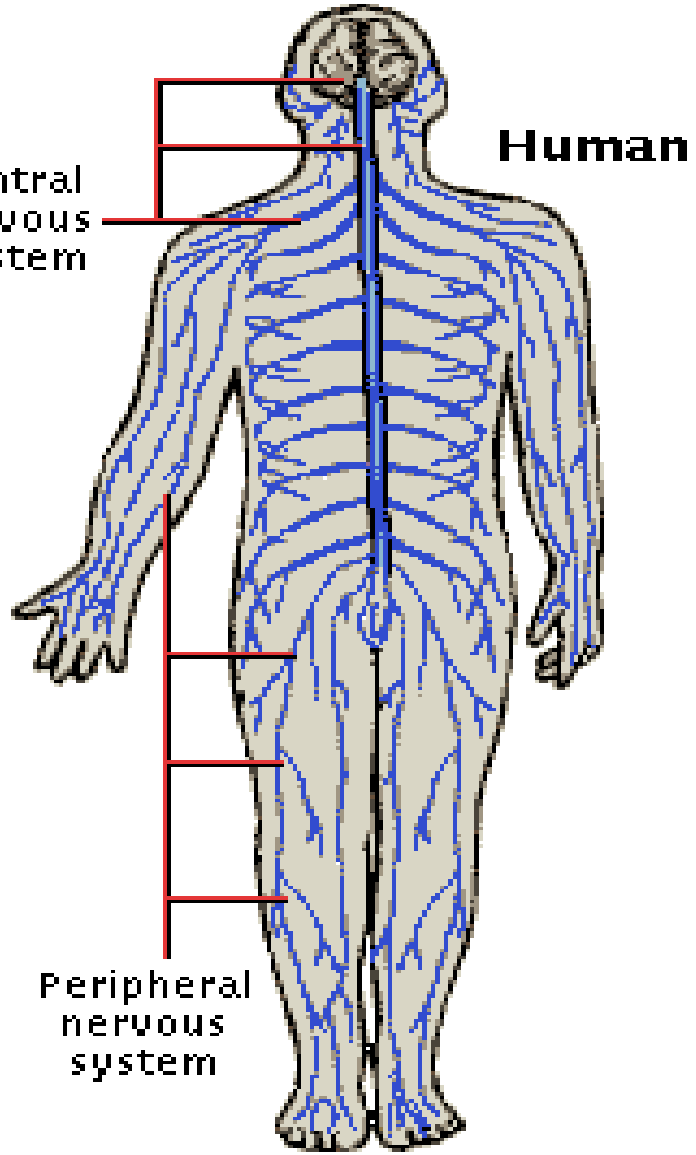
# The Nervous System

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Associate Professor
Department of Anatomy
School of Medicine
University of Patras

# Information Processing

- Nervous system process information in three stages:
  - Sensory input, integration, and motor output.

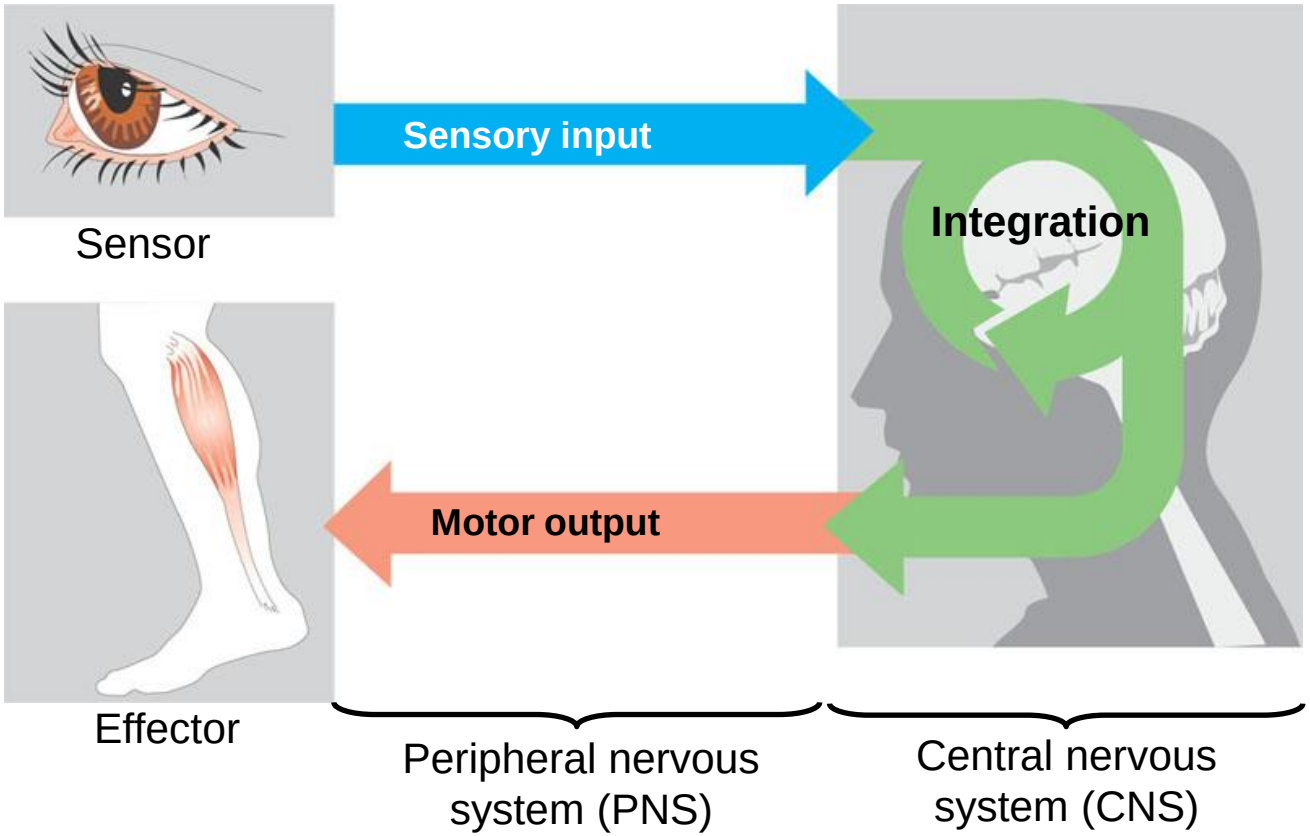



**Figure 48.3**

# In all vertebrates, the nervous system shows a high degree of cephalization and distinct CNS and PNS components.

- The **Central Nervous System** consists of a brain and dorsal spinal cord.
- The **Peripheral Nervous System** connects to the CNS.

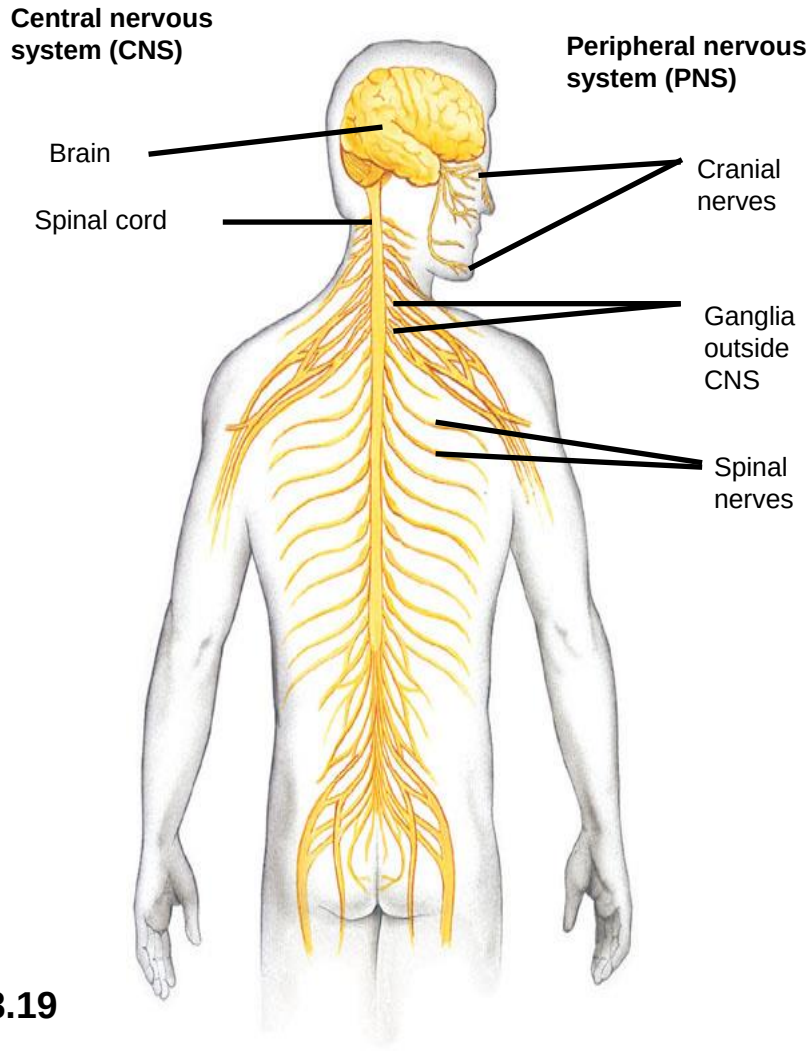
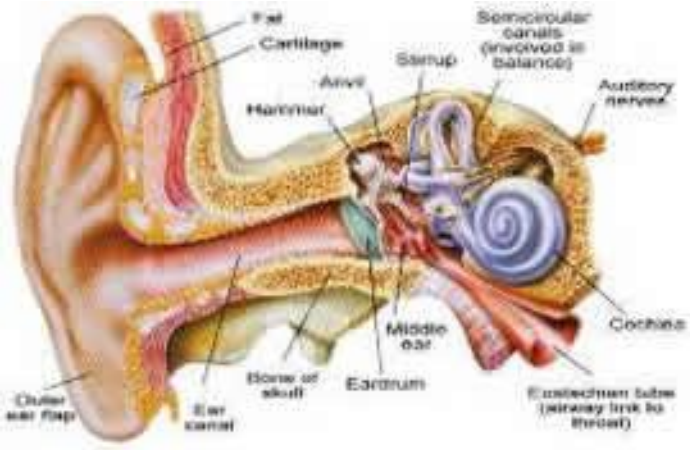



**Figure 48.19**

# The Peripheral Nervous System

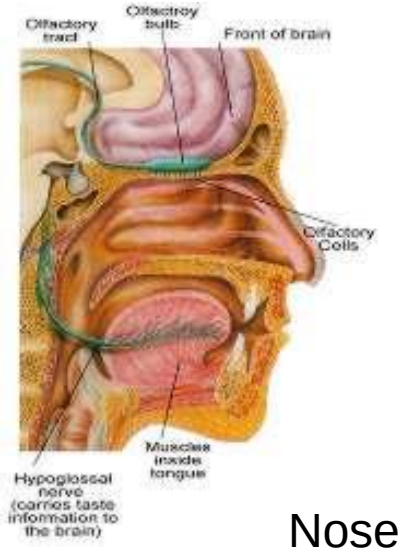
- The PNS transmits information to and from the CNS
  - and plays a large role in regulating a vertebrate's movement and internal environment.
- The **cranial nerves** originate in the brain
  - and terminate mostly in organs of the head and upper body.
- The **spinal nerves** originate in the spinal cord
  - and extend to parts of the body below the head.

**Sense organs** carry messages about the environment to the central nervous system.

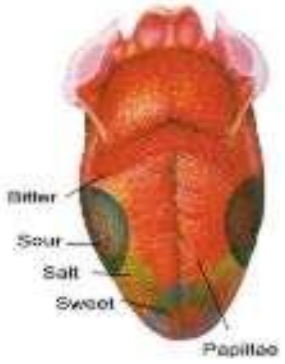



Ear

Eye




Nose




Tongue

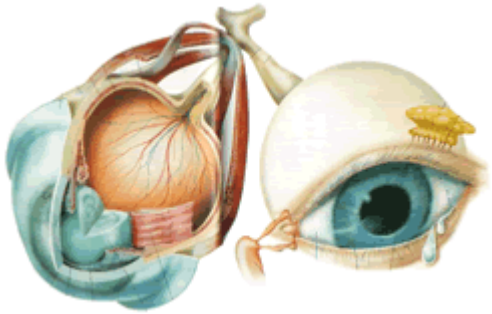
Skin

# The sense organs gather information (light, sound, heat, and pressure) from the environment.

The **sense organs** gather information from outside the body (environment), then send the messages to the brain.

# Vision is the ability to see.

- Vision involves the eye and the brain.



**The eye gathers pictures and sends them to the brain**

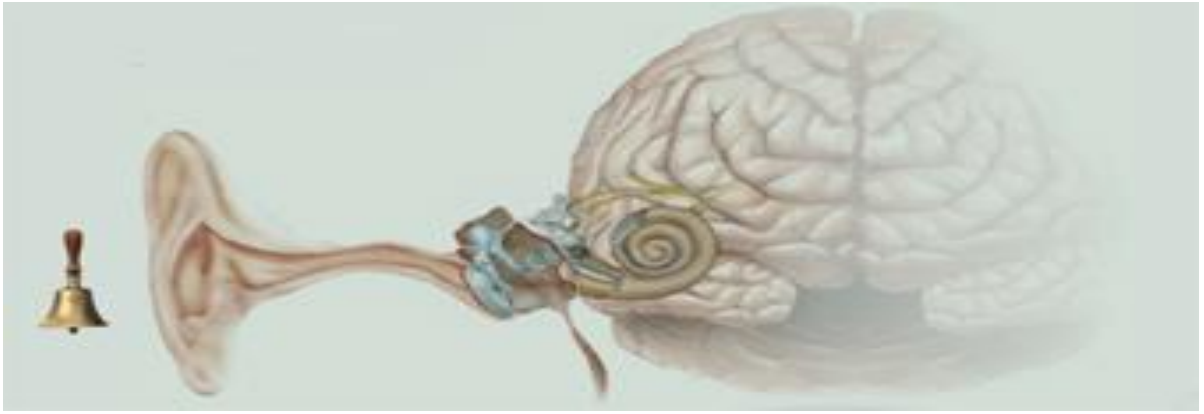
**The colored part of the eye is the iris.**

**The black part of the eye is the pupil.**

*The pupil becomes larger and smaller as it controls the light coming into the eye.*

When a sound is made, the air around the sound vibrates.

**Hearing starts when some of the sound waves go into the ear.**



**The ear works with the brain to control the balance.**

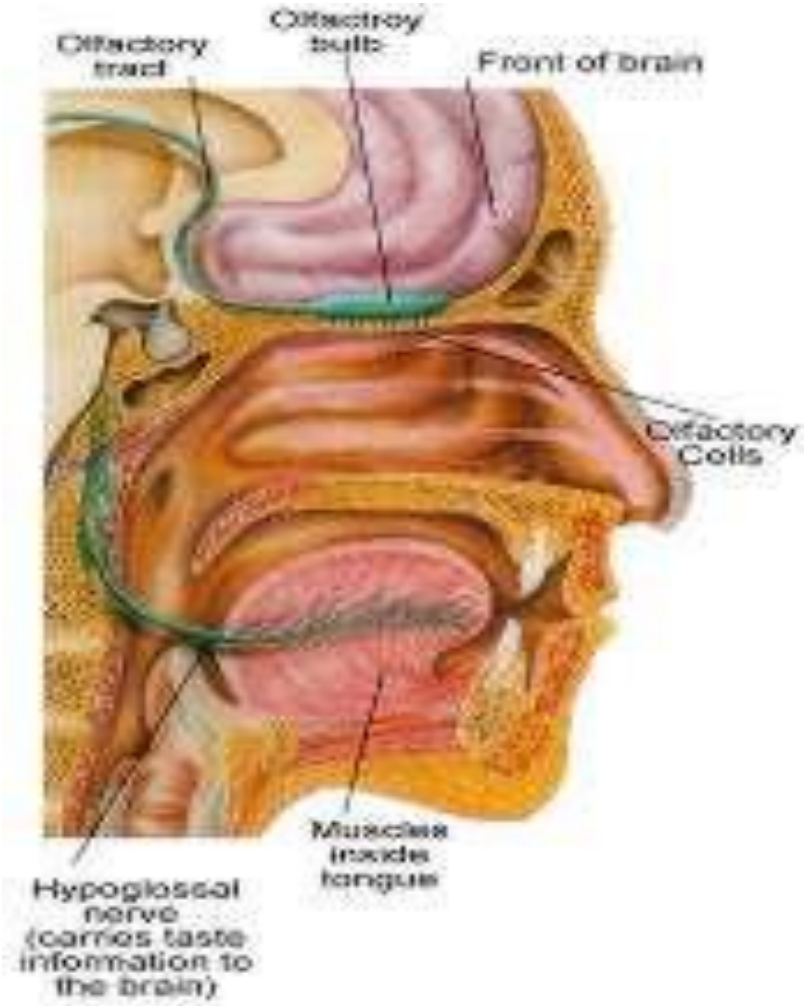
# The sense of touch is located in the skin.

The nerves in the skin allow us to feel texture, pressure, heat, cold, and pain.

Texture is how something feels.

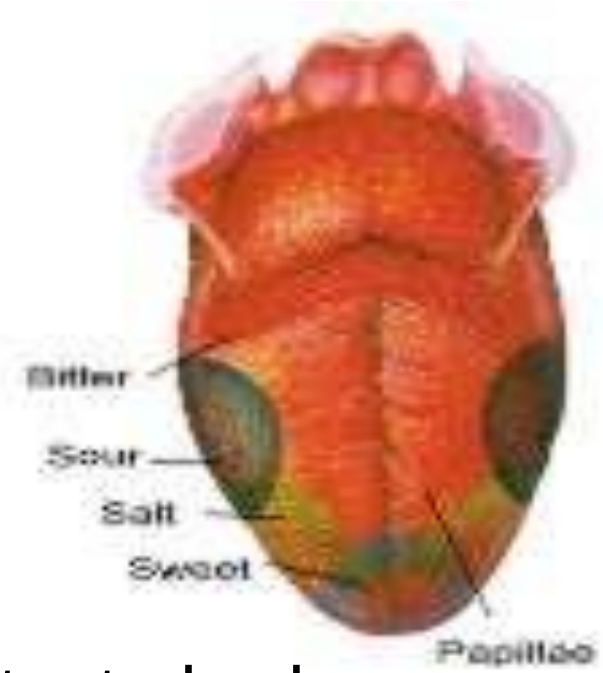
# The nose controls the sense of smell.

The nose is able to smell 80 different kinds of smells.

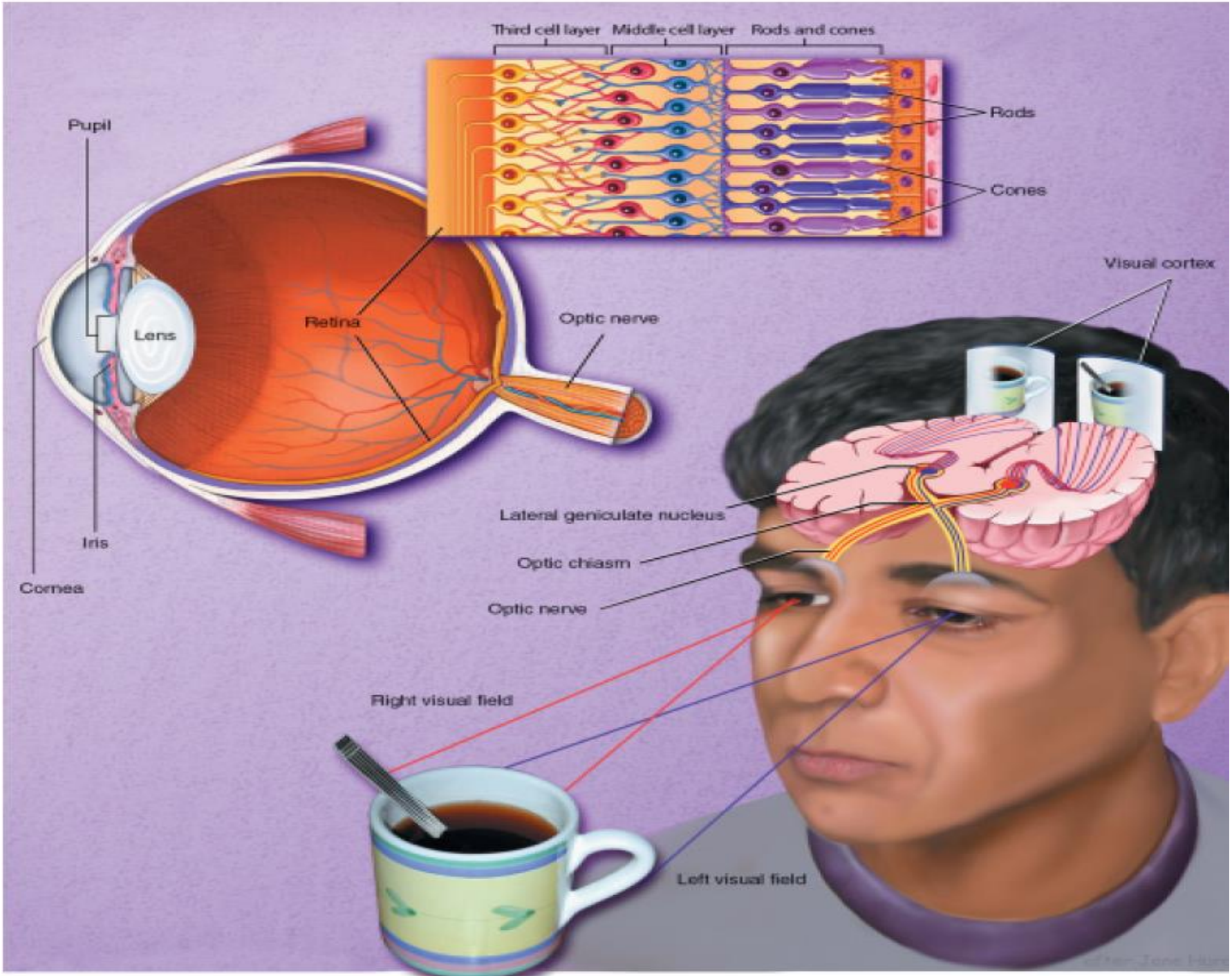


# The sense of taste comes from the taste buds in the tongue.

Taste buds are the parts on the tongue that allow us to taste.



