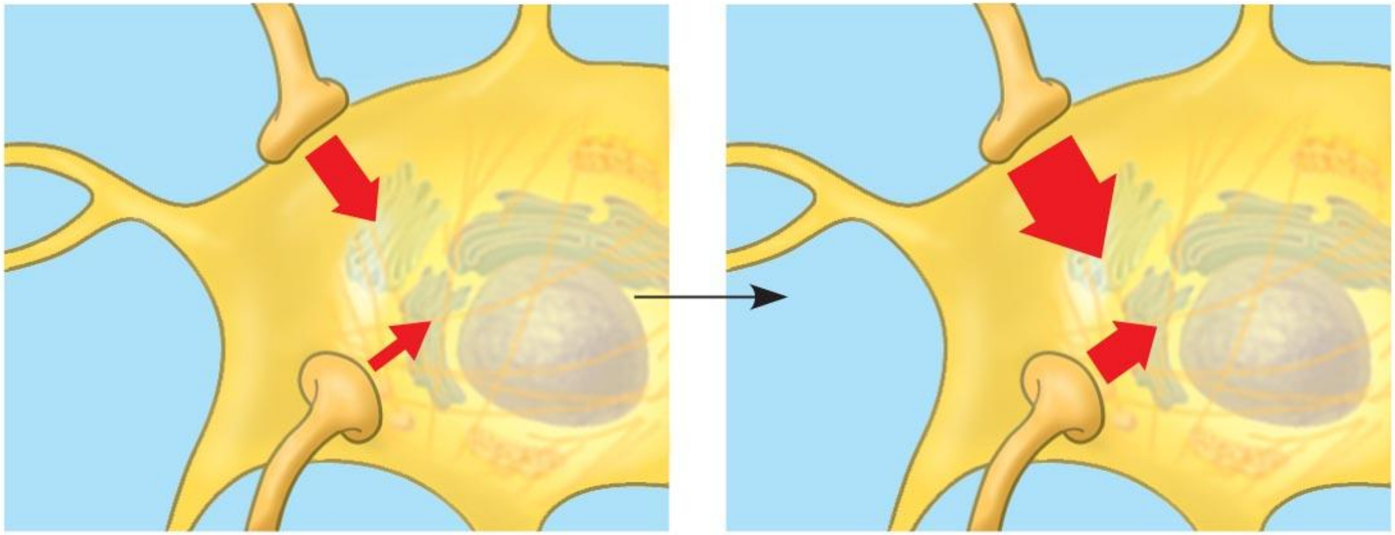
Neural Plasticity

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

Fig. 49-19



(a) Synapses are strengthened or weakened in response to activity.



(b) If two synapses are often active at the same time, the strength of the postsynaptic response may increase at both synapses.

Memory and Learning

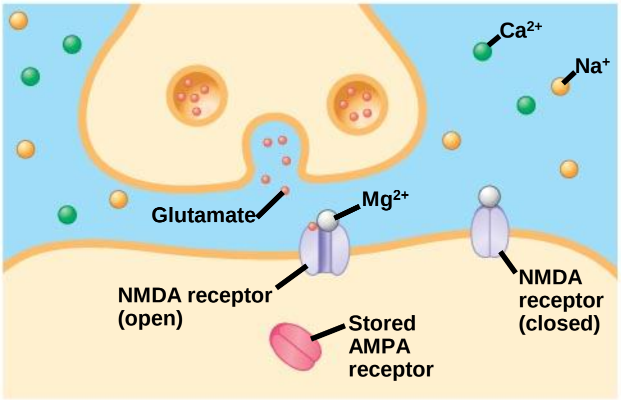
- Learning can occur when neurons make new connections or when the strength of existing neural connections changes
- **Short-term memory** is accessed via the hippocampus
- The hippocampus also plays a role in forming **long-term memory**, which is stored in the cerebral cortex

Long-Term Potentiation

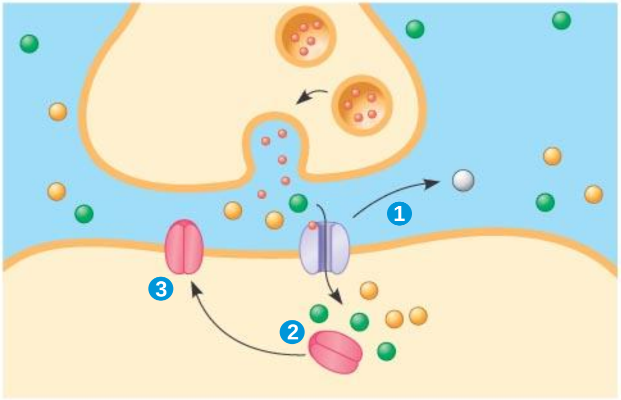
- In the vertebrate brain, a form of learning called **long-term potentiation** (**LTP**) involves an increase in the strength of synaptic transmission
- LTP involves glutamate receptors
- If the presynaptic and postsynaptic neurons are stimulated at the same time, the set of receptors present on the postsynaptic membranes changes