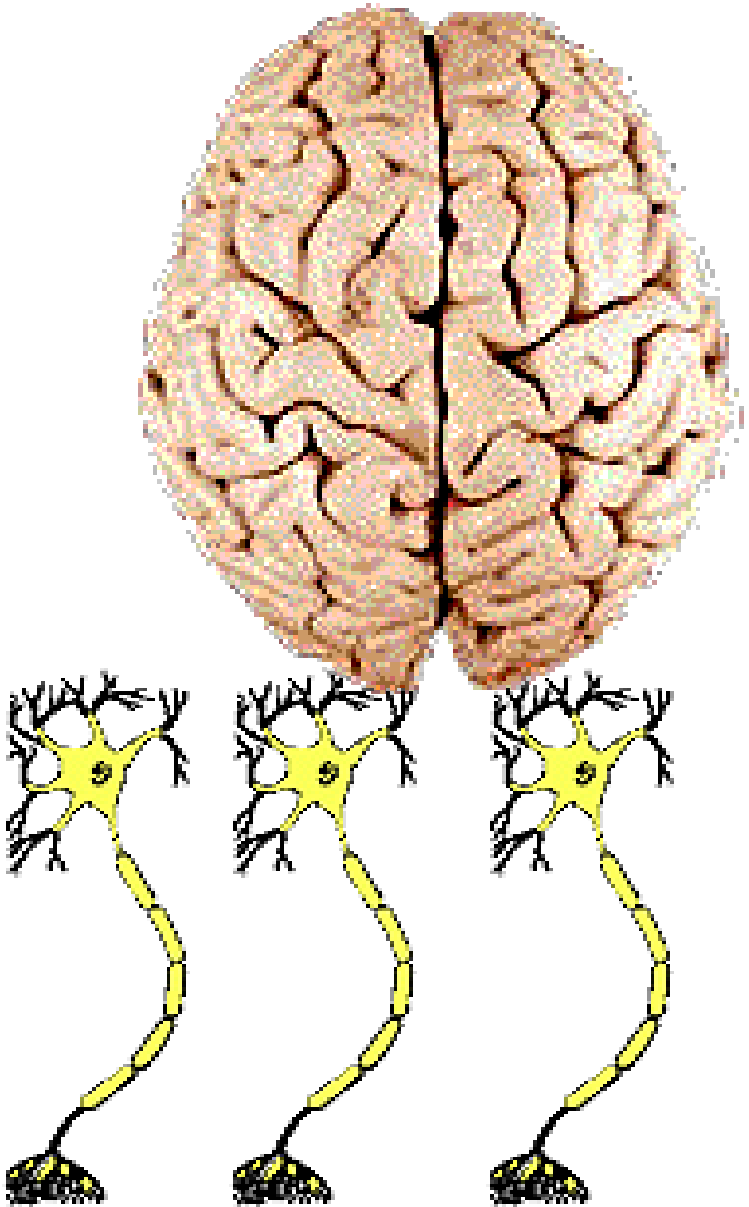

The four kinds of taste buds are sweet, sour, bitter, and salty.


Third cell layer
Middle cell layer
Rods and cones
Rods
Cones
Pupil
Lens
Retina
Optic nerve
Visual cortex
Iris
Cornea
Lateral geniculate nucleus
Optic chiasm
Optic nerve
Right visual field
Left visual field

- **Sensory neurons transmit information from sensors**
  - that detect external stimuli and internal conditions.
- Sensory information is sent to the CNS
  - where **interneurons** integrate the information.
- **Motor output** leaves the CNS via **motor neurons**
  - which communicate with effector cells.

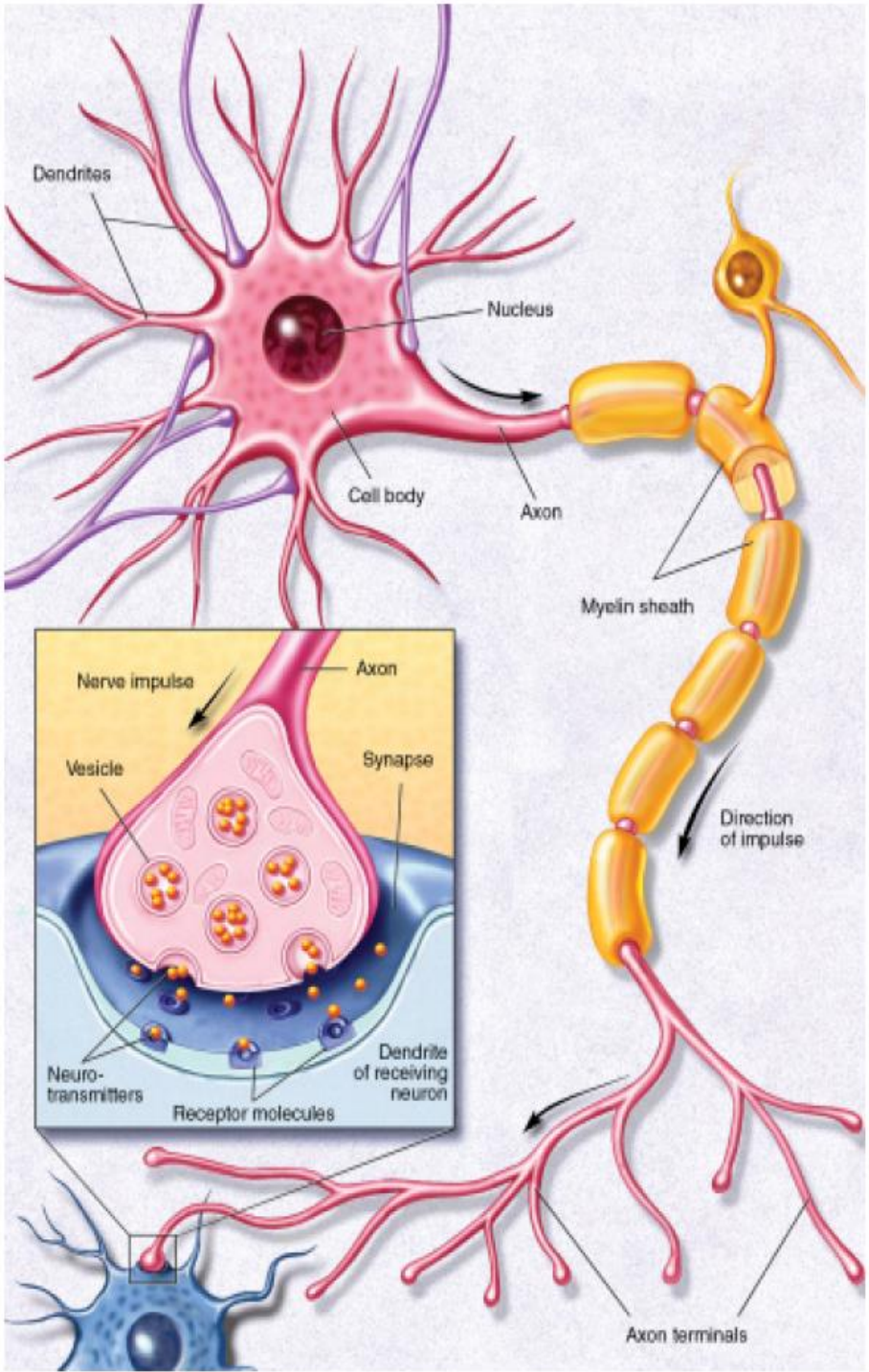
# Command and Control Center

- The **human brain**
  - contains an estimated 100 billion nerve cells, or neurons.
- Each **neuron**
  - may communicate with thousands of other neurons.



# The neuron

- A specialized cell designed to transmit information to other nerve cells, muscle, or gland cells, the neuron is the basic working unit of the brain.



# Neuron Structure (1)

- Most of a neuron's organelles
  - are located in the cell body.

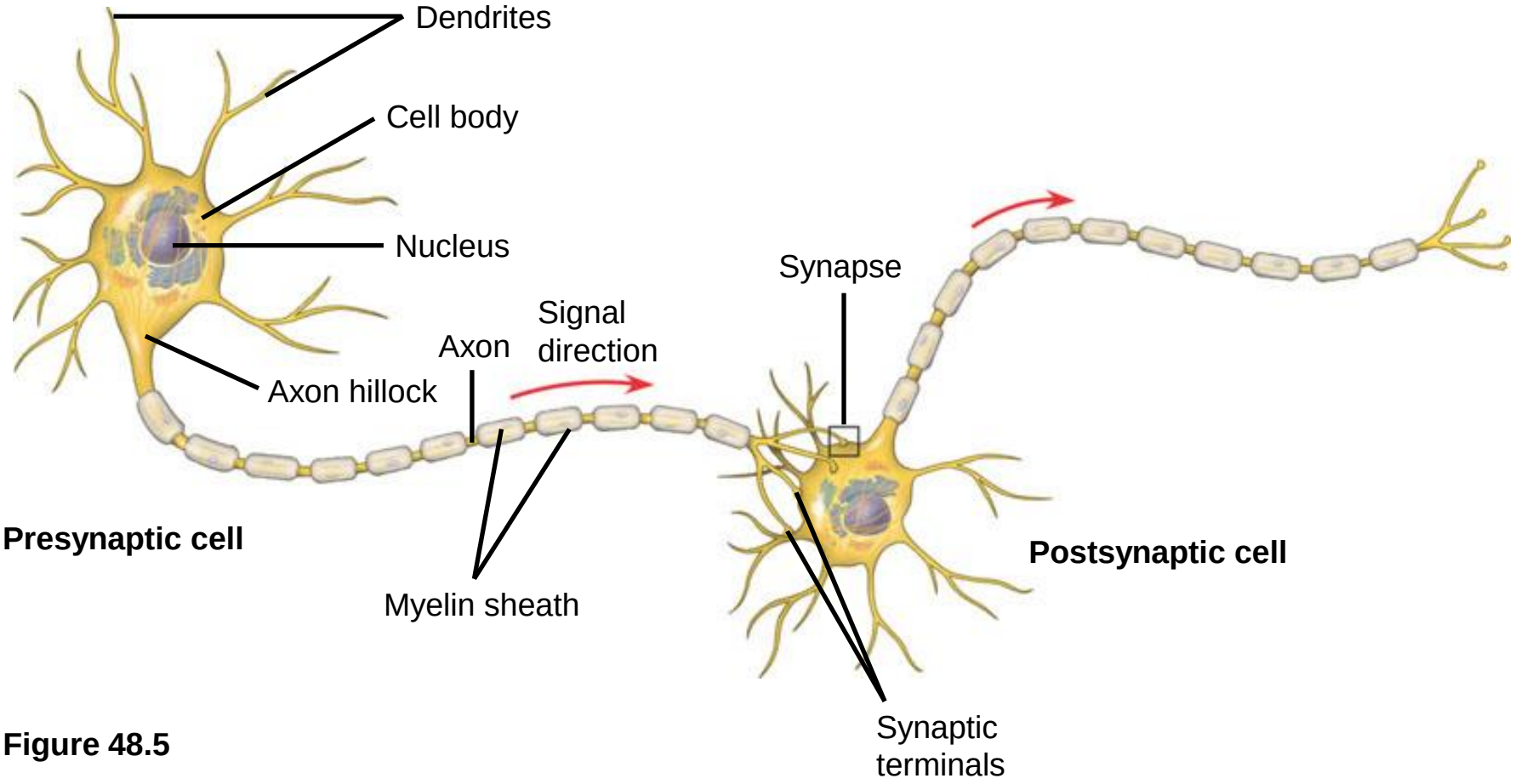
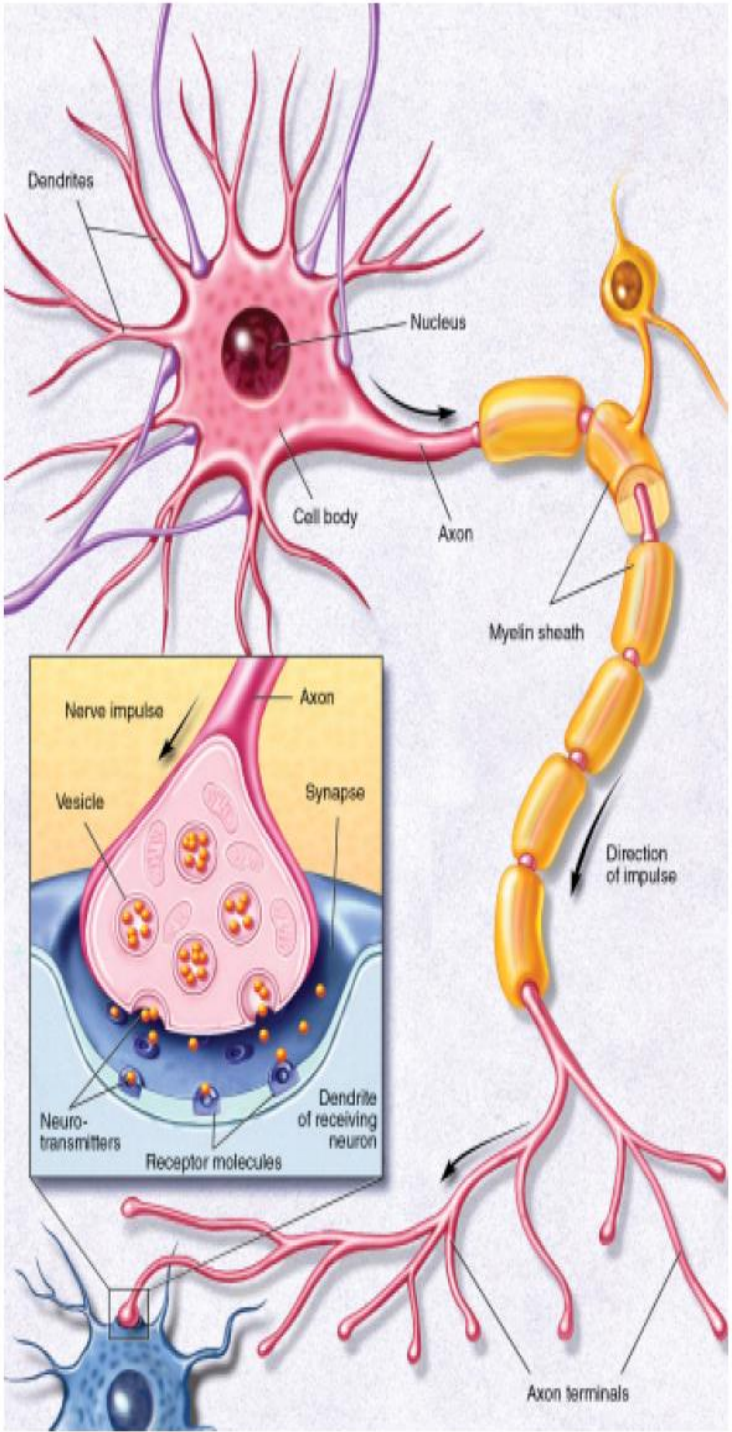



**Figure 48.5**

# Neuron Structure (2)

- Most neurons have **dendrites**
  - highly branched extensions that receive signals from other neurons.
- The **axon** is typically a much longer extension
  - that transmits signals to other cells at synapses,
  - that may be covered with a myelin sheath.




A neuron fires by transmitting electrical signals along its axon.

When signals reach the end of the axon, they trigger the release of neurotransmitters that are stored in pouches called vesicles.

Neurotransmitters bind to receptor molecules that are present on the surfaces of adjacent neurons.

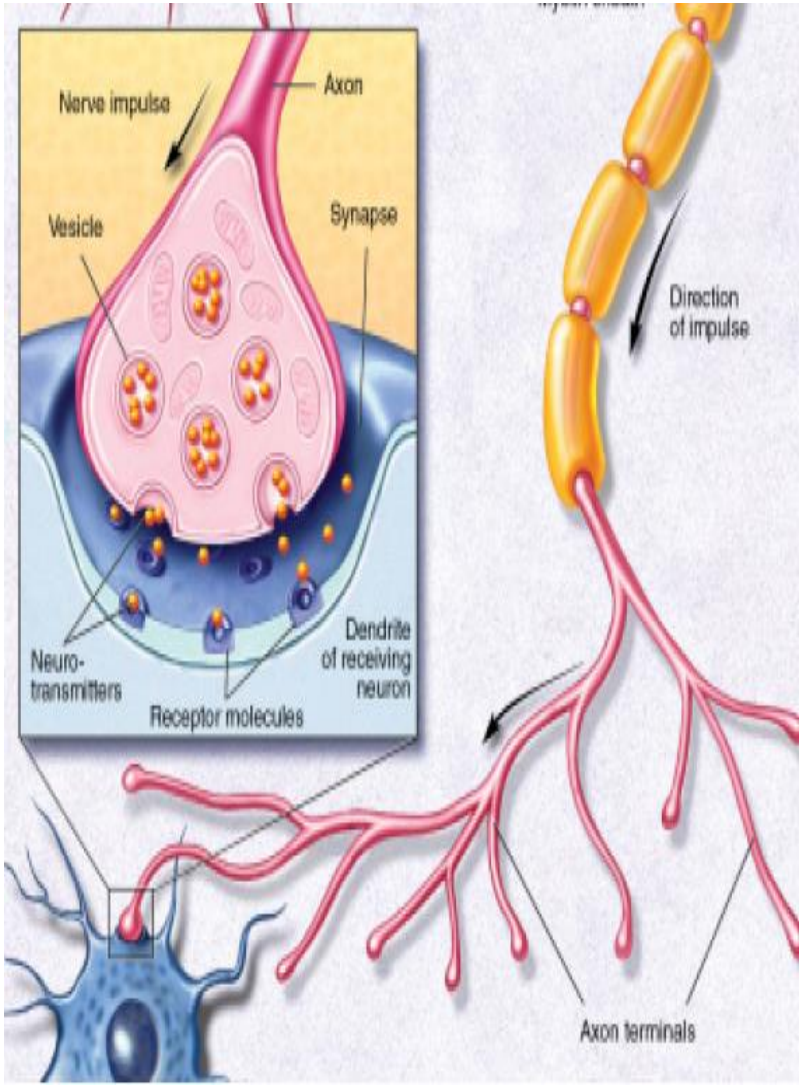
The point of virtual contact is known as the synapse.

# Neuron Structure (3)

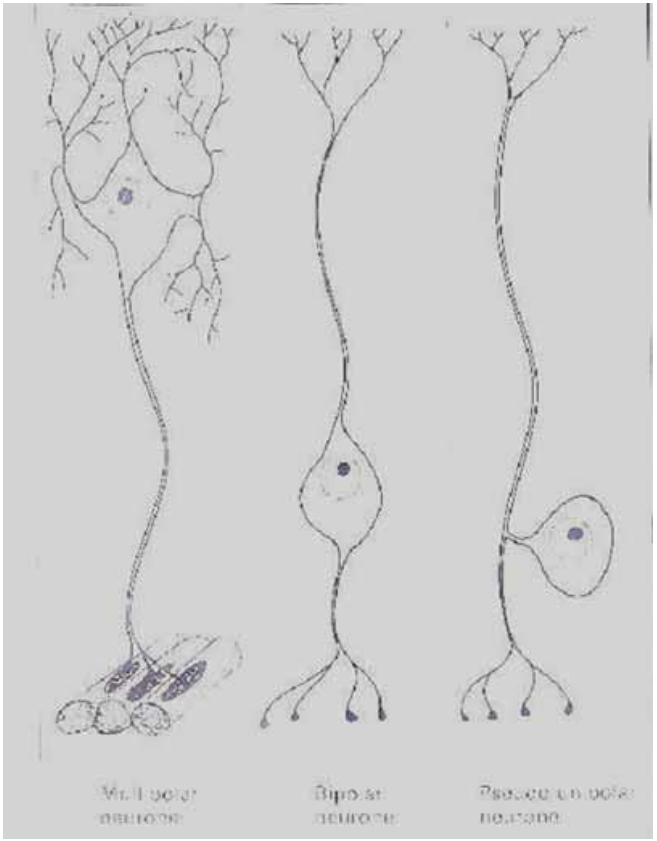
Most axons give rise to many smaller branches before ending at **nerve terminals**.

**Synapses**, from the Greek word meaning “to clasp together”, are the contact points where one neuron communicates with another.

The dendrites and cell body are covered with synapses formed by the ends of axons of other neurons.



# Neurons have a wide variety of shapes that reflect their input and output interactions.



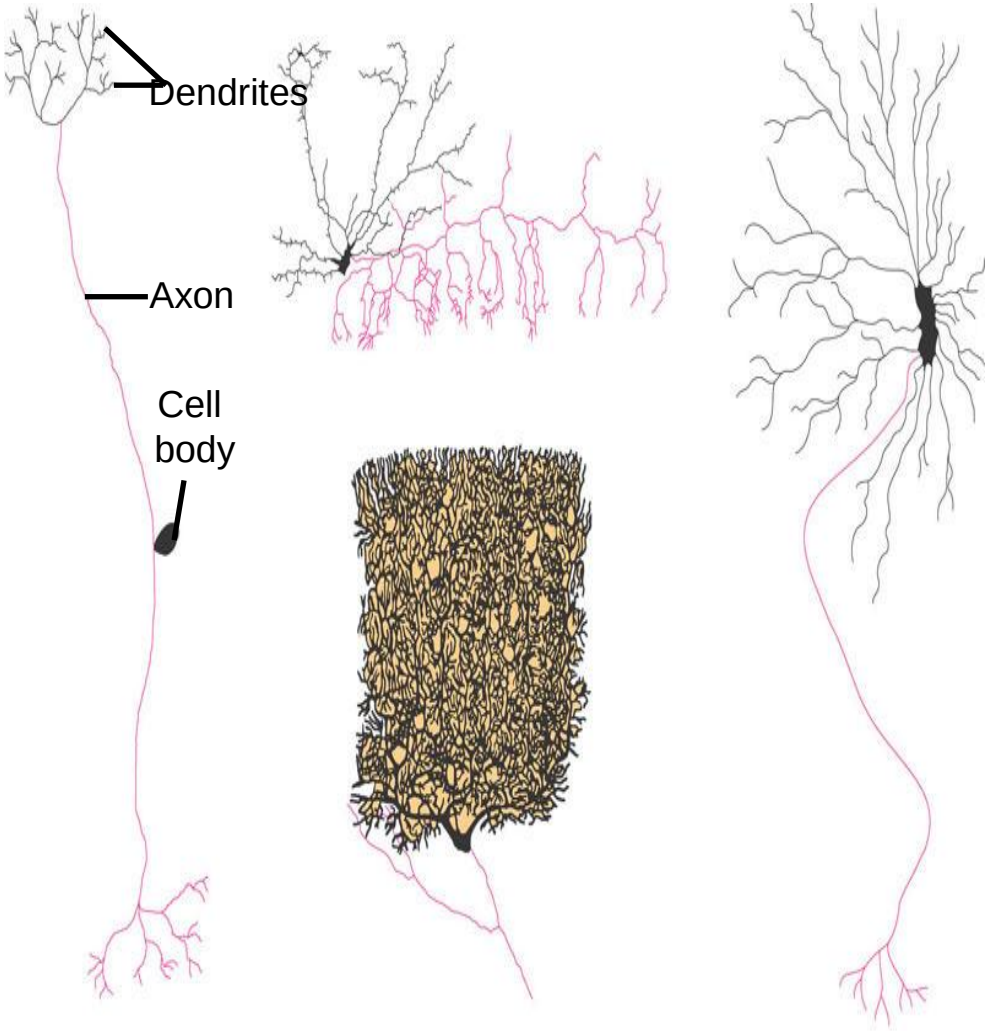
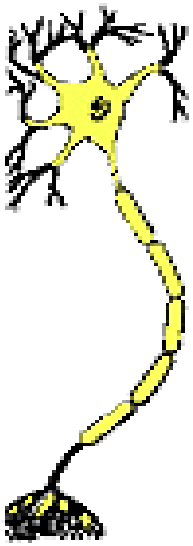
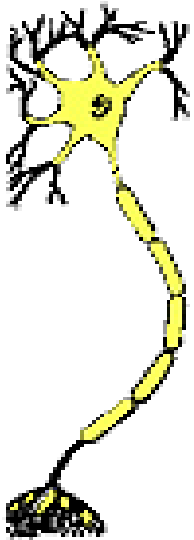



**Figure 48.6a–c** (a) Sensory neuron (b) Interneurons (c) Motor neuron

# A system that controls all of the activities of the body.

- Nervous system consist of **circuits of neurons** and **supporting cells**.