Fig. 49-20

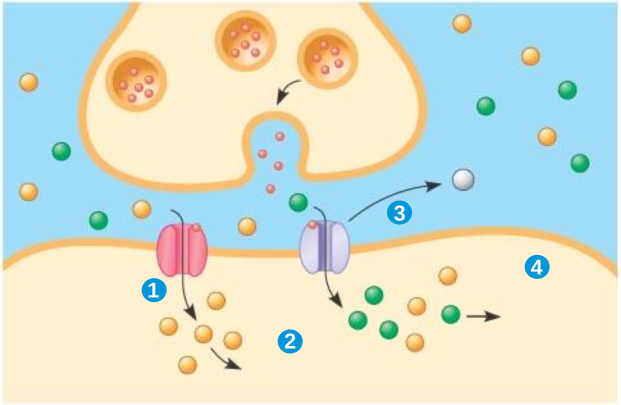
Long-term potentiation in the brain



(a) Synapse prior to long-term potentiation (LTP)



(b) Establishing LTP



(c) Synapse exhibiting LTP

Concept 49.5: Nervous system disorders can be explained in molecular terms

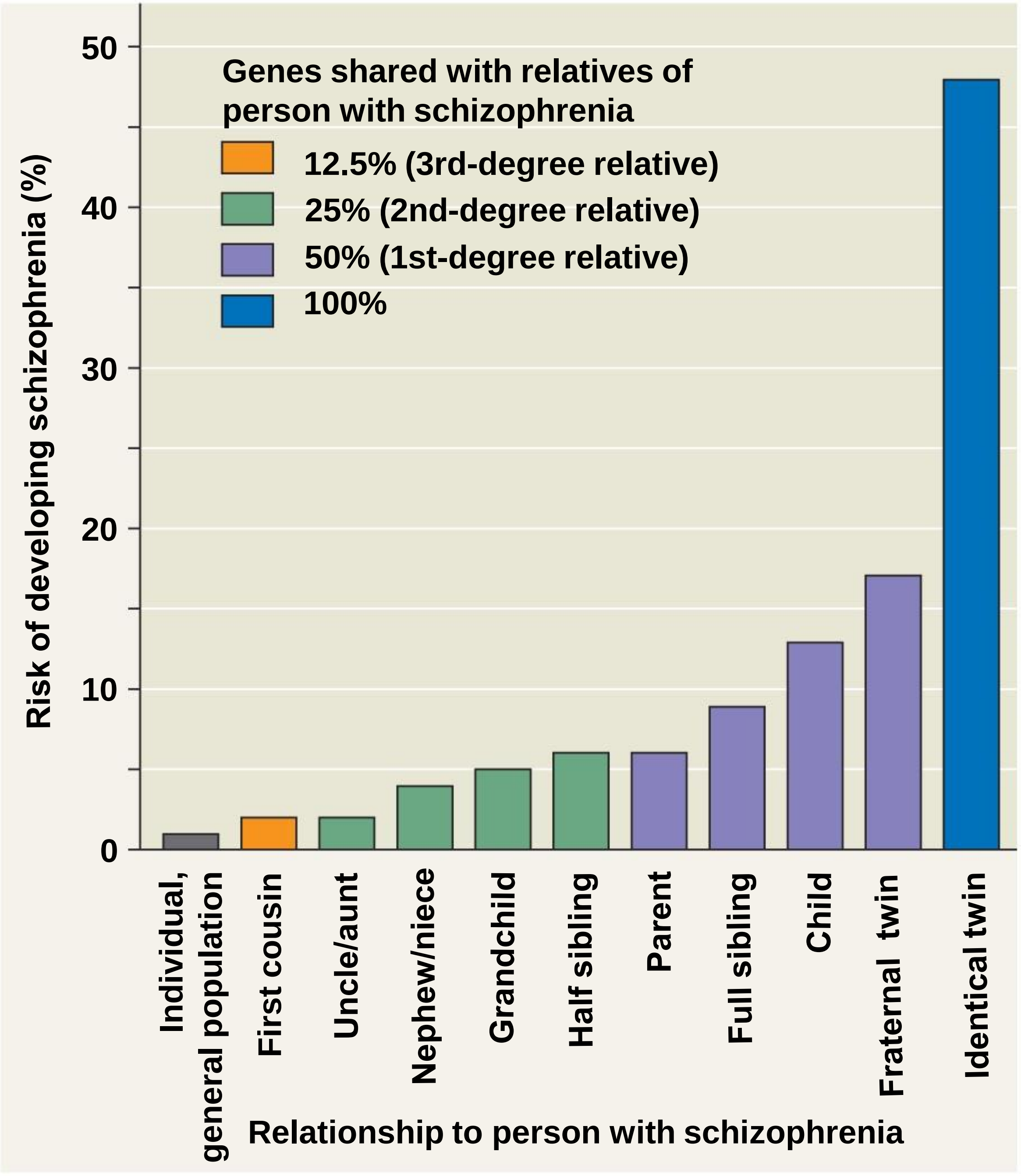
- Disorders of the nervous system include schizophrenia, depression, Alzheimer’s disease, and Parkinson’s disease
- Genetic and environmental factors contribute to diseases of the nervous system