# Supporting Cells (Glia)

- Glia are supporting cells
  - that are essential for the structural integrity of the nervous system and for the normal functioning of neurons.

In the CNS, **astrocytes** provide structural support for neurons and regulate the extracellular concentrations of ions and neurotransmitters.

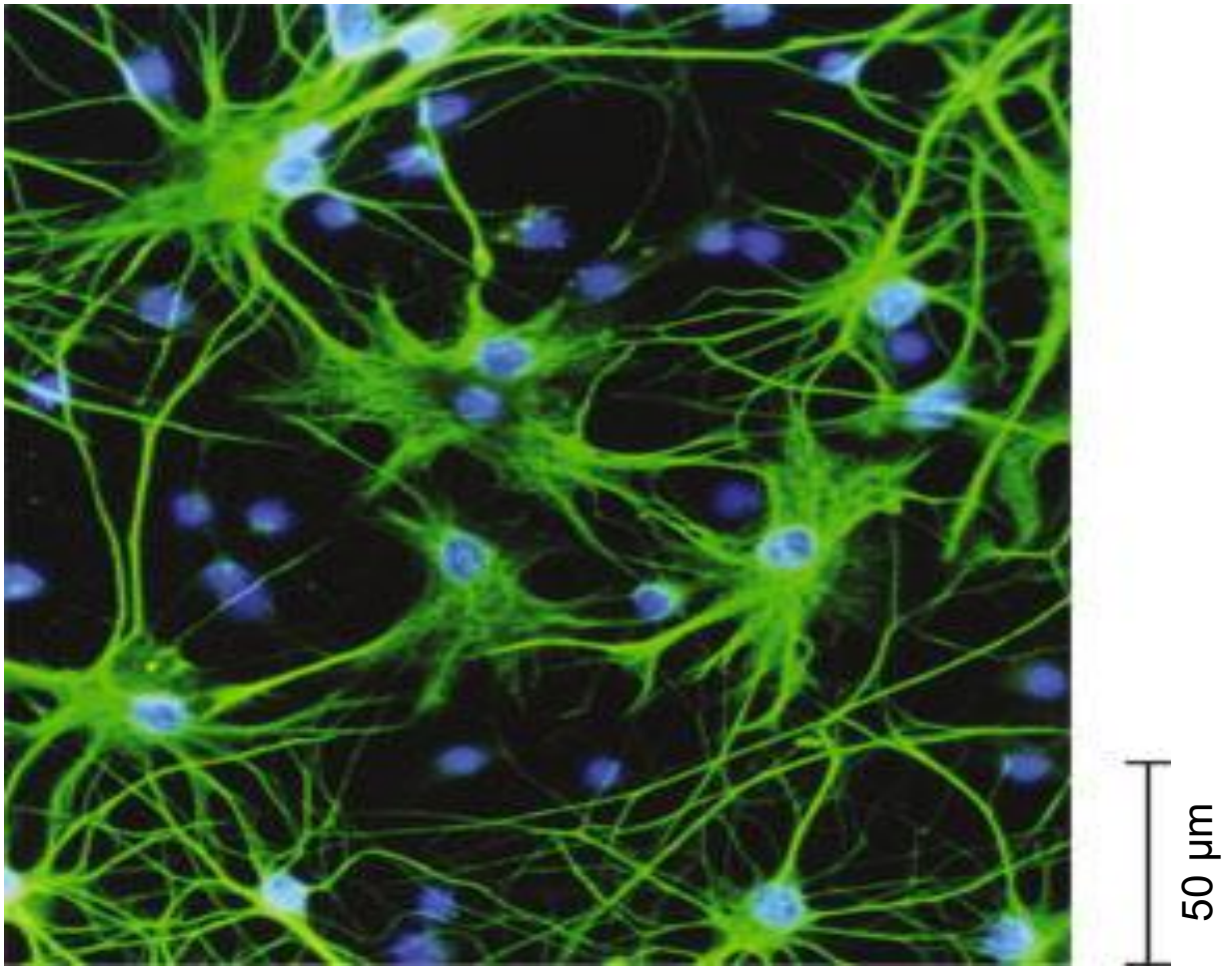
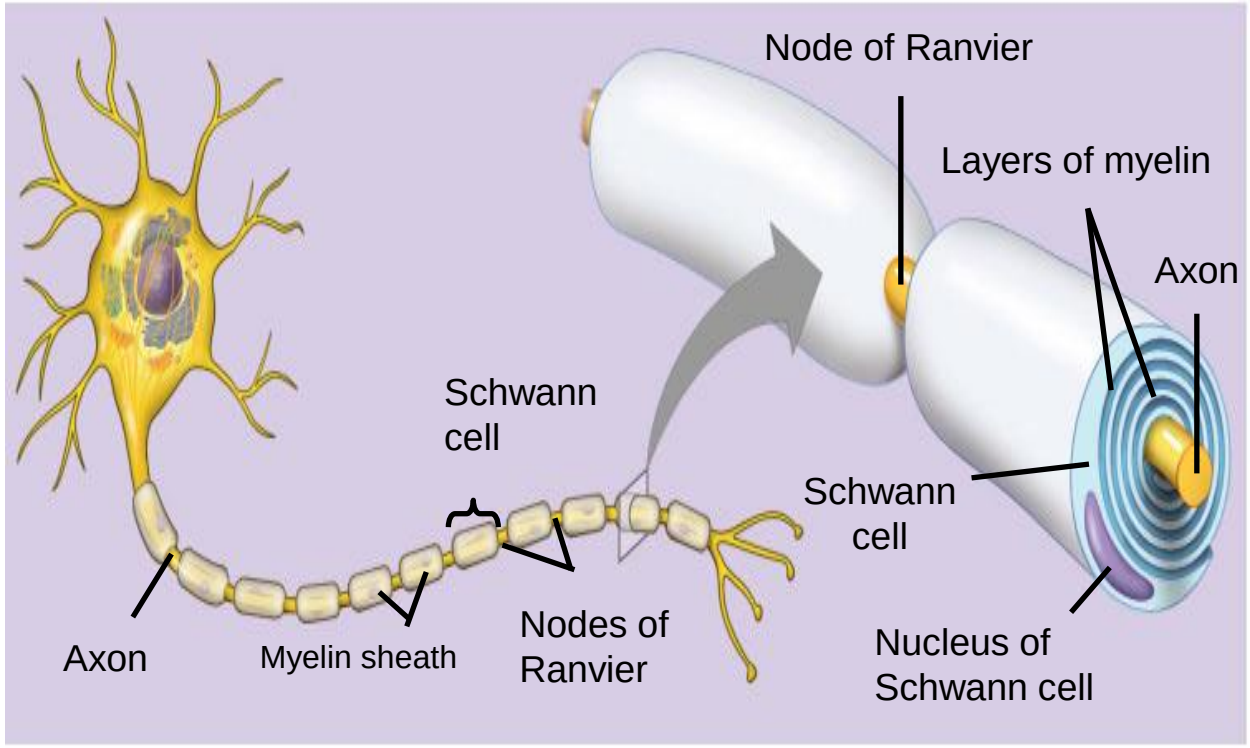



**Figure 48.7**

**Oligodendrocytes** (in the CNS) and **Schwann cells** (in the PNS) are glia that form the myelin sheaths around the axons of many vertebrate neurons.



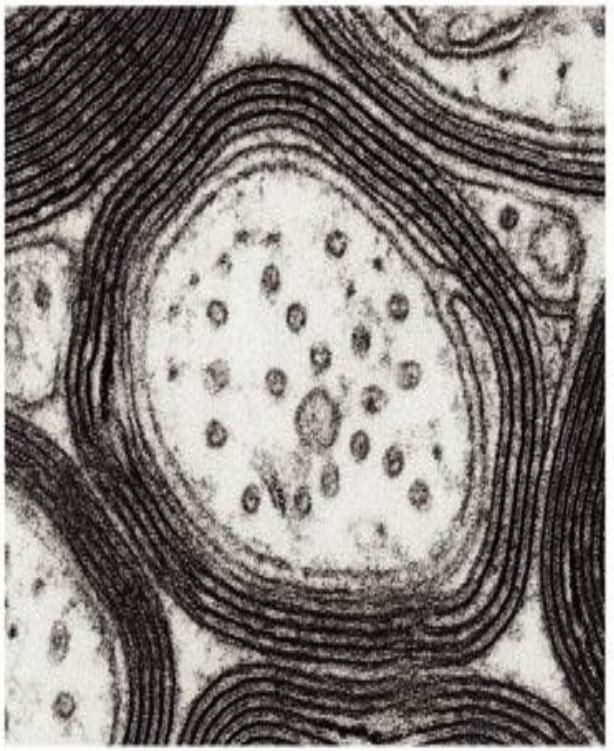




**Figure 48.8**

- The myelin sheath speeds the transmission of electrical signals along the axon.

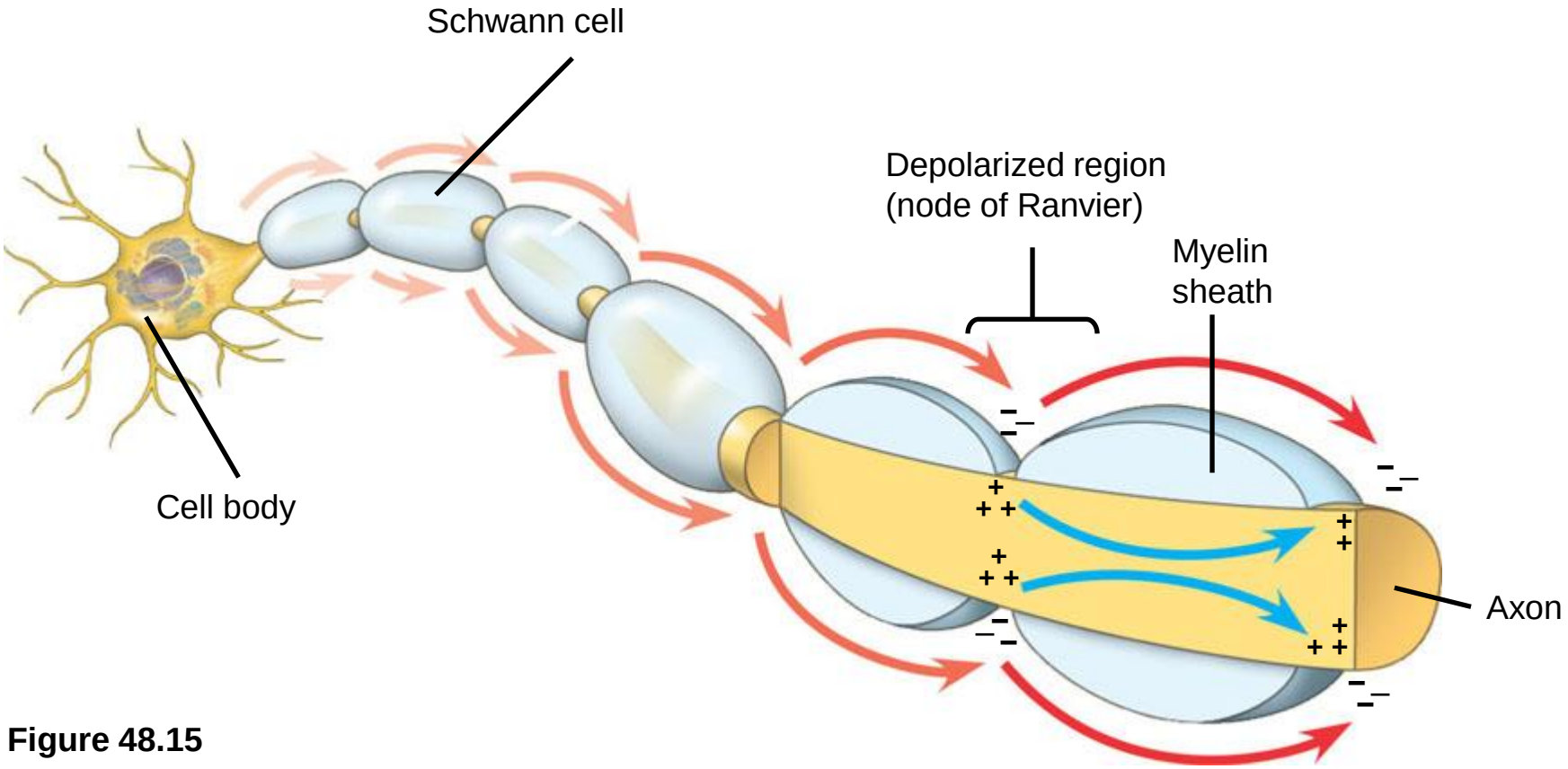



**Figure 48.15**

- Nerve impulses involve the opening and closing of ion channels, water filled molecular tunnels that pass through the cell membrane and allow ions -electrically charged atoms- or small molecules to enter or leave the cell. The flow of these ions creates an electrical current that produces tiny voltage changes across the membrane.

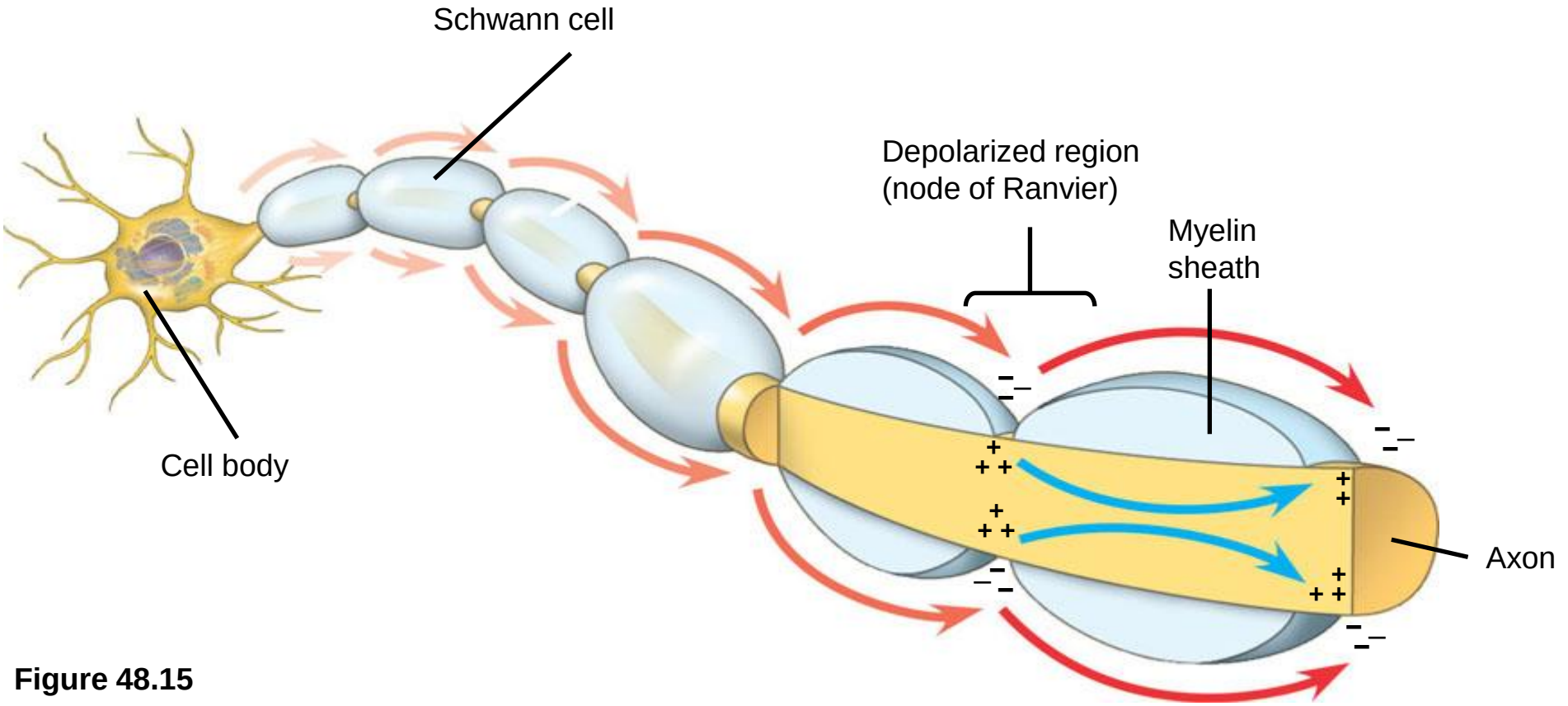



**Figure 48.15**

# Synapses

- Neurons communicate with other cells at synapses
- In an electrical synapse
  - Electrical current flows directly from one cell to another via a gap junction
- The vast majority of synapses
  - Are chemical synapses

# In a chemical synapse, a presynaptic neuron Releases chemical neurotransmitters, which are stored in the synaptic terminal

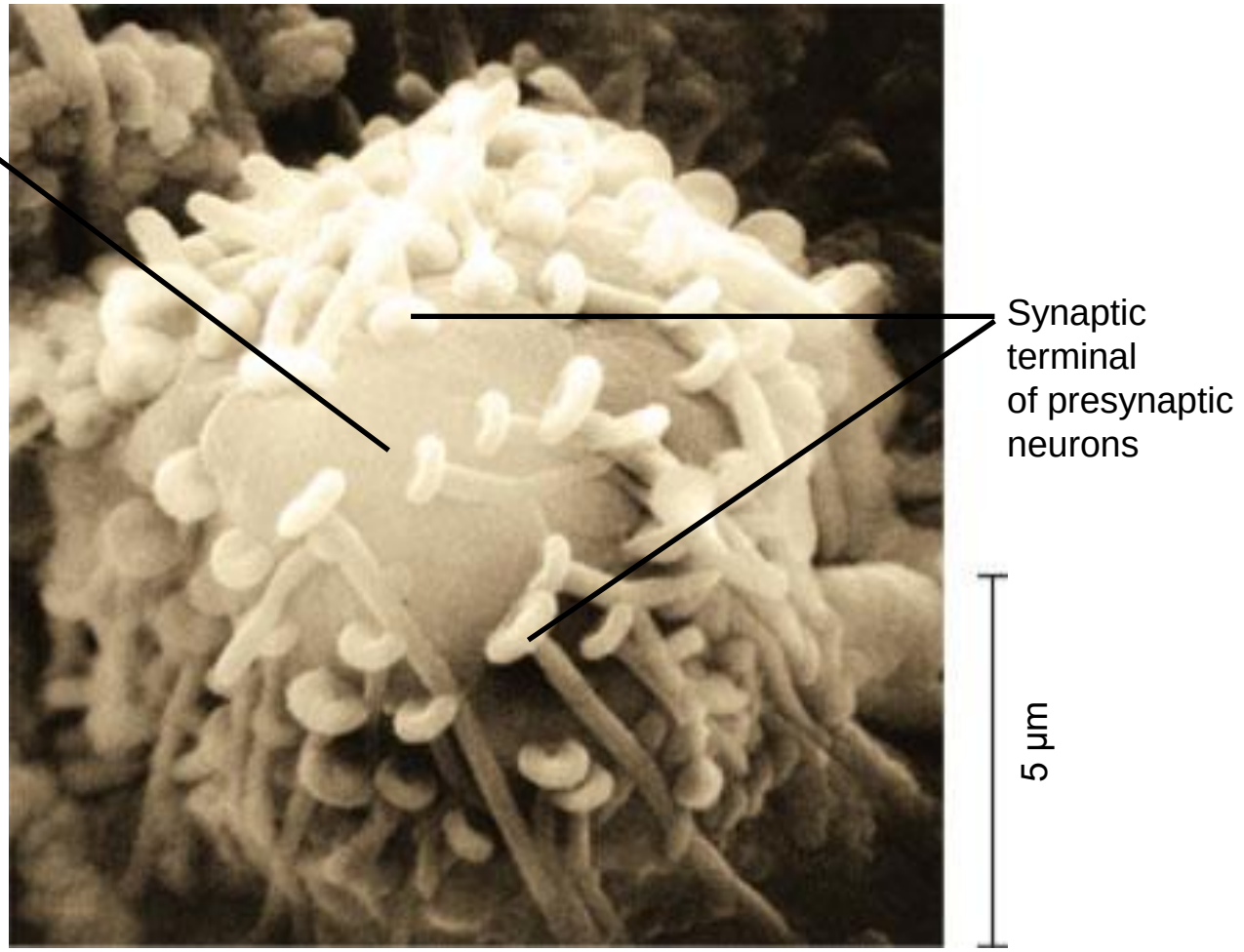



**Figure 48.16**

# When an action potential reaches a terminal The final result is the release of neurotransmitters into the synaptic cleft