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

Fig. 49-21

Genetic contribution to schizophrenia



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

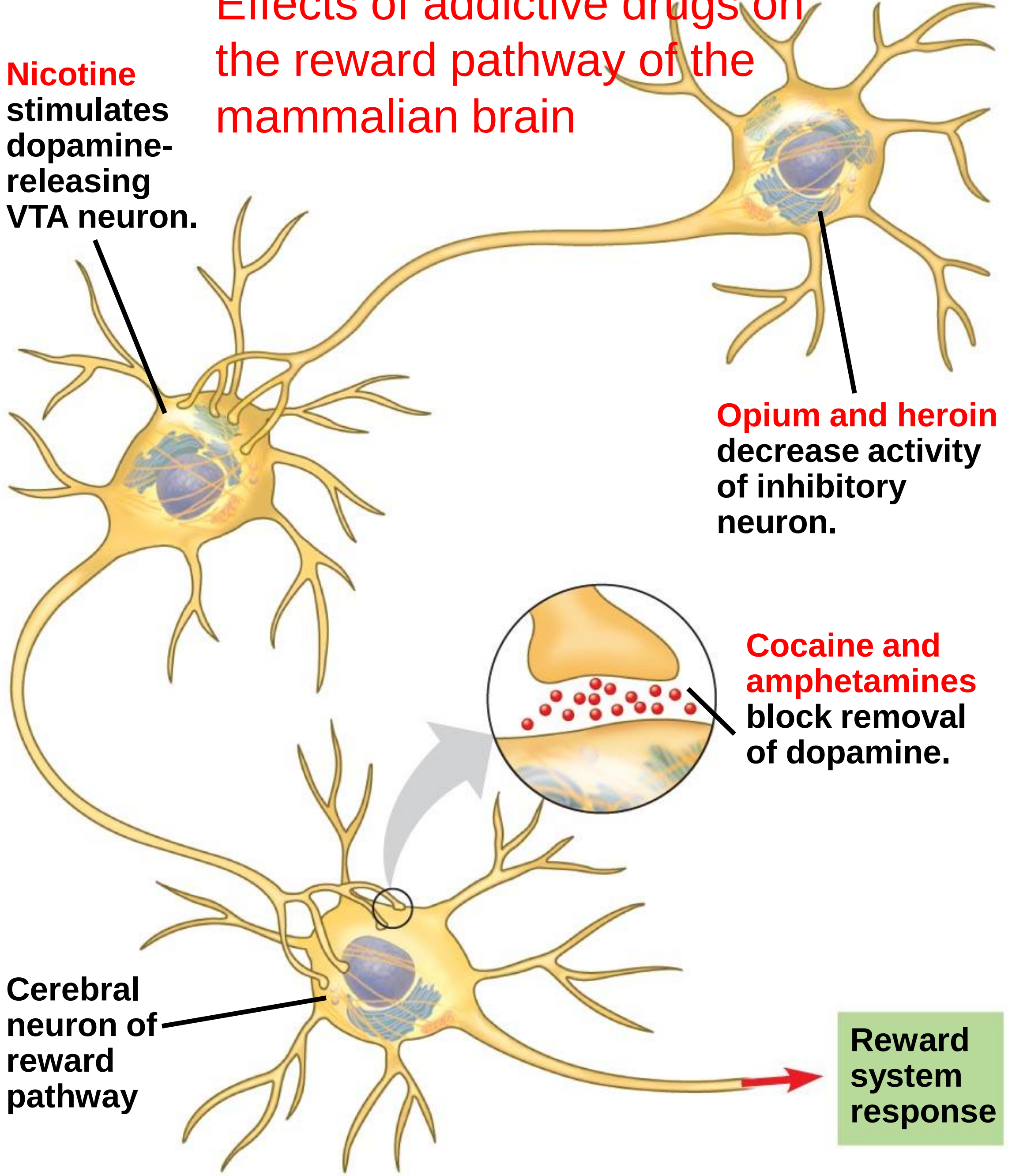
Drug Addiction and the Brain Reward System