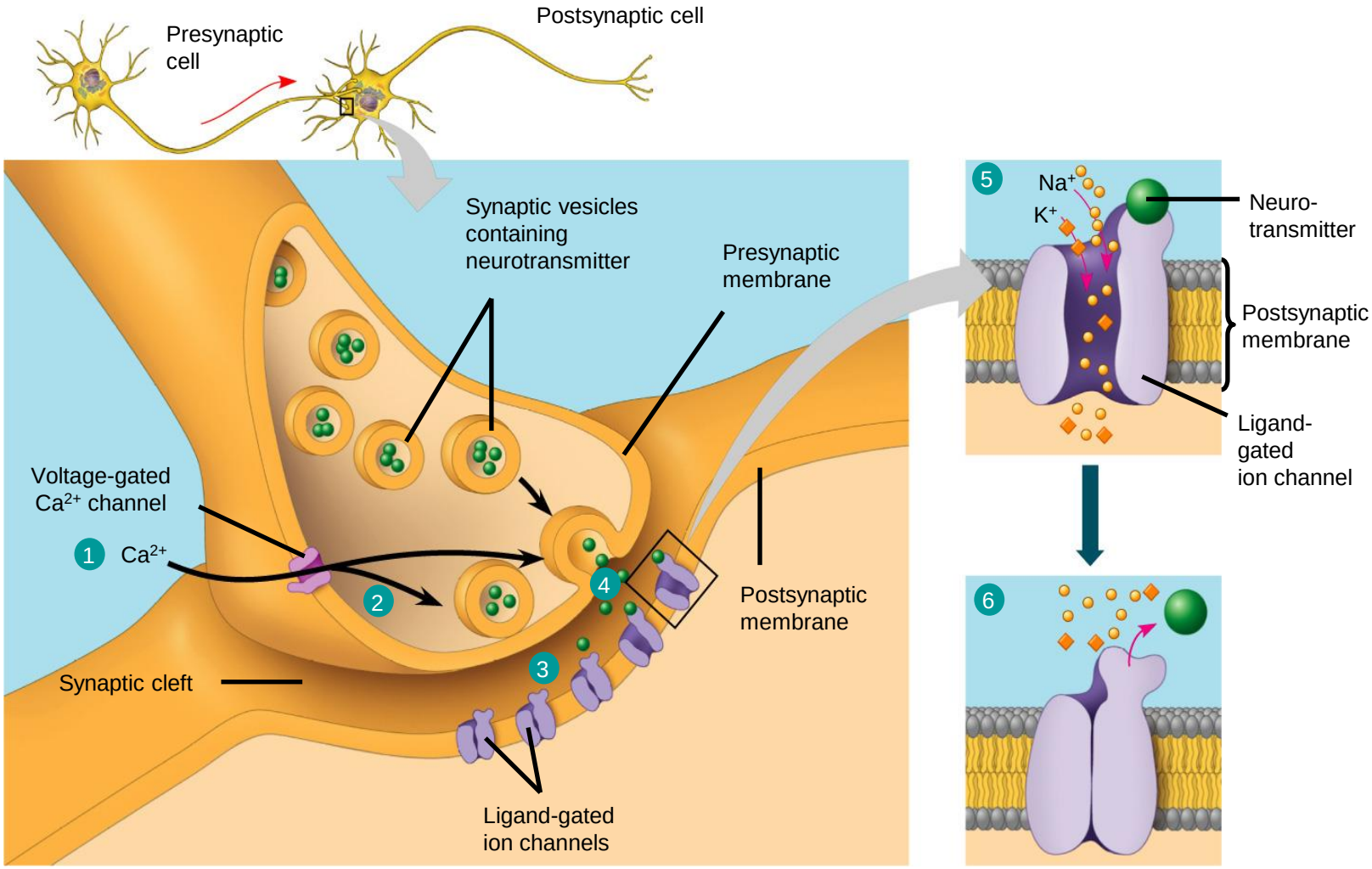



**Figure 48.17**

## Table 48.1 Major Neurotransmitters

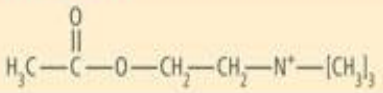
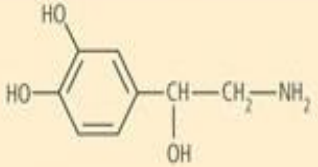
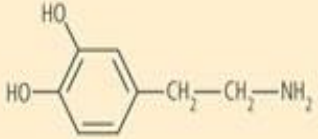
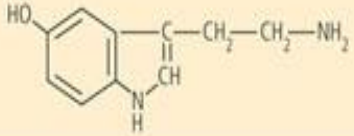
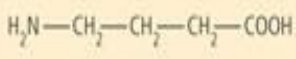
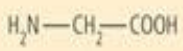
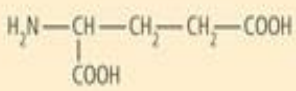
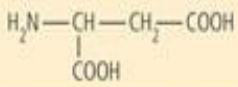
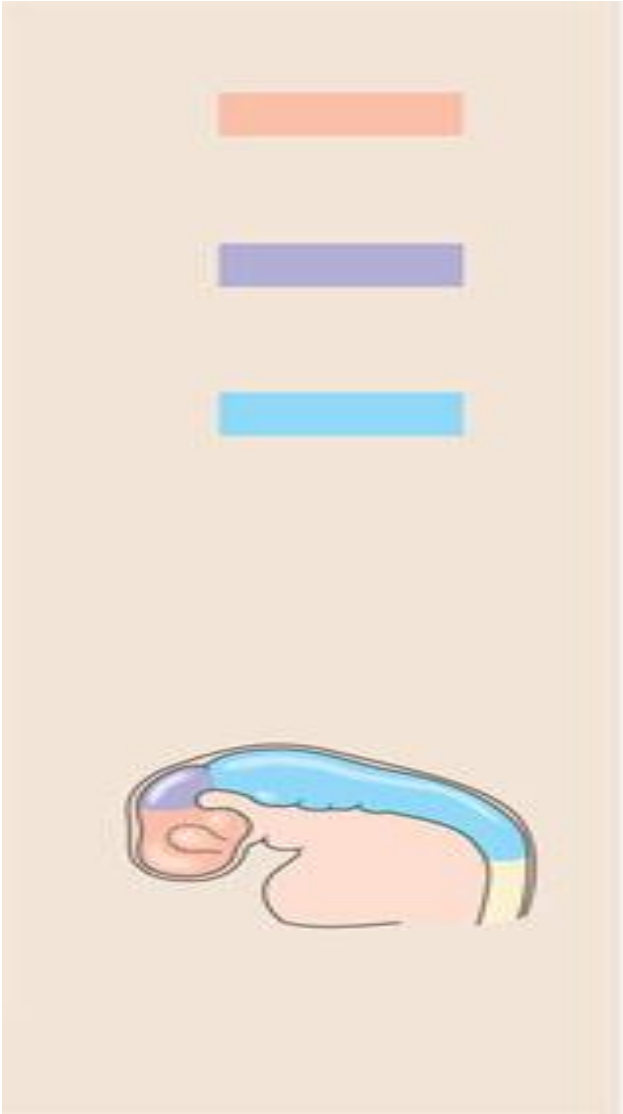
| Neurotransmitter | Structure | Functional Class | Secretion Sites |
|---|---|---|---|
| **Acetylcholine** |  | Excitatory to vertebrate skeletal muscles; excitatory or inhibitory at other sites | CNS; PNS; vertebrate neuromuscular junction |
| **Biogenic Amines** | | | |
| Norepinephrine |  | Excitatory or inhibitory | CNS; PNS |
| Dopamine |  | Generally excitatory; may be inhibitory at some sites | CNS; PNS |
| Serotonin |  | Generally inhibitory | CNS |
| **Amino Acids** | | | |
| GABA (gamma aminobutyric acid) |  | Inhibitory | CNS; invertebrate neuromuscular junction |
| Glycine |  | Inhibitory | CNS |
| Glutamate |  | Excitatory | CNS; invertebrate neuromuscular junction |
| Aspartate |  | Excitatory | CNS |
| **Neuropeptides** (a very diverse group, only two of which are shown) | | | |
| Substance P | Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met | Excitatory | CNS; PNS |
| Met-enkephalin (an endorphin) | Tyr—Gly—Gly—Phe—Met | Generally inhibitory | CNS |

Table 48.1

# Embryonic Development of the Brain

- In all vertebrates
  - the brain develops from three embryonic regions: the forebrain, the midbrain, and the hindbrain.



- By the fifth week of human embryonic development
  - five brain regions have formed from the three embryonic regions.

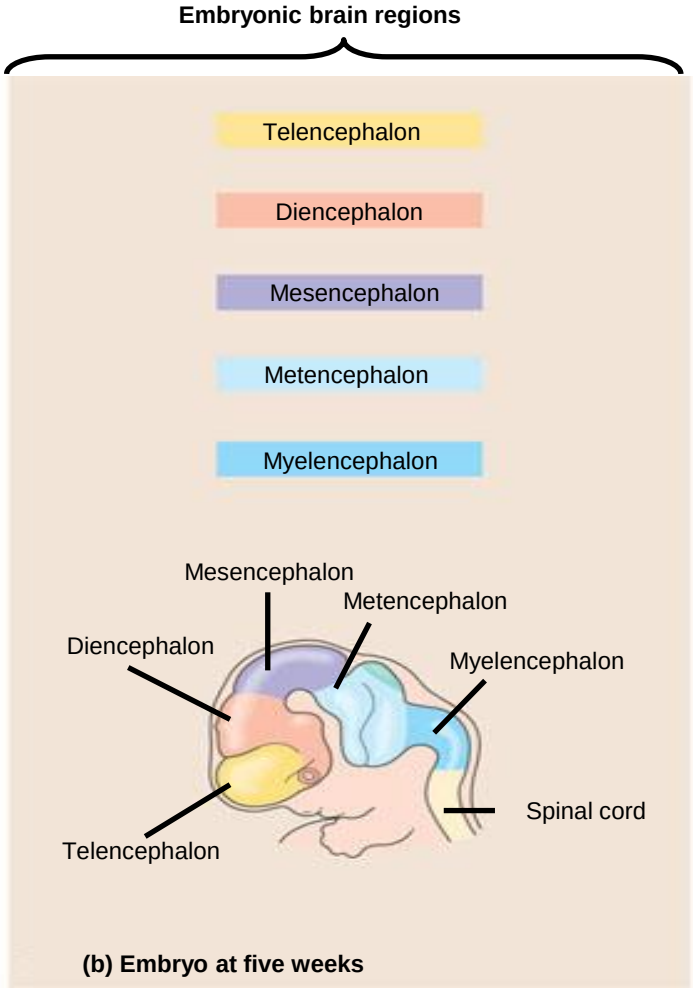



**Figure 48.23b**

- As a human brain develops further
  - the most profound change occurs in the forebrain, which gives rise to the cerebrum.

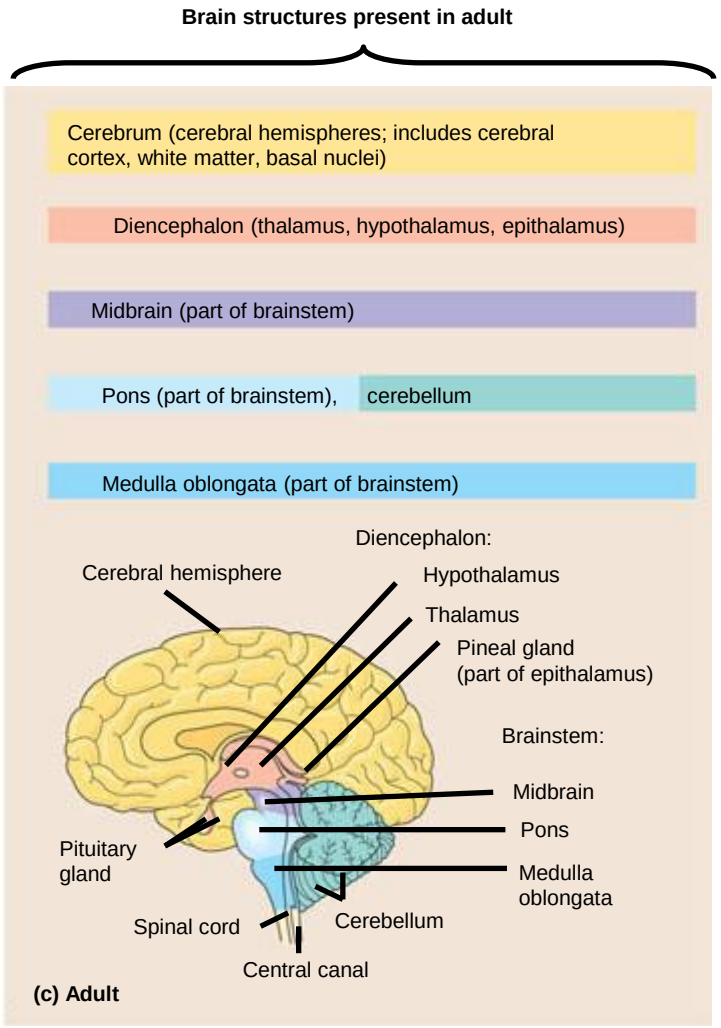
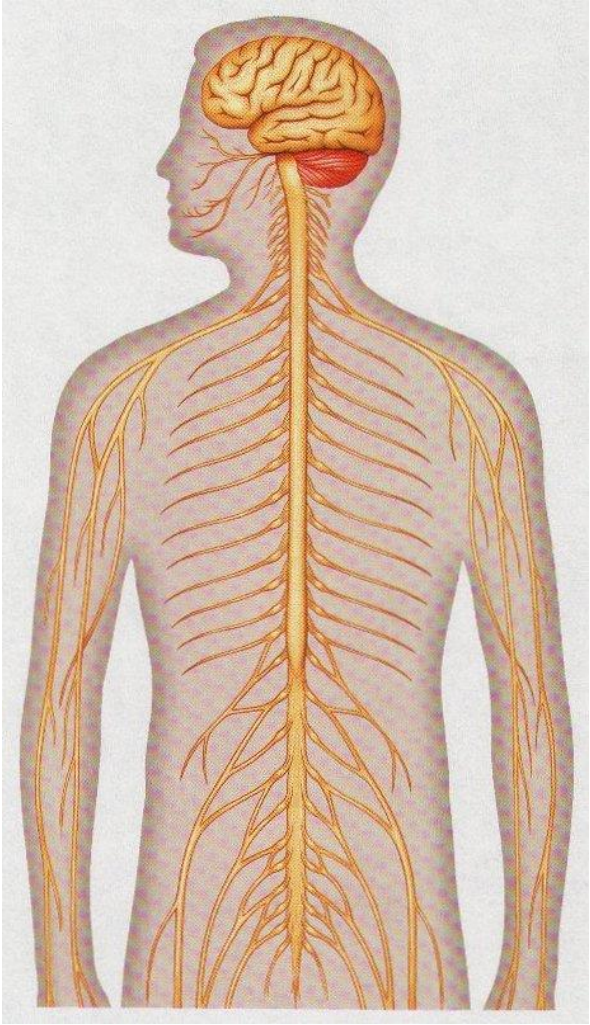



**Figure 48.23c**

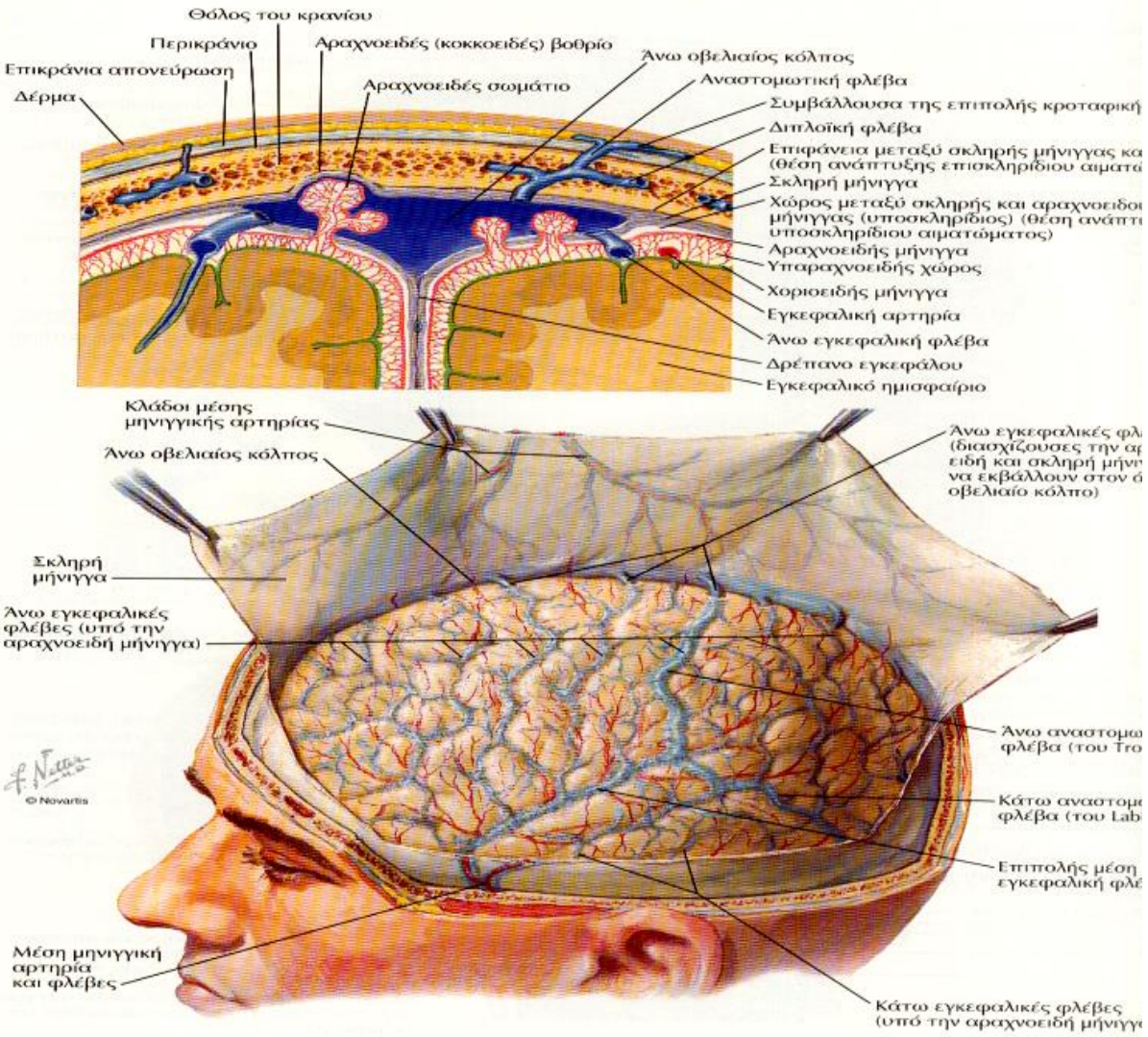
# Central Nervous System (CNS)

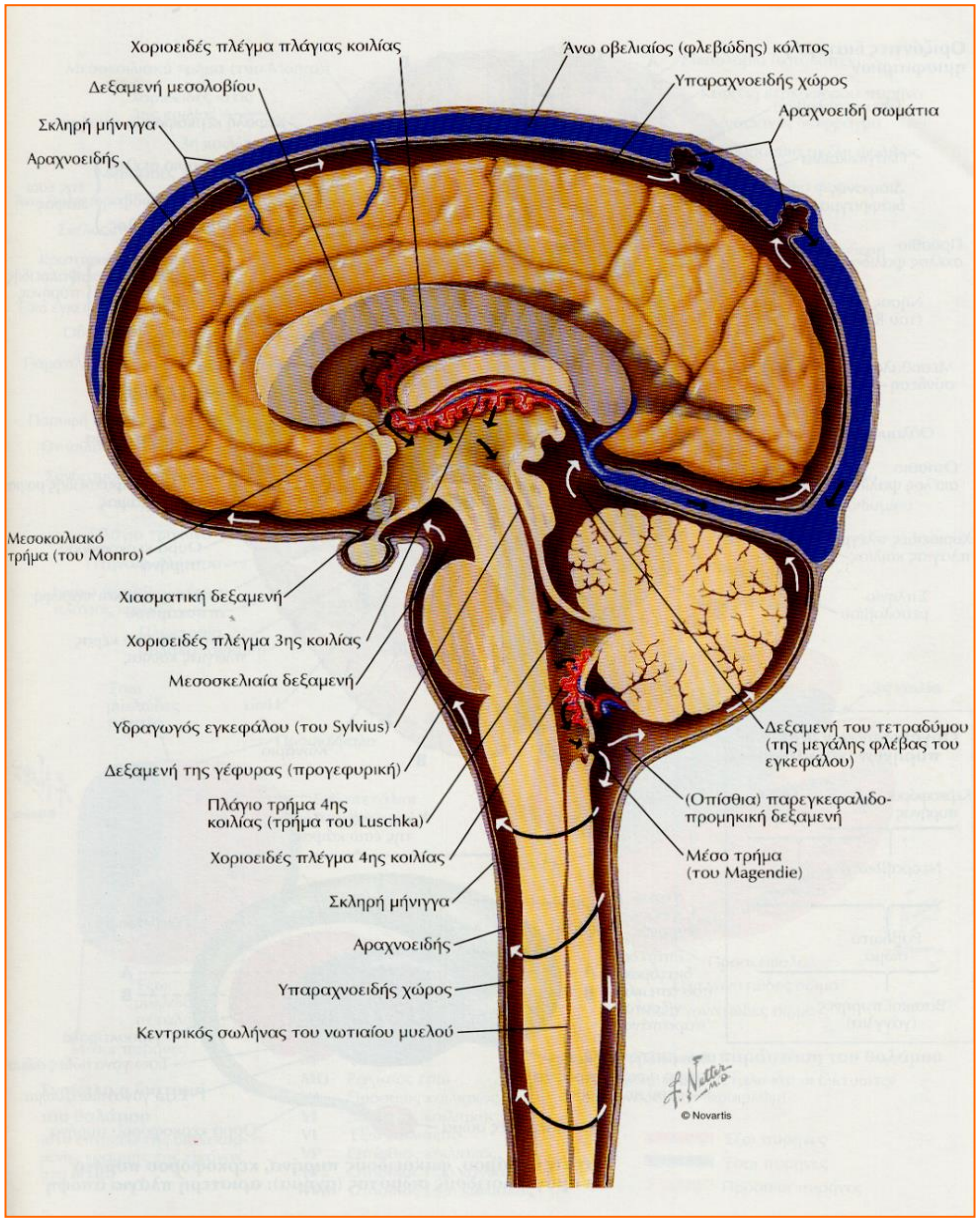
- Brain and Spinal Cord
- “Command Central”
- PNS (Peripheral Nervous System) are nerves that go out to targets in body



# Μήνιγγες και Επιπολής Εγκεφαλικές Φλέβες

*ΓΙΑ ΕΝ ΤΩ ΒΑΘΕΙ ΦΛΕΒΕΣ ΕΓΚΕΦΑΛΟΥ ΒΛ. ΕΙΚΟΝΑ 138*




Χοριοειδές πλέγμα πλάγιας κοιλίας
Άνω οβελιαίος (φλεβώδης) κόλπος
Δεξαμενή μεσολοβίου
Υπαραχνοειδής χώρος
Σκληρή μήνιγγα
Αραχνοειδή σωμάτια
Αραχνοειδής
Μεσοκοιλιακό τρήμα (του Monro)
Χιασματική δεξαμενή
Χοριοειδές πλέγμα 3ης κοιλίας
Μεσοσκελιαία δεξαμενή
Υδραγωγός εγκεφάλου (του Sylvius)
Δεξαμενή της γέφυρας (προγεφυρική)
Δεξαμενή του τετραδύμου (της μεγάλης φλέβας του εγκεφάλου)
Πλάγιο τρήμα 4ης κοιλίας (τρήμα του Luschka)
(Οπίσθια) παρεγκεφαλιδο-προμηκική δεξαμενή
Χοριοειδές πλέγμα 4ης κοιλίας
Μέσο τρήμα (του Magendie)
Σκληρή μήνιγγα
Αραχνοειδής
Υπαραχνοειδής χώρος
Κεντρικός σωλήνας του νωτιαίου μυελού
© Novartis

The **central canal** of the spinal cord and the **four ventricles** of the brain are hollow, since they are derived from the dorsal embryonic nerve cord.

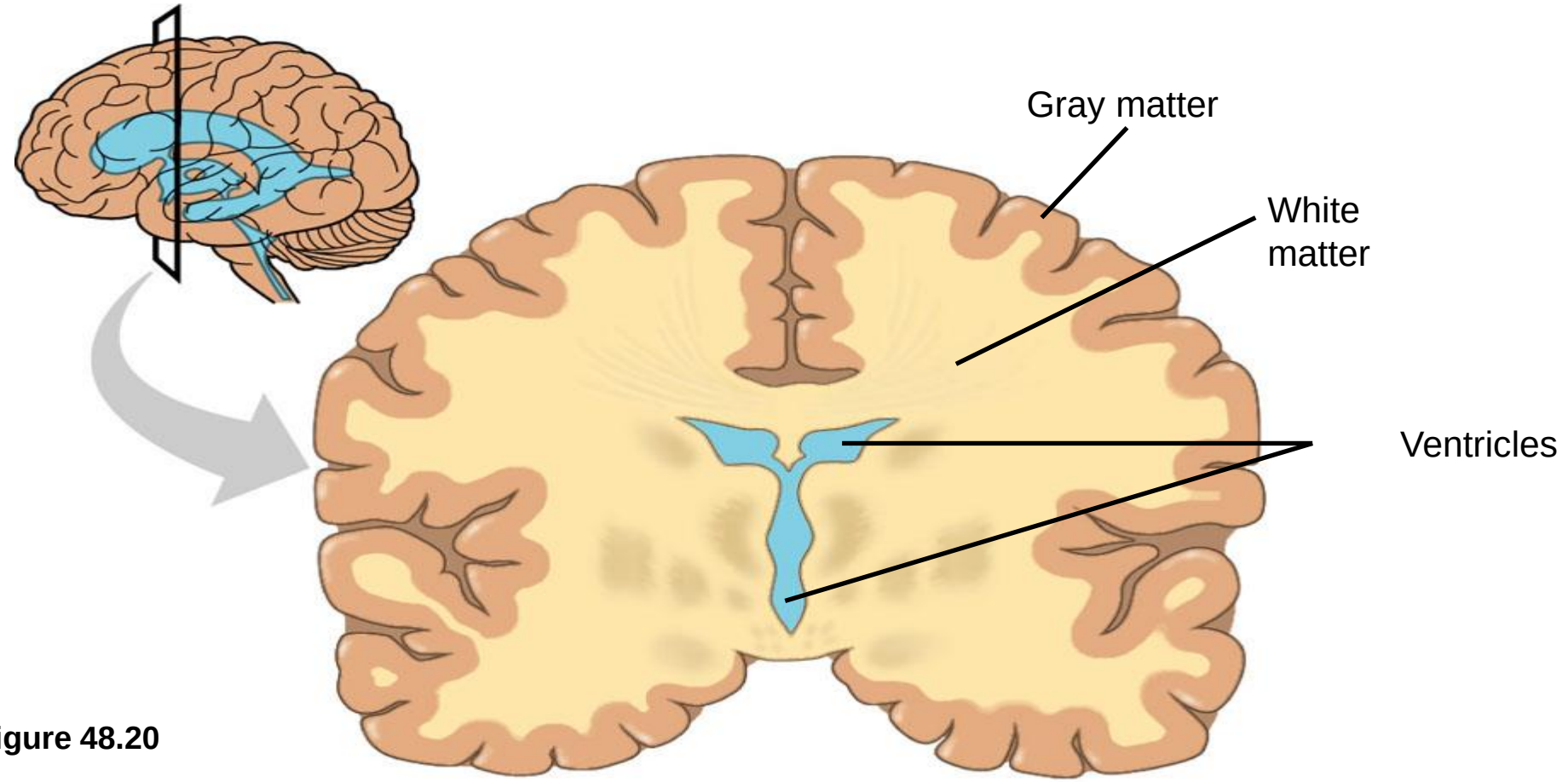
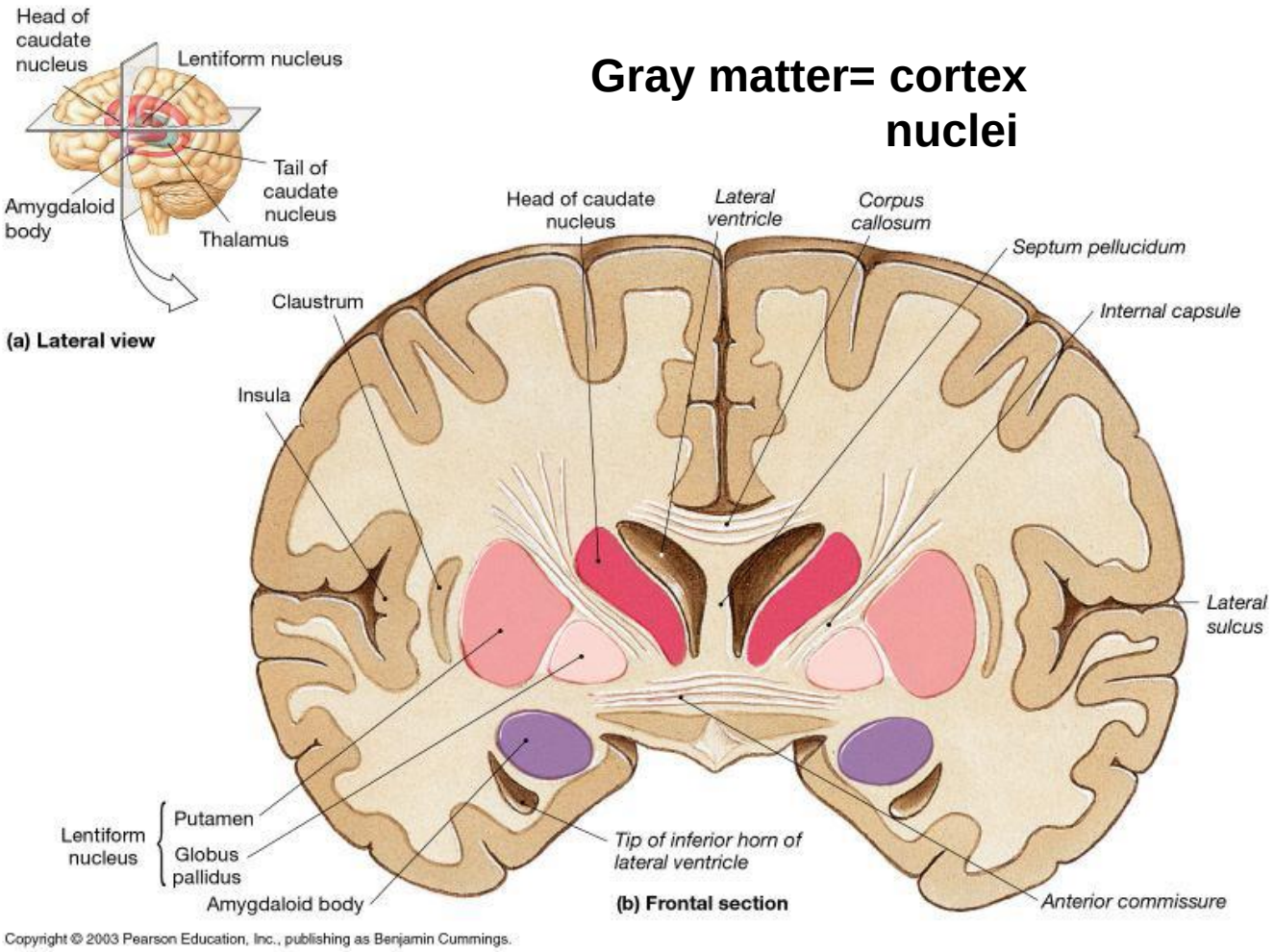



**Figure 48.20**

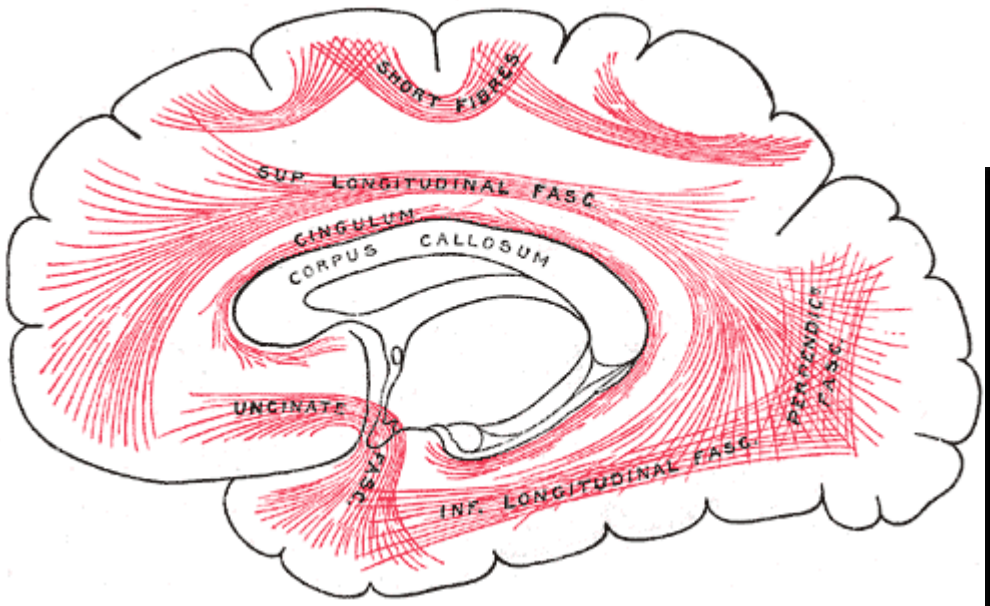
e human brain
otograph by Fred Hossler/Getty Images

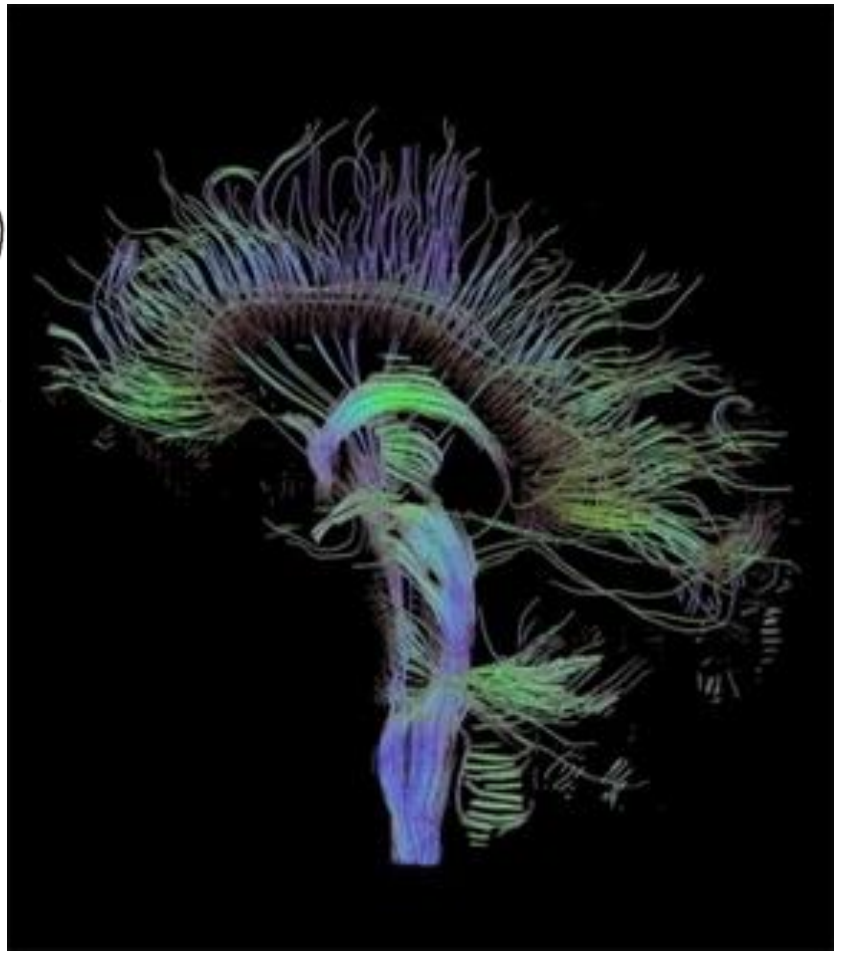
NATIONA
GEOGRAP

# Gray matter= cortex nuclei



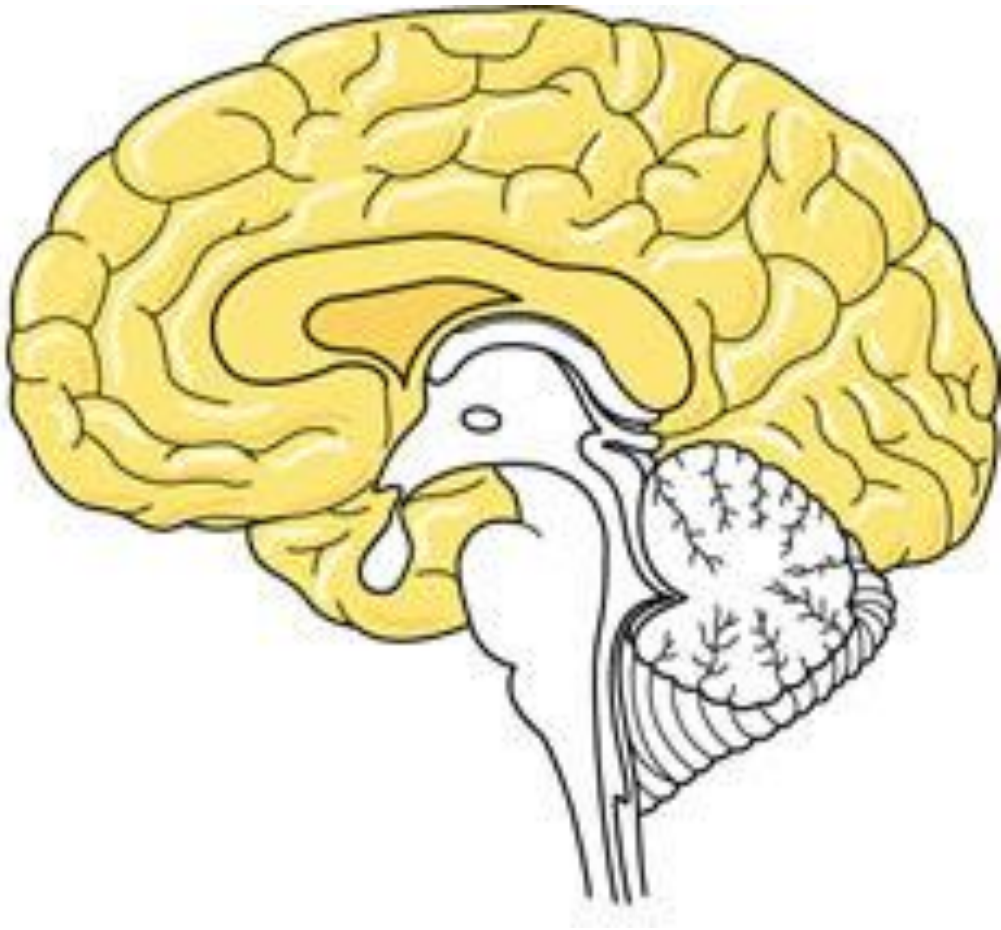
# White matter



# The Cerebrum

- The cerebrum
  - develops from the embryonic telencephalon.



- The cerebrum has **right and left cerebral hemispheres**
  - that each consist of cerebral cortex overlying white matter and basal nuclei.

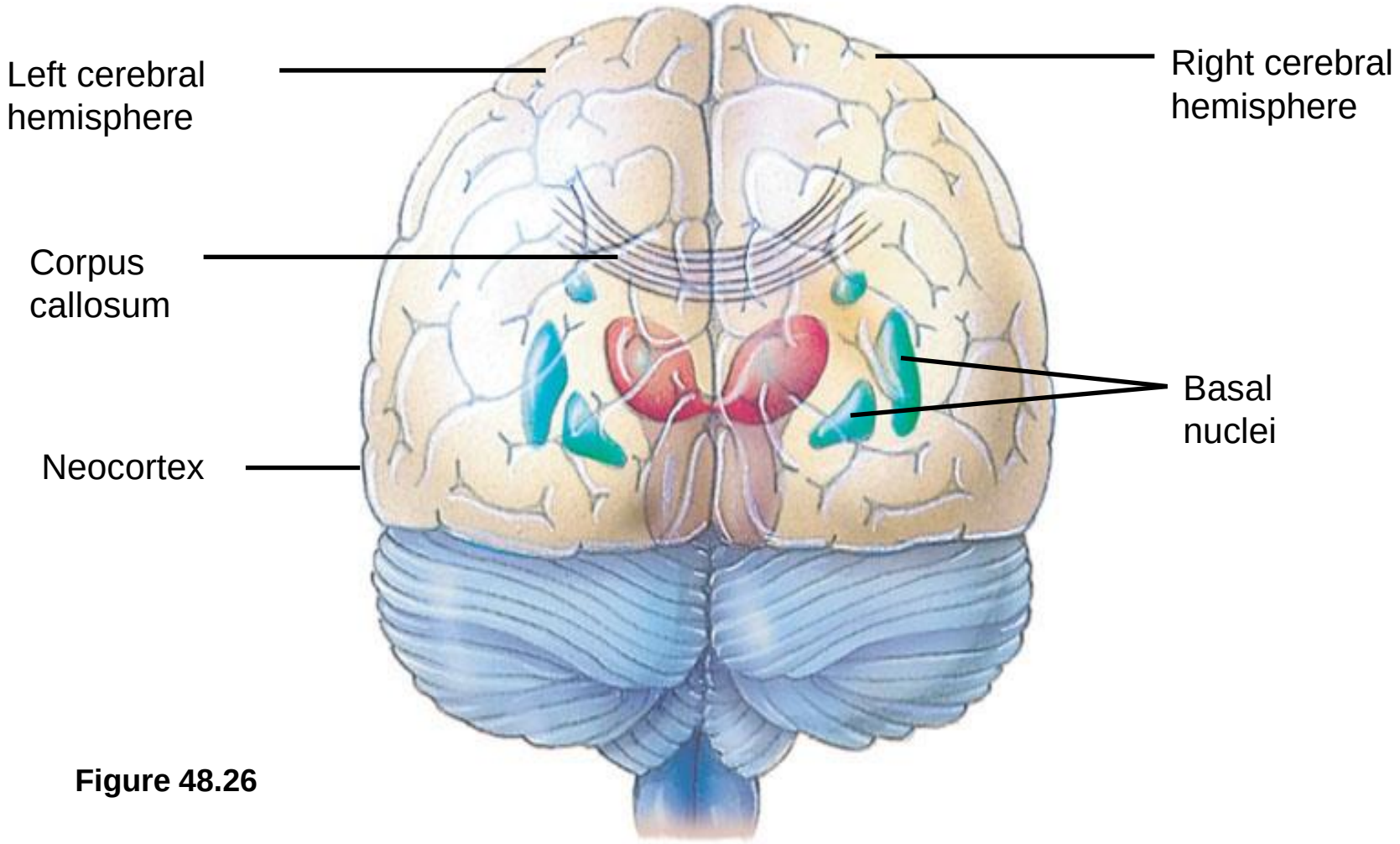



**Figure 48.26**

*In humans,*
*the largest and most complex part of the brain*
*Is the cerebral cortex, where*

*sensory information is analyzed,*

*motor commands are issued, and language is generated.*

- A thick band of axons, the **corpus callosum**
  - provides communication between the right and left cerebral cortices.
- The **basal nuclei**
  - are important centers for planning and learning movement sequences.
- In mammals
  - the cerebral cortex has a convoluted surface called the neocortex.

- The cerebral cortex controls voluntary movement and cognitive functions.
- Each side of the cerebral cortex has four lobes:
  - Frontal, parietal, temporal, and occipital.