- 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

Fig. 49-22

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

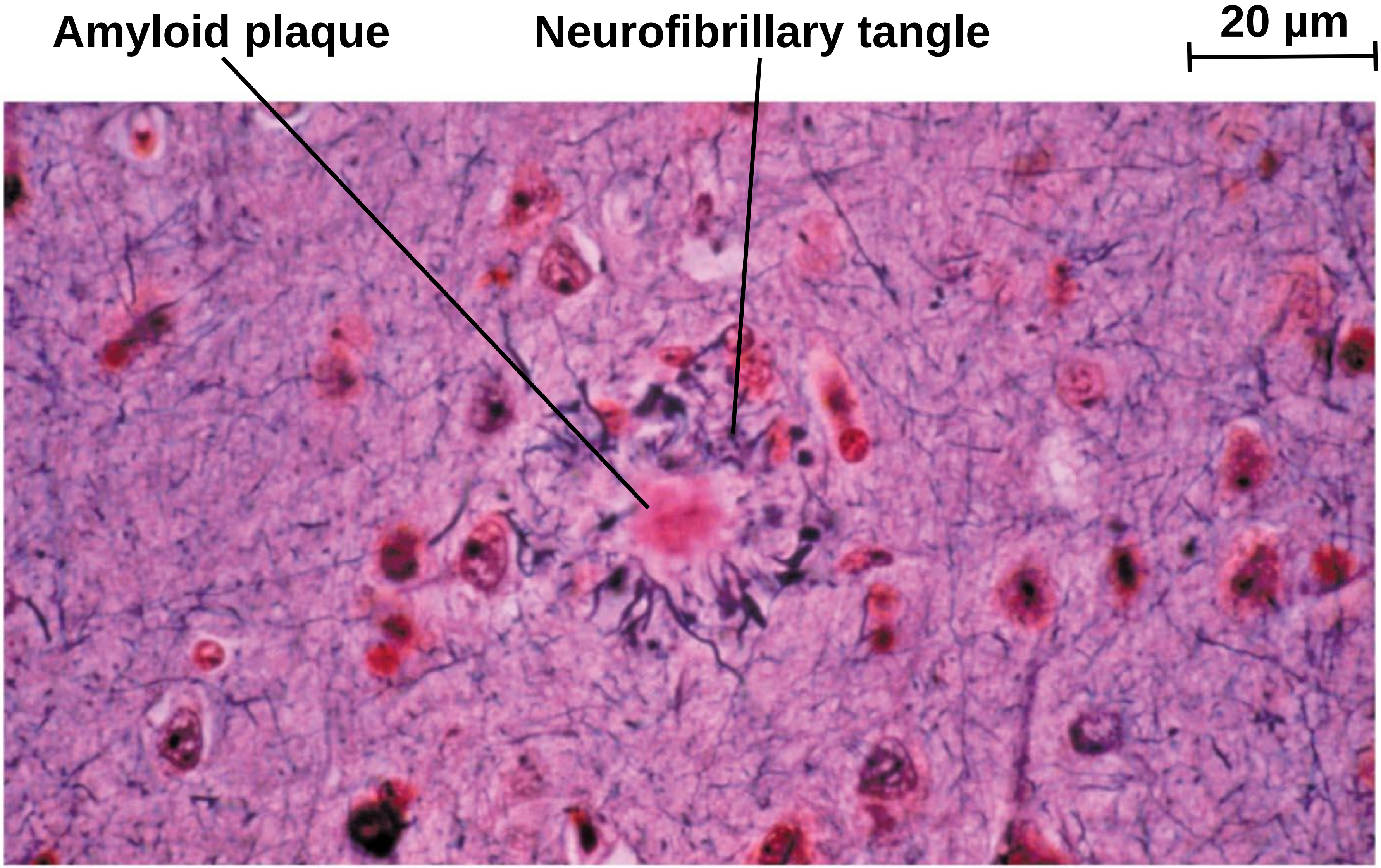


Alzheimer's Disease

- **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

Fig. 49-23

Microscopic signs of Alzheimer’s disease



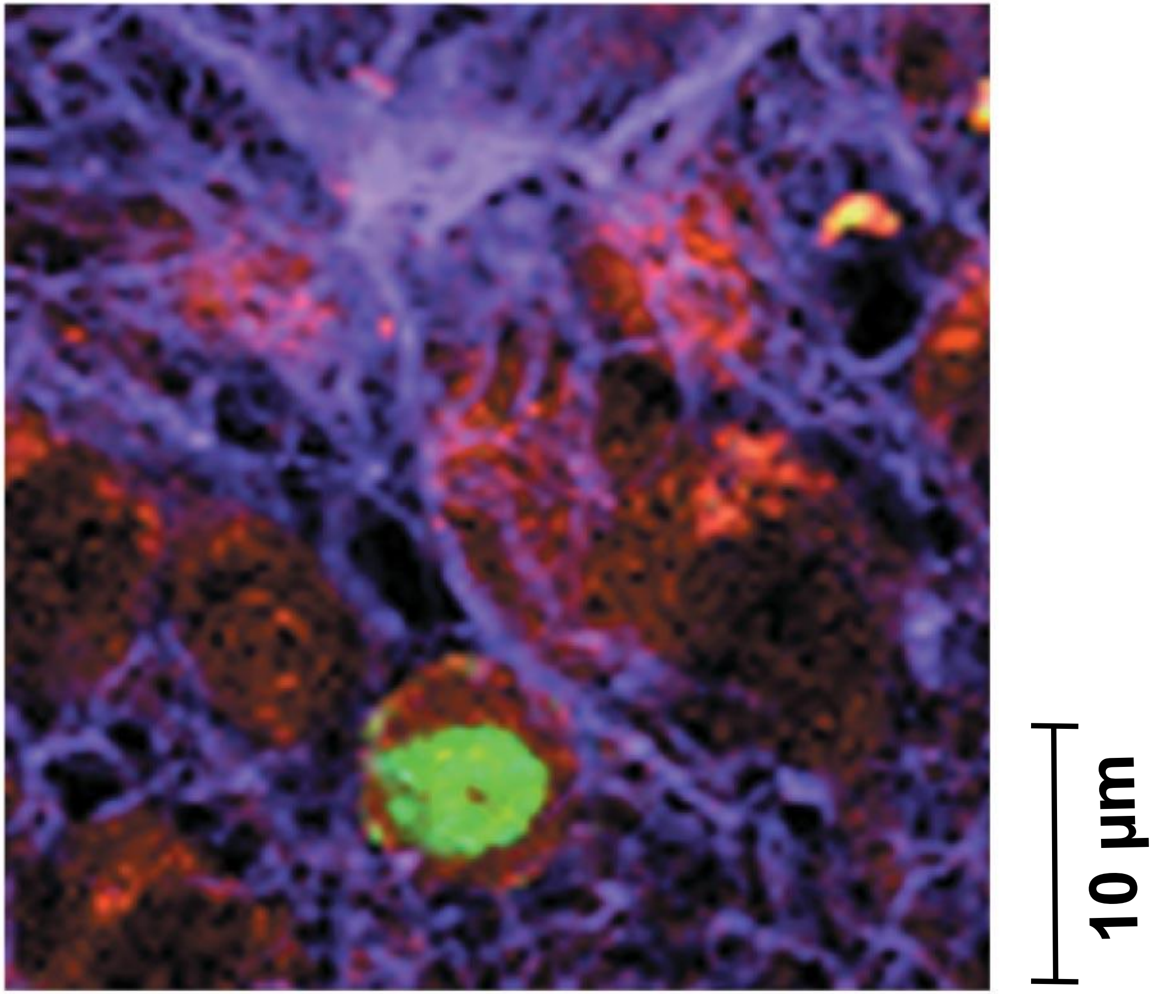
Parkinson's Disease

- **Parkinson's disease** is a motor disorder caused by death of dopamine-secreting neurons in the midbrain
- It is characterized by difficulty in initiating movements, muscle tremors, slowness of movement, and rigidity
- There is no cure, although drugs and various other approaches are used to manage symptoms

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

A newly born neuron in the hippocampus of a human adult



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
7. Explain the possible role of long-term potentiation in memory storage 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