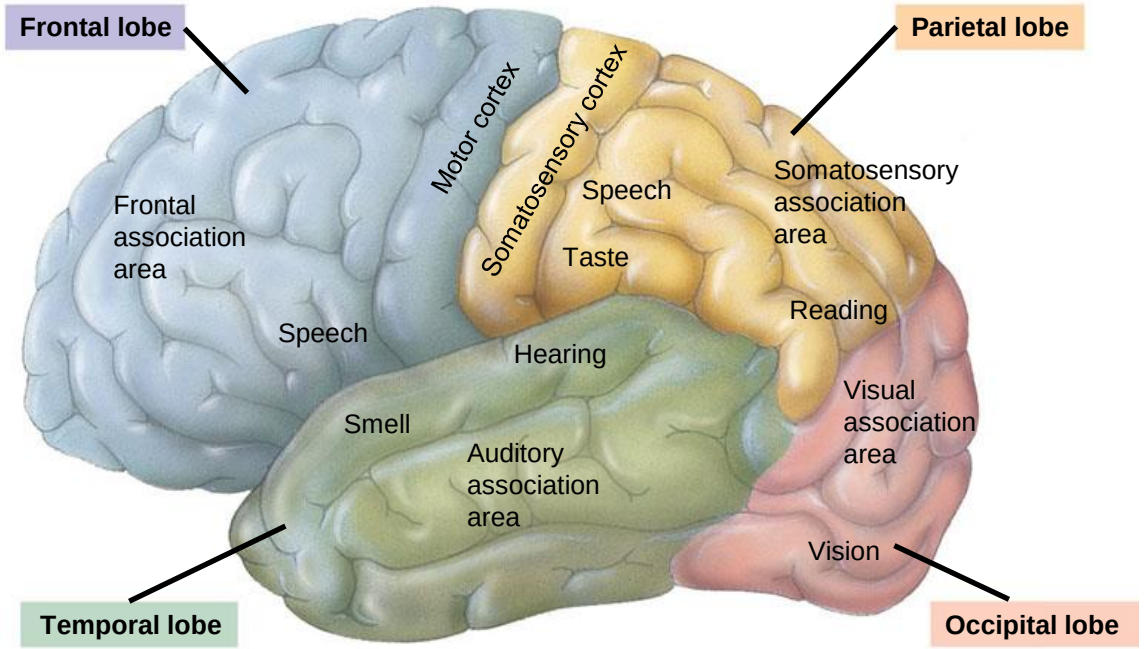



**Figure 48.27**

- In the somatosensory cortex and motor cortex:
  - Neurons are distributed according to the part of the body that generates sensory input or receives motor input.

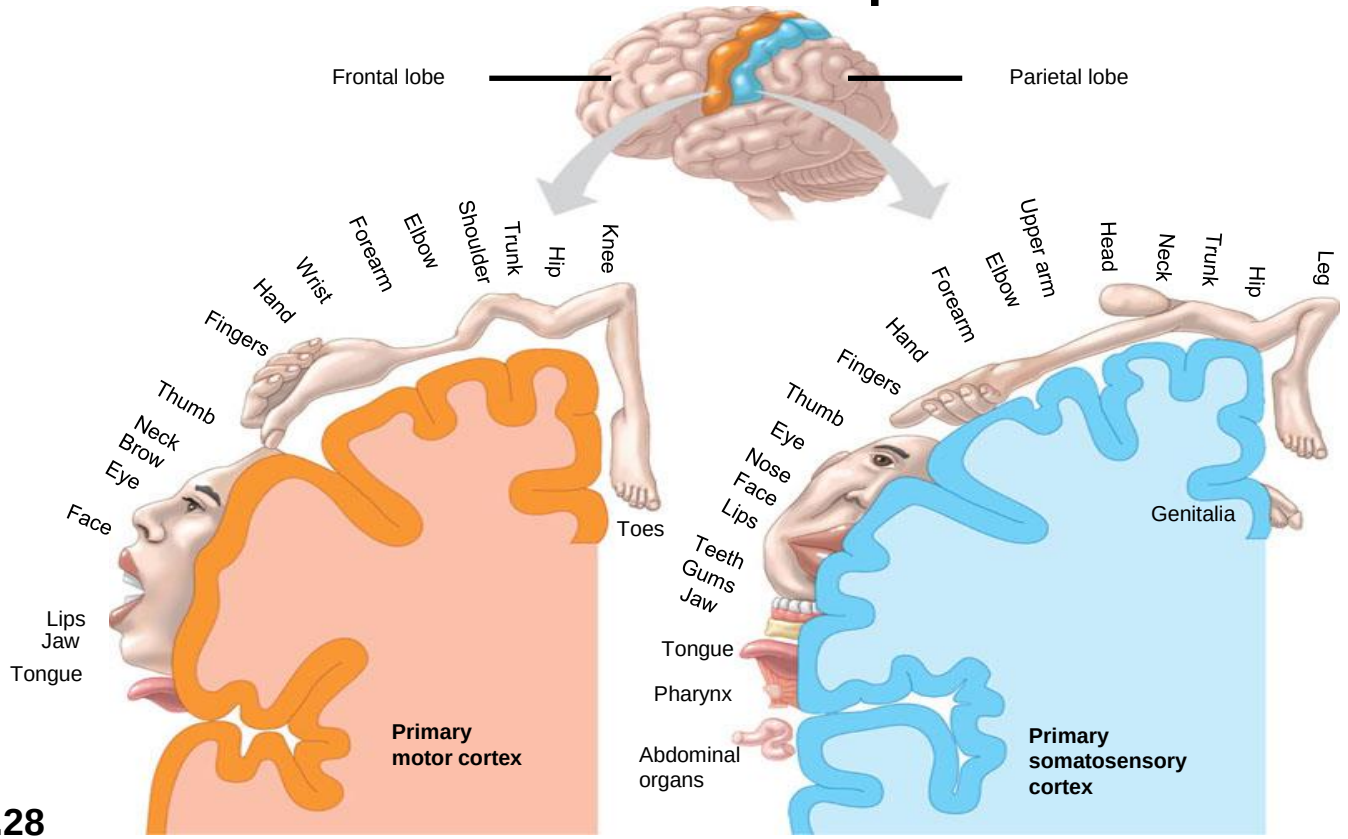



**Figure 48.28**

- During brain development, in a process called *lateralization*
  - Competing functions segregate and displace each other in the cortex of the left and right cerebral hemispheres.
- The left hemisphere
  - Becomes more adept **at language, math, logical operations, and the processing of serial sequences.**
- The right hemisphere
  - Is stronger at pattern recognition, nonverbal **thinking, and emotional processing.**

# Language and Speech

- Studies of brain activity
  - Have mapped specific areas of the brain responsible for language and speech.

Portions of the frontal lobe, Broca's area and Wernicke's are essential for the generation and understanding of language.

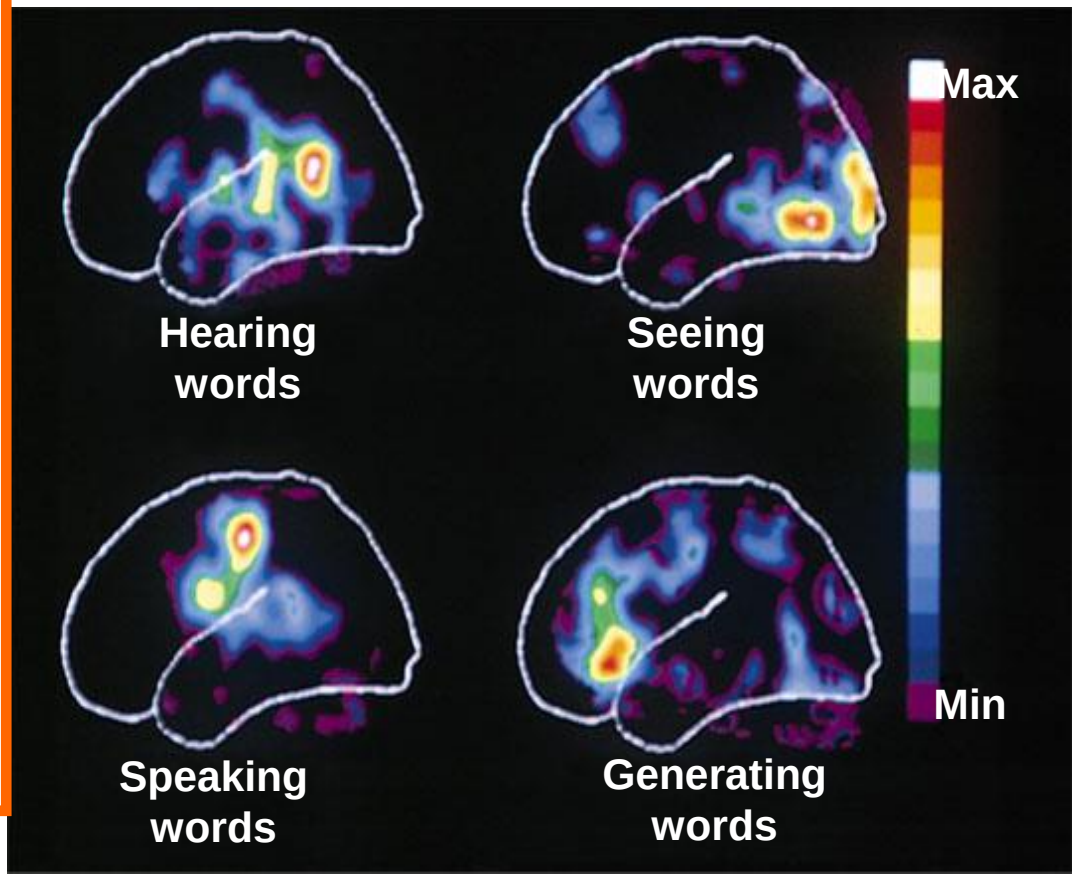
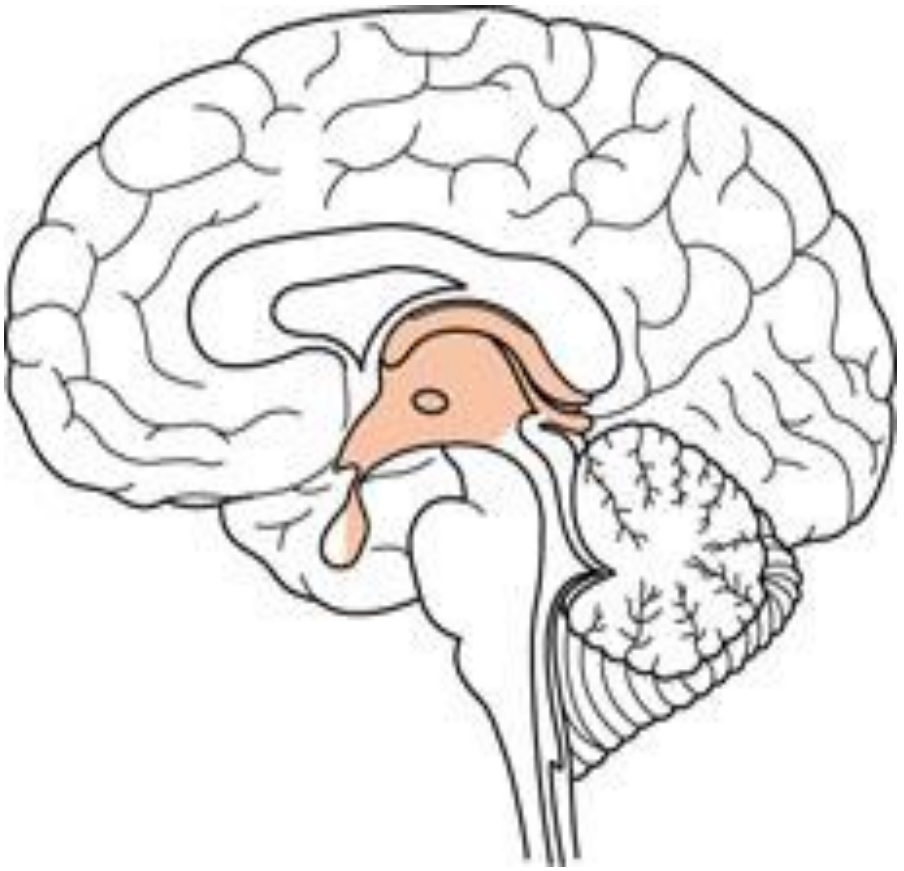



**Figure 48.29**

# The Diencephalon

- The embryonic diencephalon develops into three adult brain regions
  - the epithalamus, thalamus, and hypothalamus.



- The **epithalamus**
  - includes the pineal gland and the choroid plexus.

- **The thalamus**
  is the **main input center for sensory** information going to the cerebrum and the main output center for motor information leaving the cerebrum.

- The **hypothalamus** regulates

  Homeostasis
  Basic survival behaviors such as feeding, fighting, fleeing, and reproducing.

# Emotions

- The limbic system
  - is a ring of structures around the brainstem.

***Structures of the limbic system form in early development and provide a foundation for emotional memory, associating emotions with particular events or experiences.***

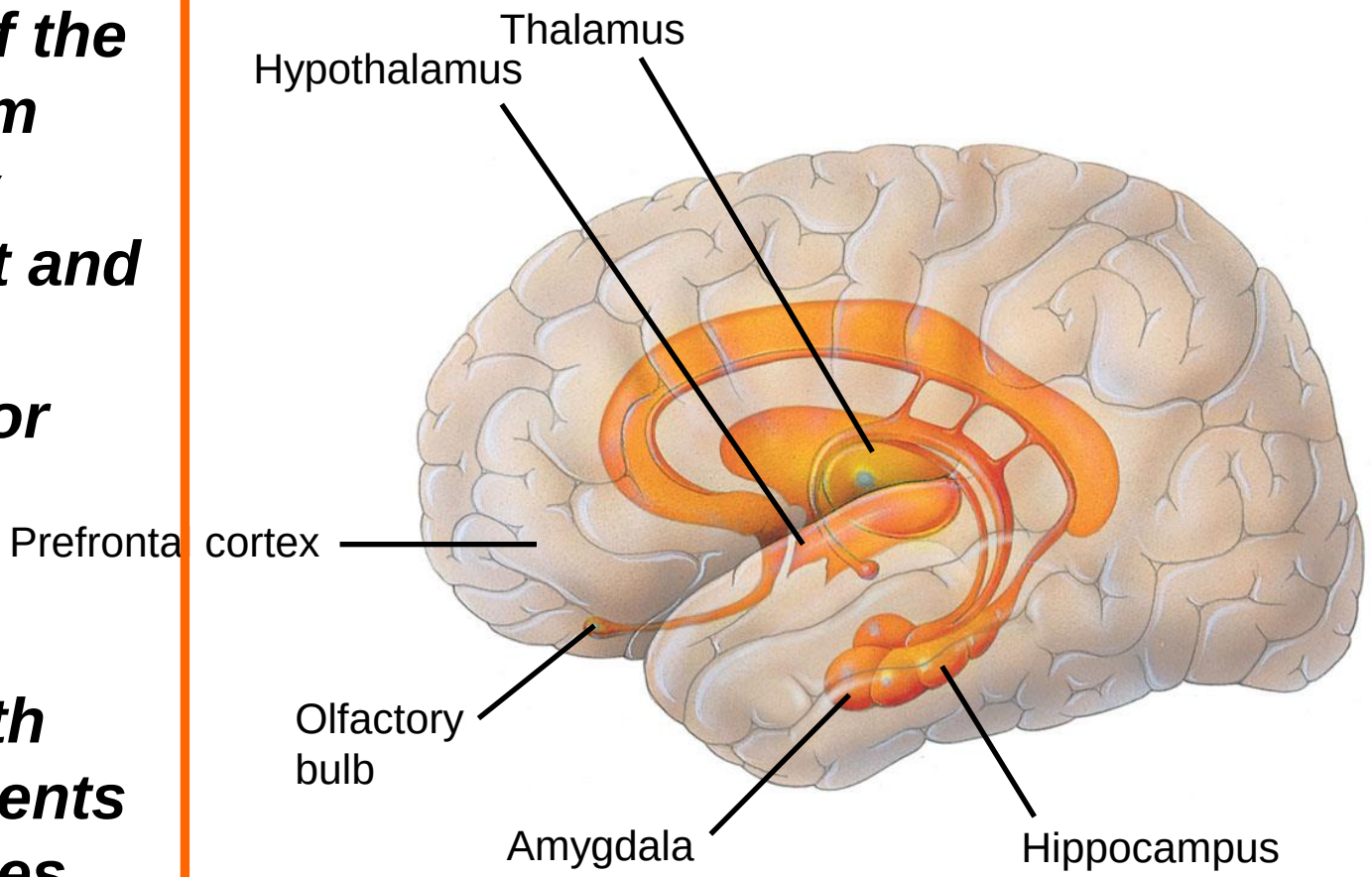
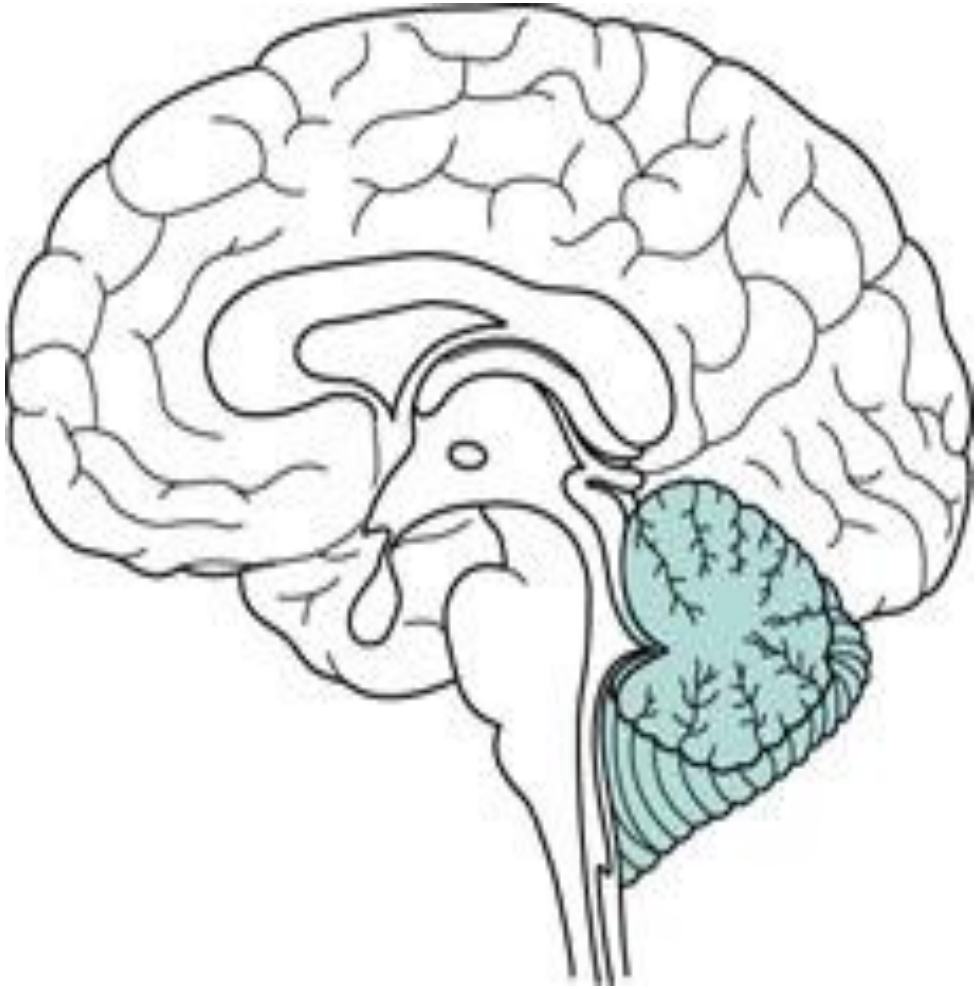



**Figure 48.30**

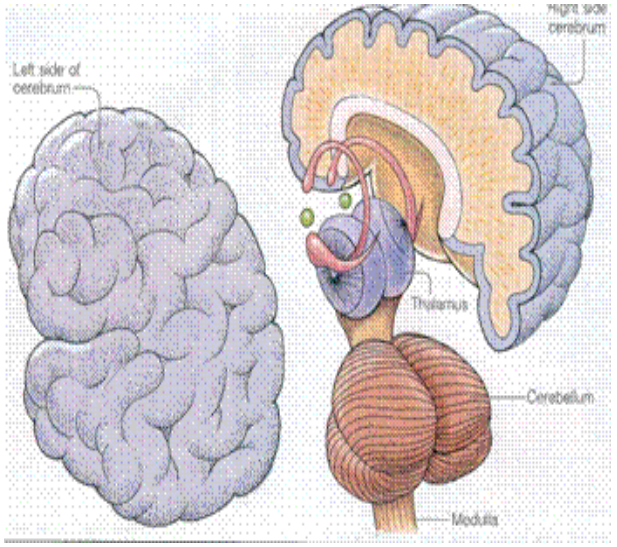
# The Cerebellum

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

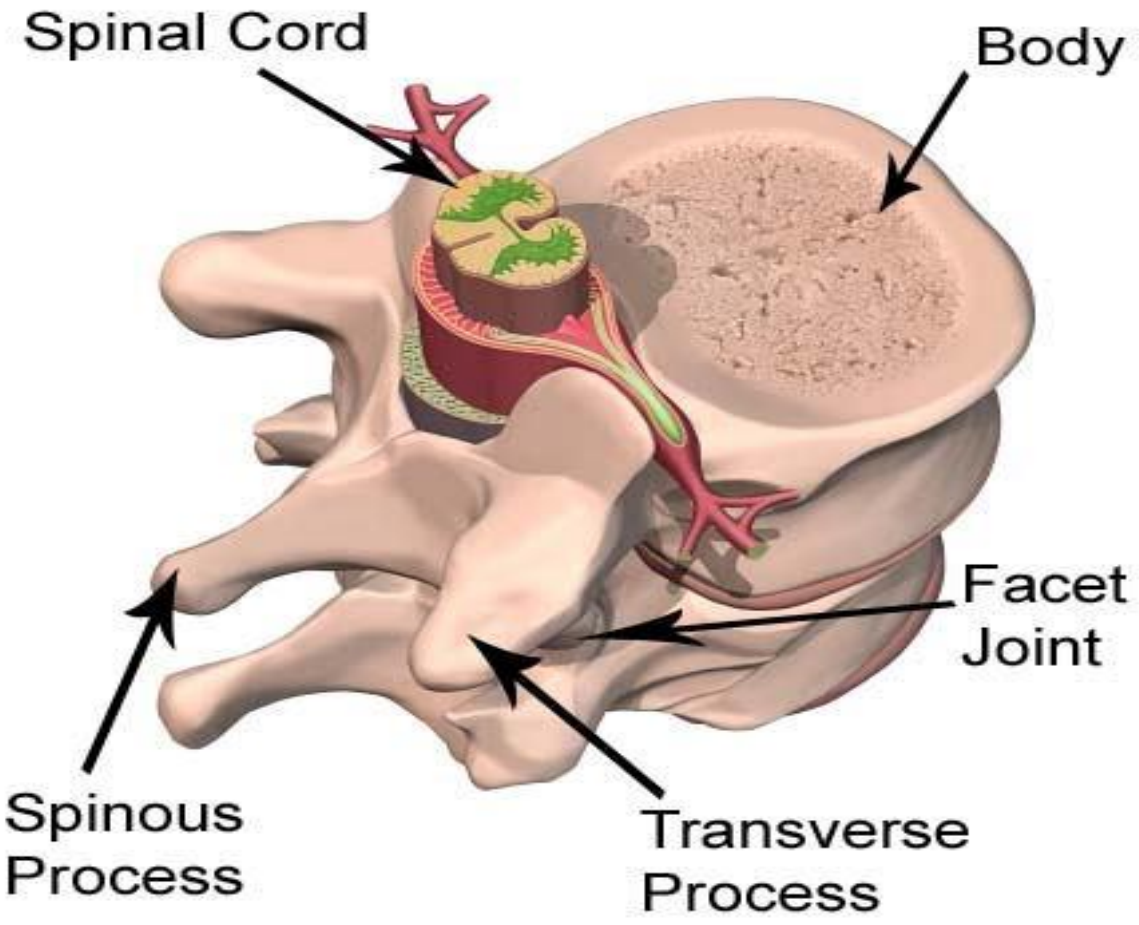


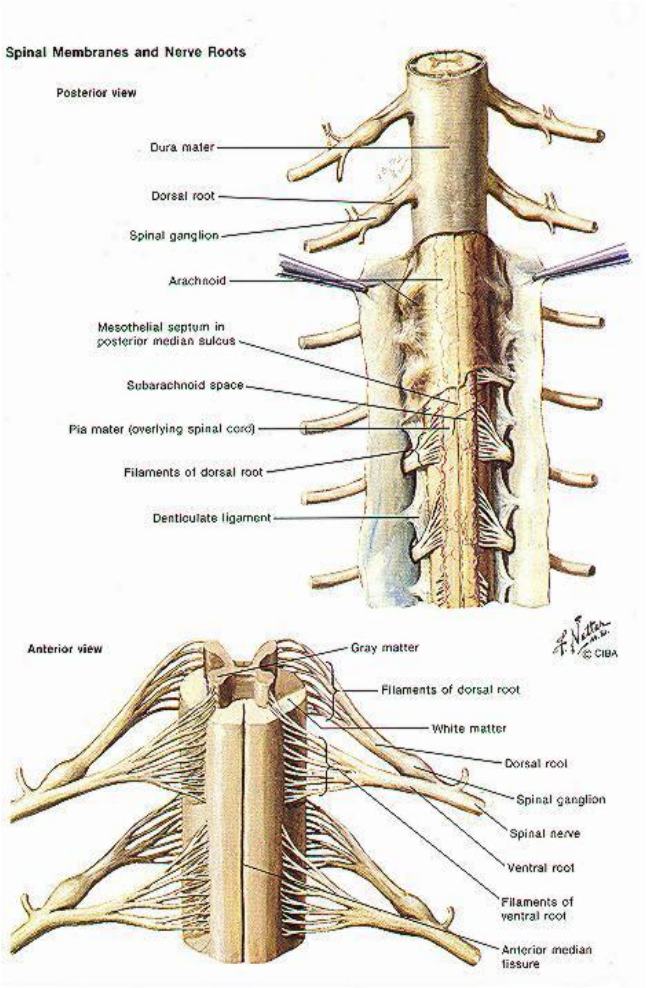
* The Brain Stem connects the brain to the spinal cord.

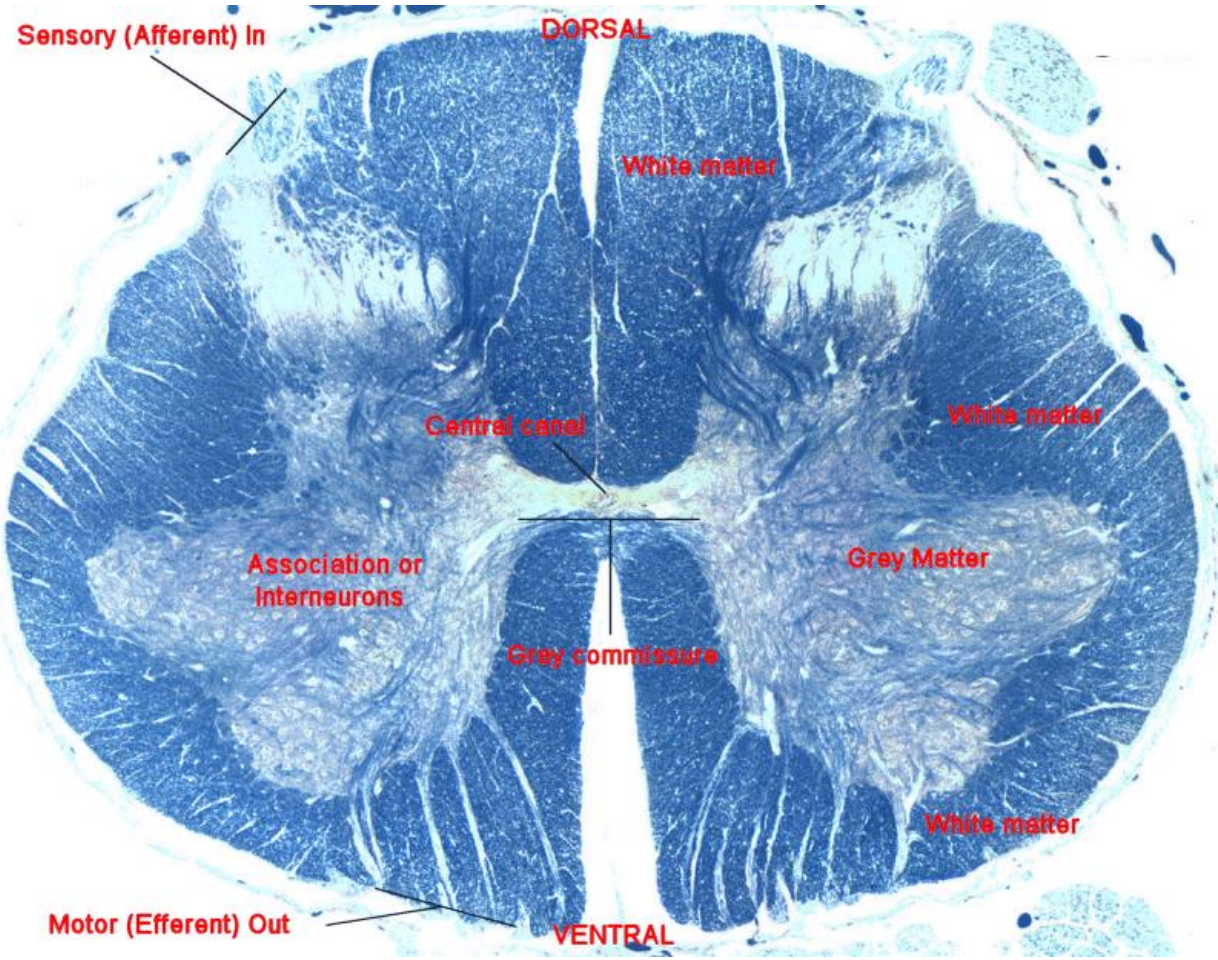
The nerves in the brain stem control your heartbeat, breathing, and blood pressure.



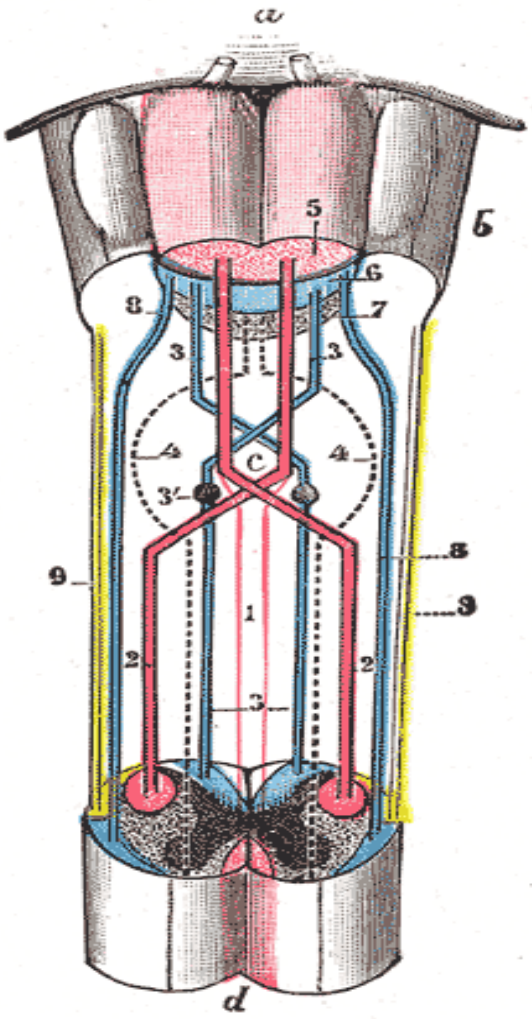
# The spinal level

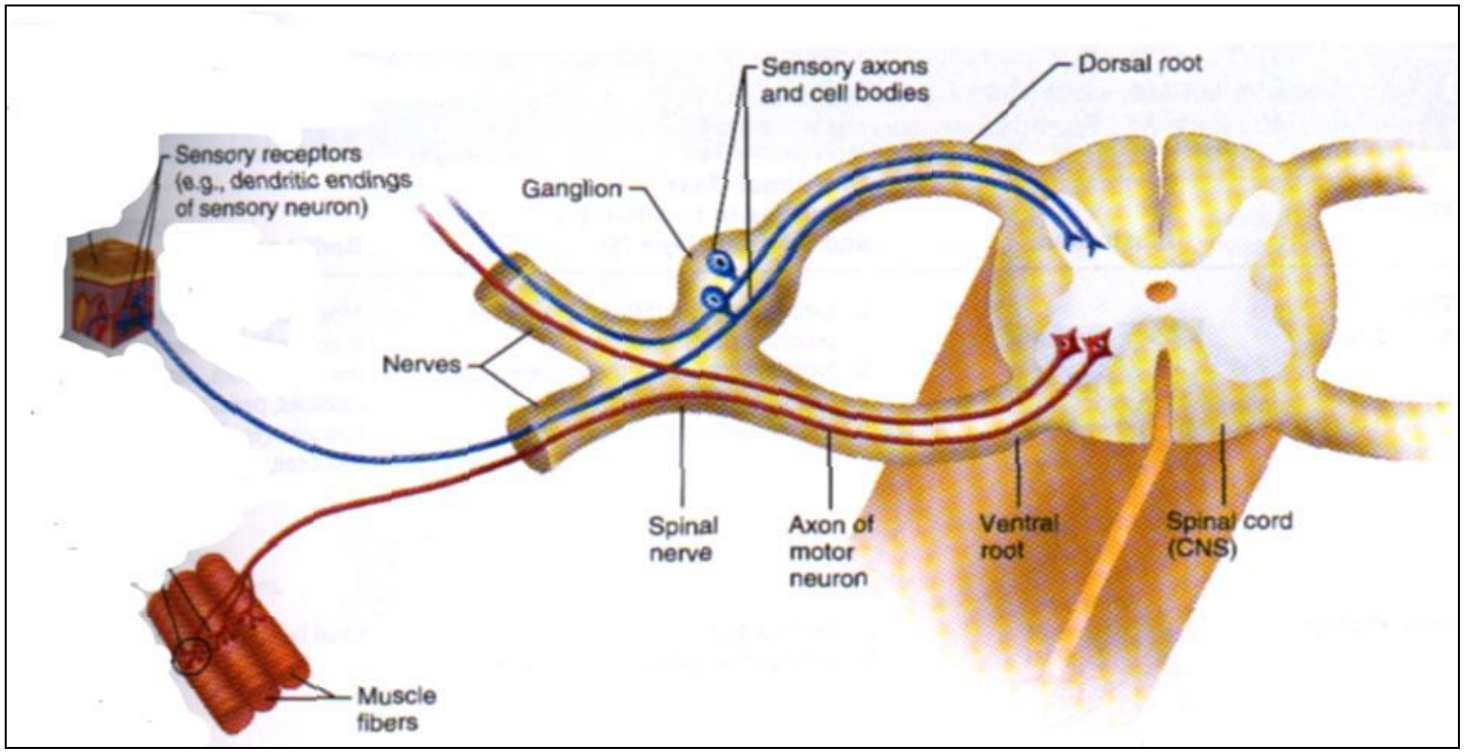



Spinal Membranes and Nerve Roots
Posterior view
Dura mater
Dorsal root
Spinal ganglion
Arachnoid
Mesothelial septum in posterior median sulcus
Subarachnoid space
Pia mater (overlying spinal cord)
Filaments of dorsal root
Denticulate ligament
Anterior view
Gray matter
Filaments of dorsal root
White matter
Dorsal root
Spinal ganglion
Spinal nerve
Ventral root
Filaments of ventral root
Anterior median fissure
© CIBA

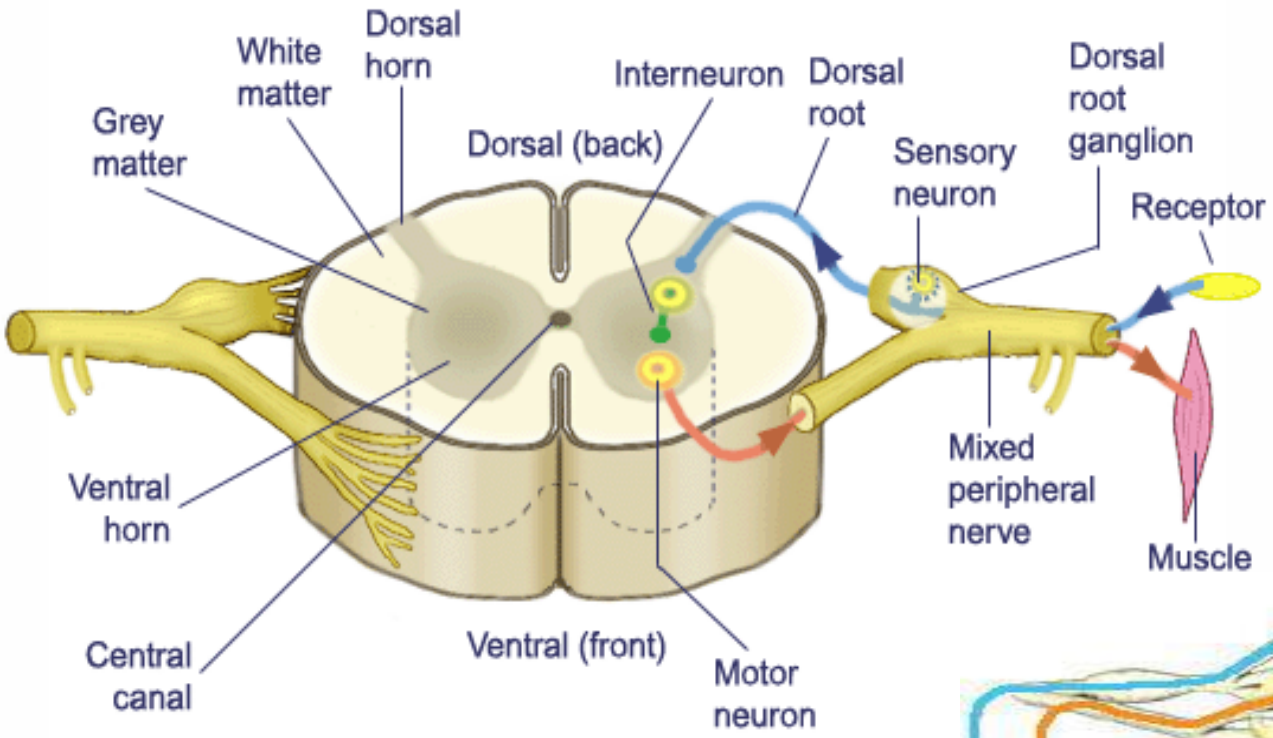

Sensory (Afferent) In
DORSAL
White matter
Central canal
White matter
Association or Interneurons
Grey Matter
Grey commissure
White matter
Motor (Efferent) Out
VENTRAL

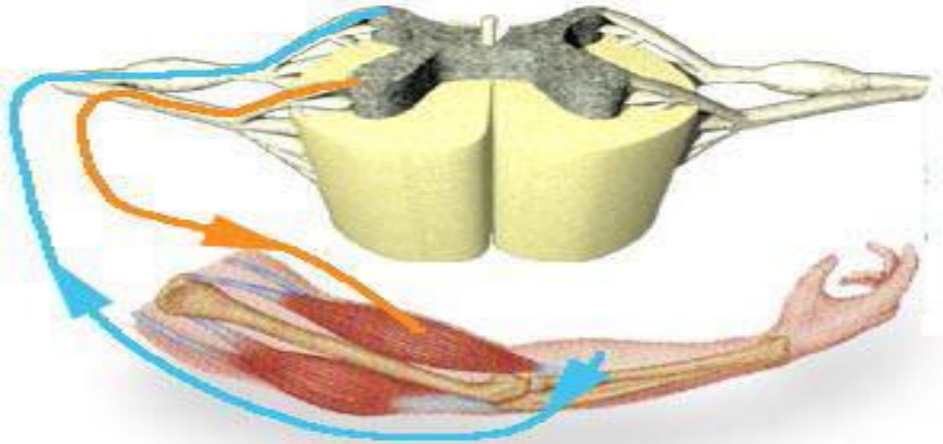
tracts

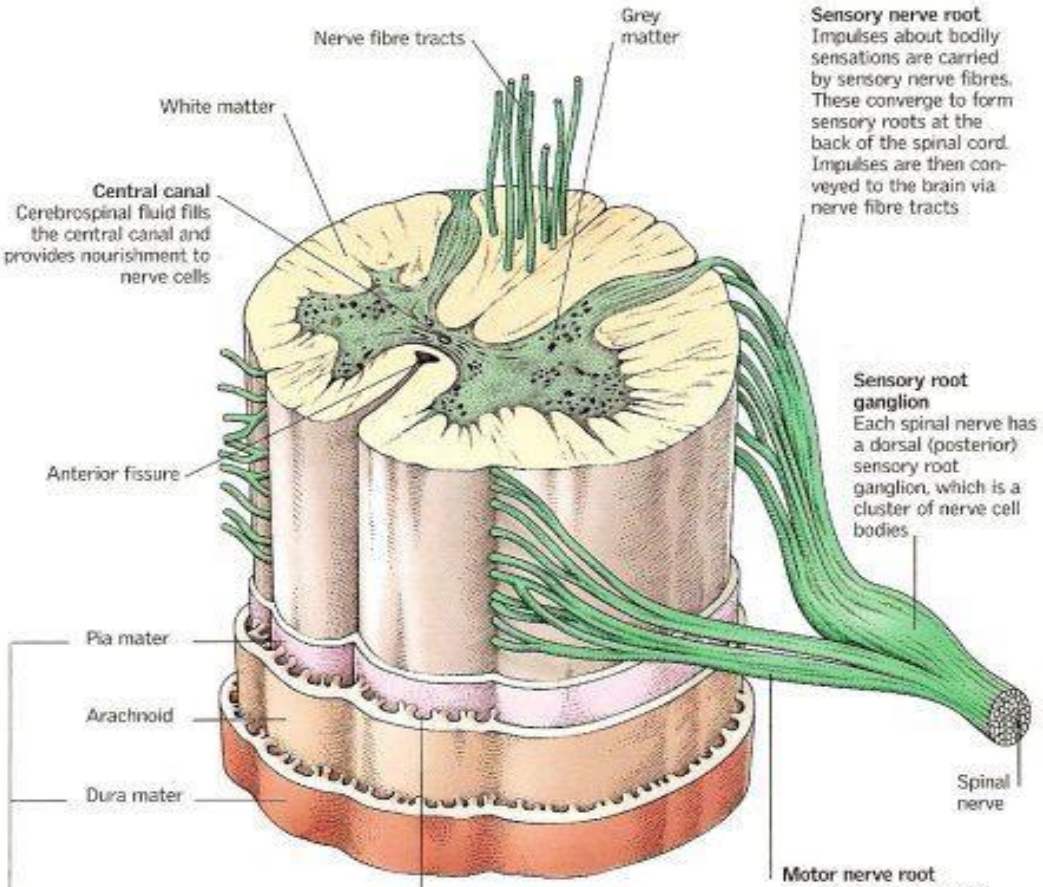




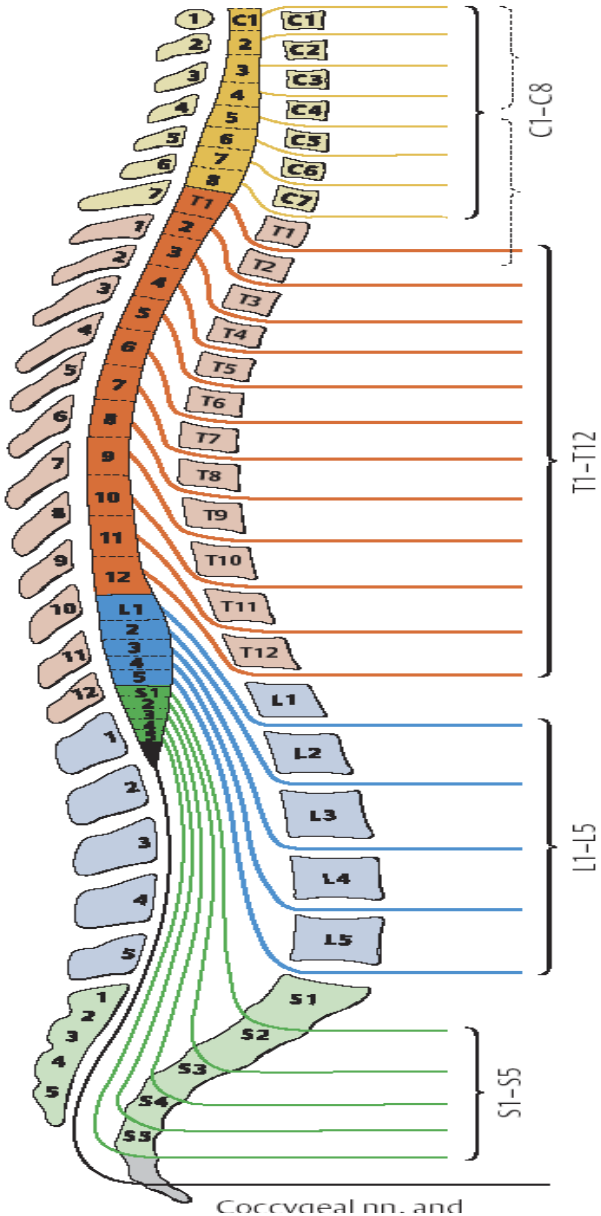

***The spinal nerves originate in the spinal cord and extend to parts of the body below the head.***






Structure of spinal cord



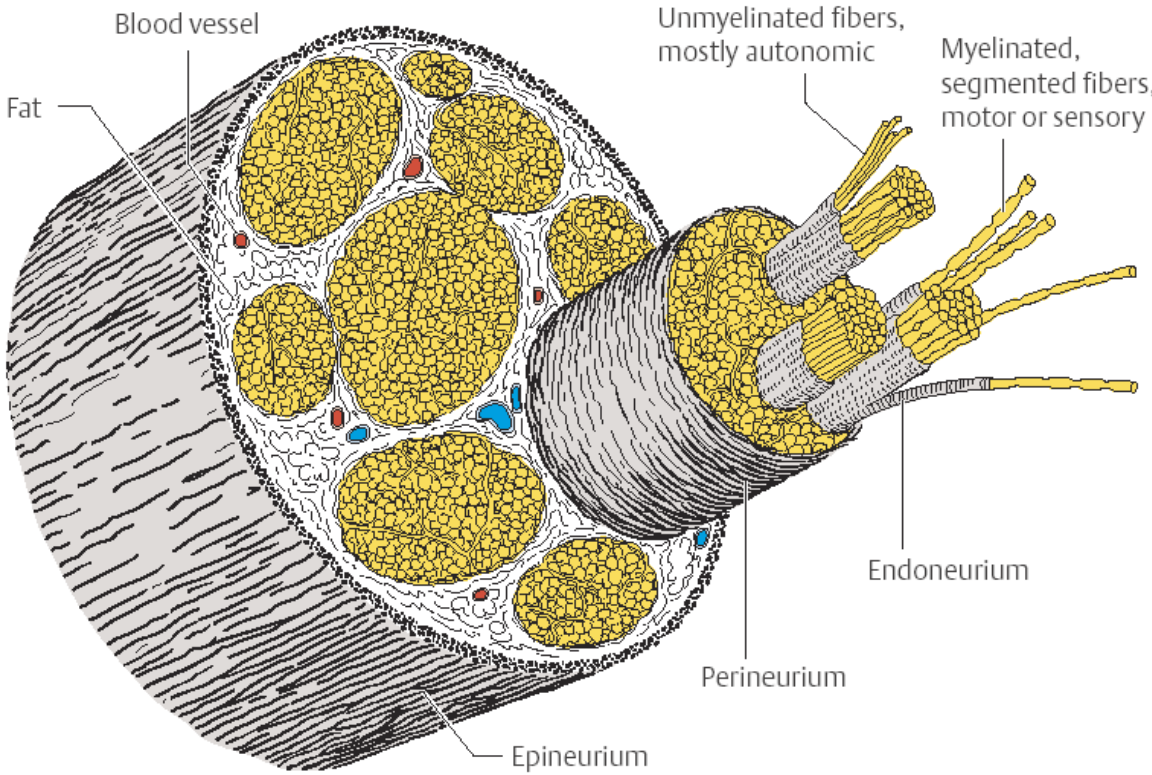




Fig. 2.**3 Cross section of a mixed peripheral nerve**

# Peripheral Nervous System (PNS)

- All nerves that leave the CNS
- Two Modalities:

Sensory/Afferent → Somatic
Visceral/Autonomic
(info. In)

Motor/Efferent → Somatic
Visceral/Autonomic
--smooth mm.
--heart
--glands
(commands out)

Parasympathetic
Sympathetic

# The PNS can be divided into two functional components: The **somatic nervous system** and the **autonomic nervous system.**

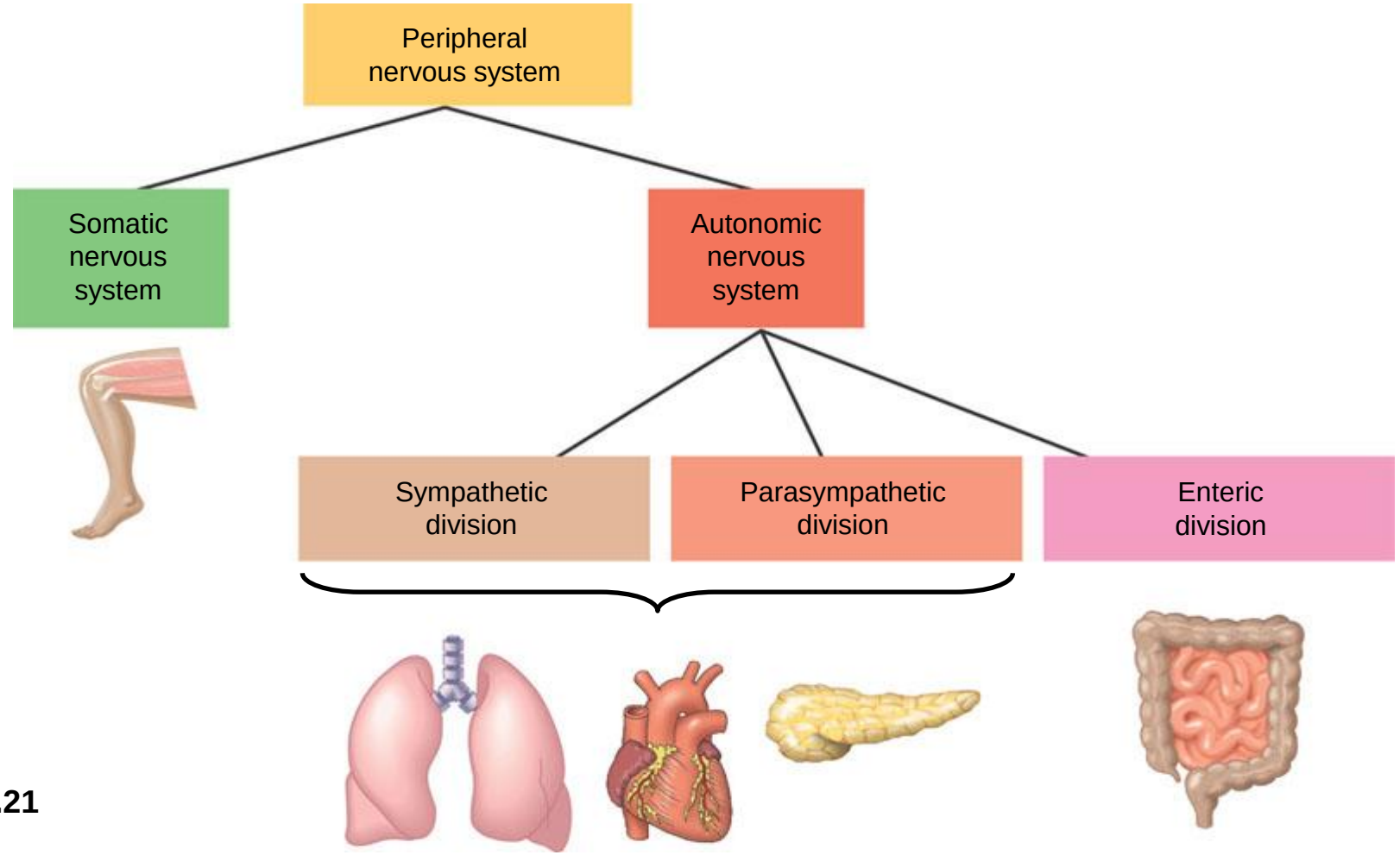



**Figure 48.21**

- The somatic nervous system
  - carries signals to skeletal muscles.

- The autonomic nervous system
  - regulates the internal environment, in an involuntary manner,
  - is divided into the sympathetic, parasympathetic, and enteric divisions.

# Autonomic and Somatic Motor Systems

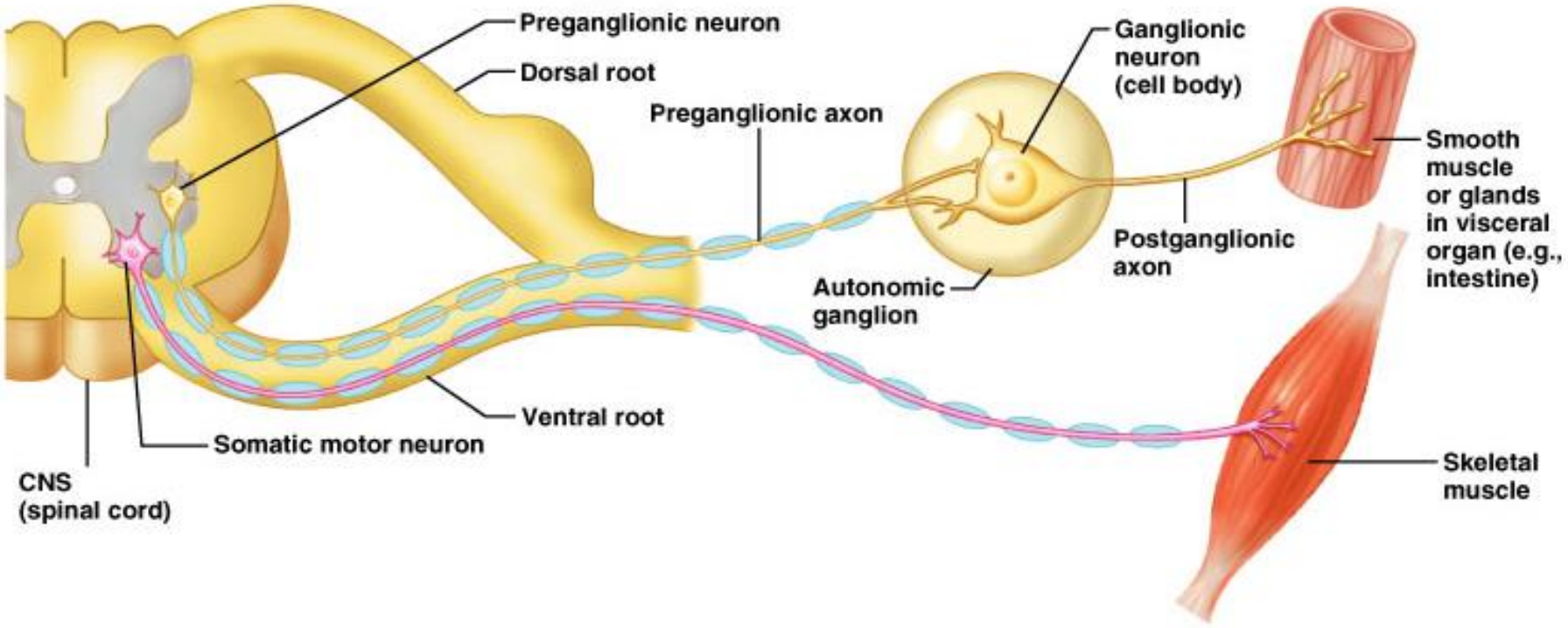





**Figure 15.2**

# Divisions of the Autonomic Nervous System

- Sympathetic and parasympathetic divisions
  - Innervate mostly the same structures
  - Cause opposite effects

# Divisions of the Autonomic Nervous System

- Sympathetic – “fight, flight, or fright”
  - Activated during exercise, excitement, and emergencies
- Parasympathetic – “rest and digest”
  - Concerned with conserving energy

# Anatomical Differences in Sympathetic and Parasympathetic Divisions

- Issue from different regions of the CNS
  - Sympathetic – also called the t**horacolumba**r division
  - Parasympathetic – also called the **craniosacral** division

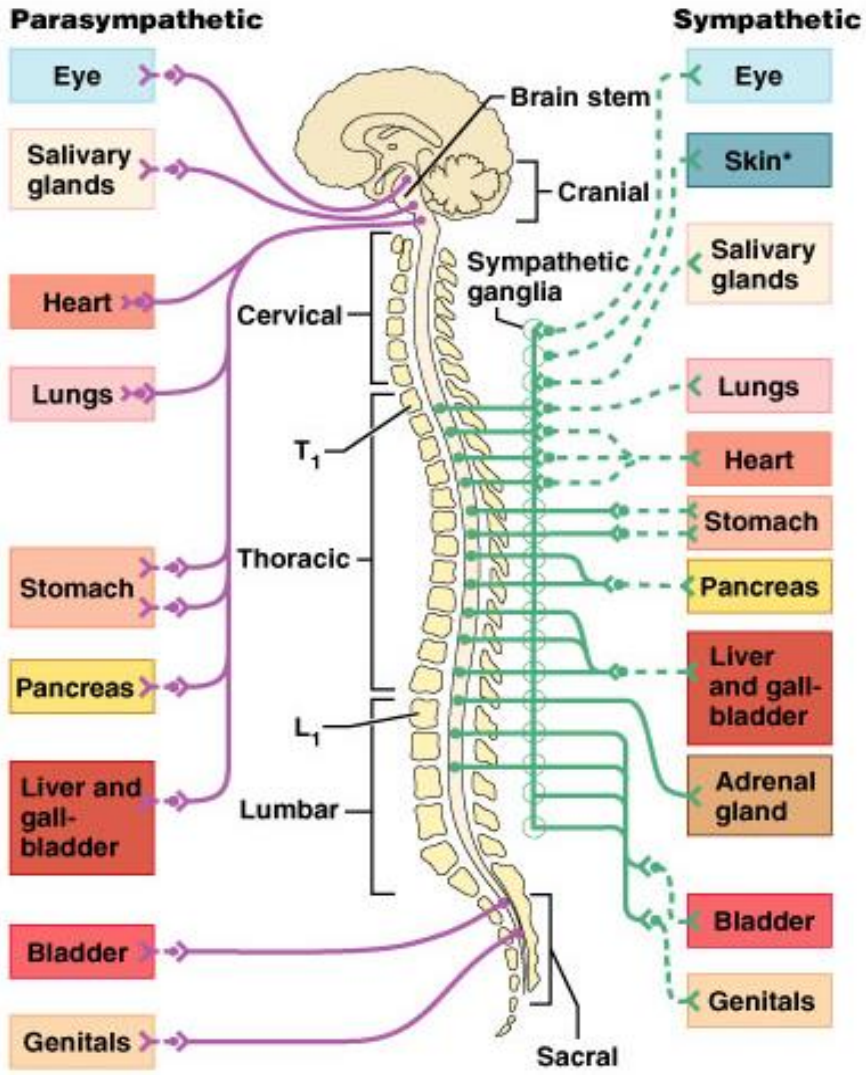



**Figure 15.3**

# Anatomical Differences in Sympathetic and Parasympathetic Divisions

- Length of postganglionic fibers
  - Sympathetic – long postganglionic fibers
  - Parasympathetic – short postganglionic fibers
- Branching of axons
  - Sympathetic axons – highly branched
    - Influences many organs
  - Parasympathetic axons – few branches
    - Localized effect

# The **sympathetic and parasympathetic divisions** have antagonistic effects on target organs.

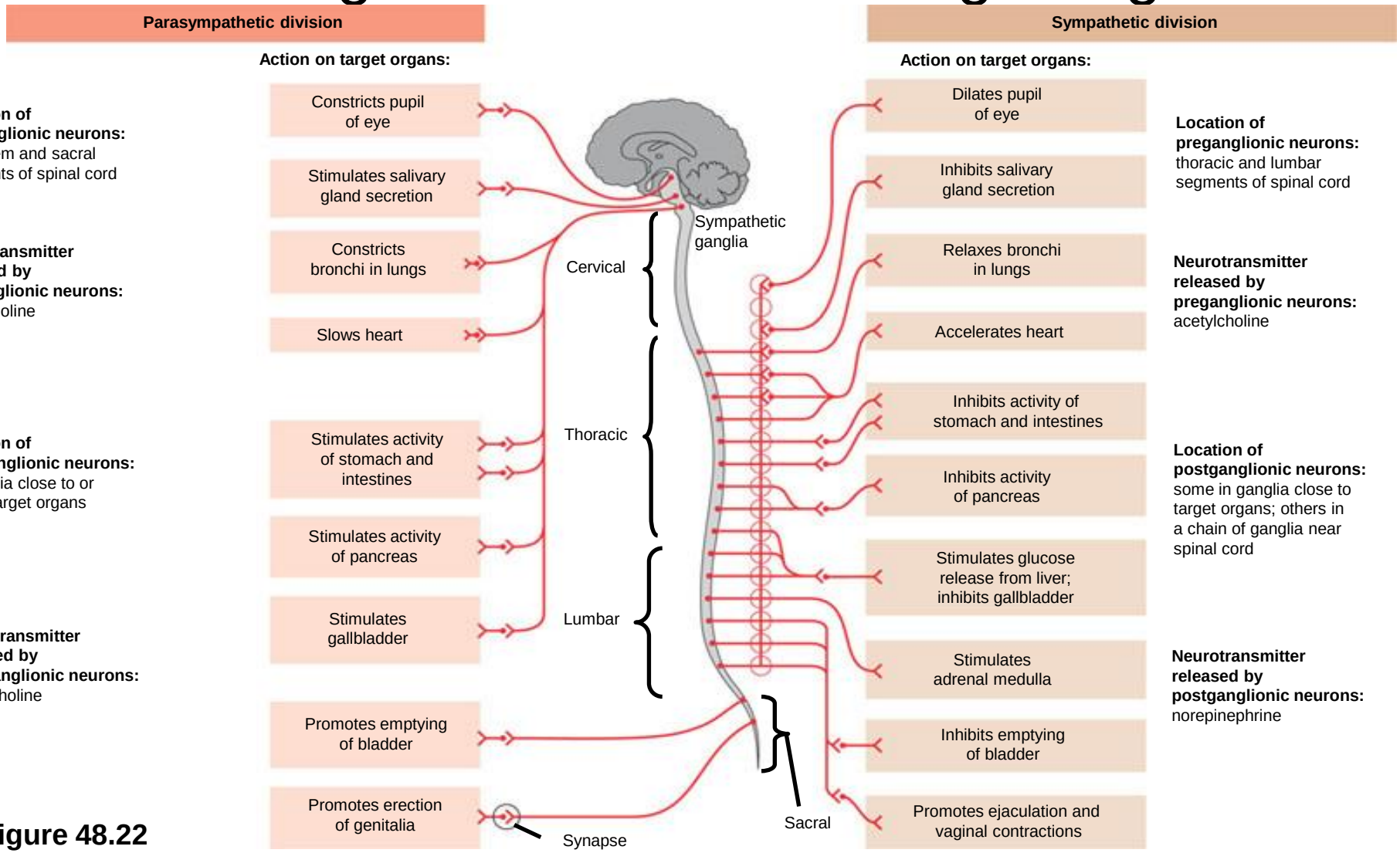
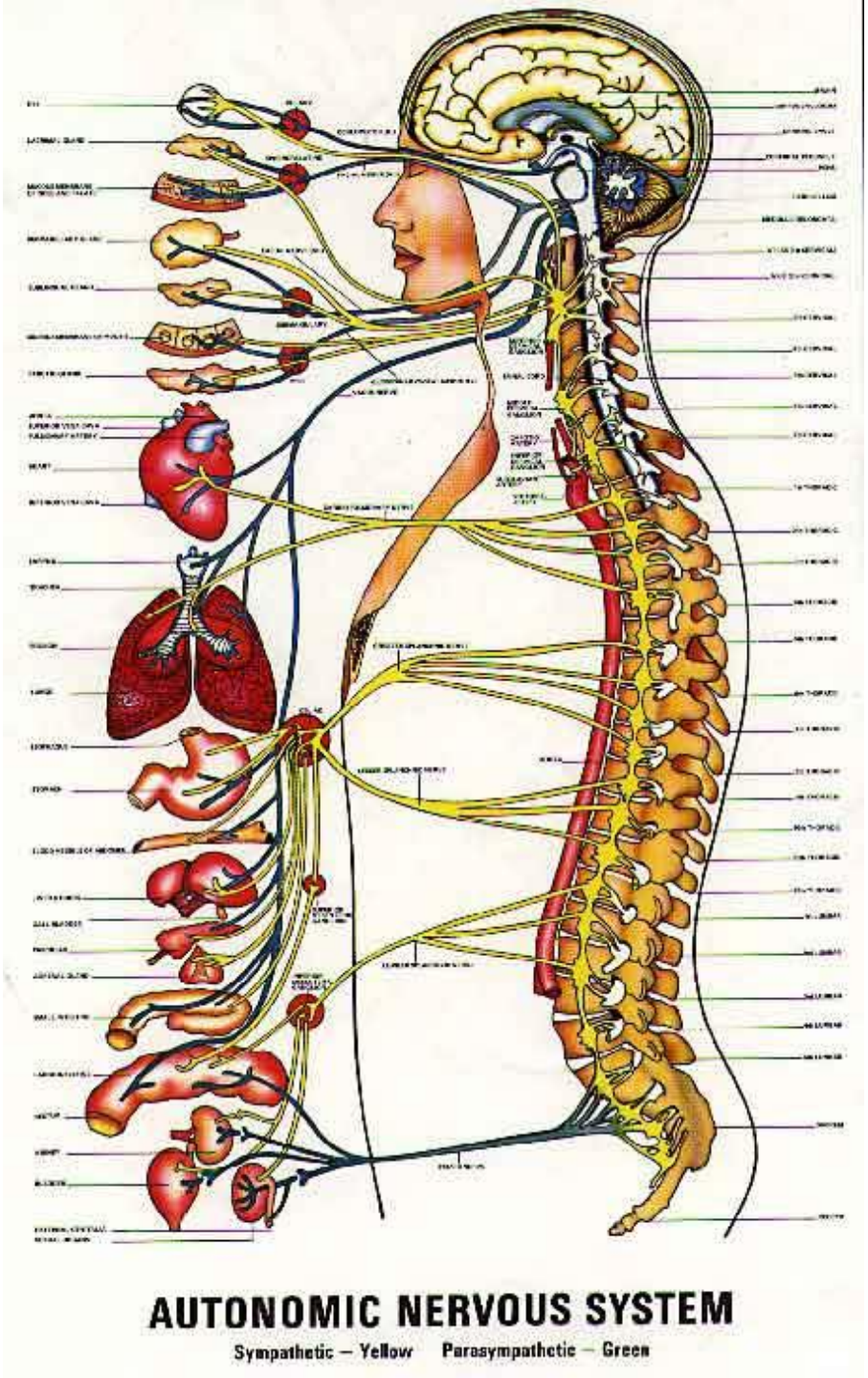



**Figure 48.22**



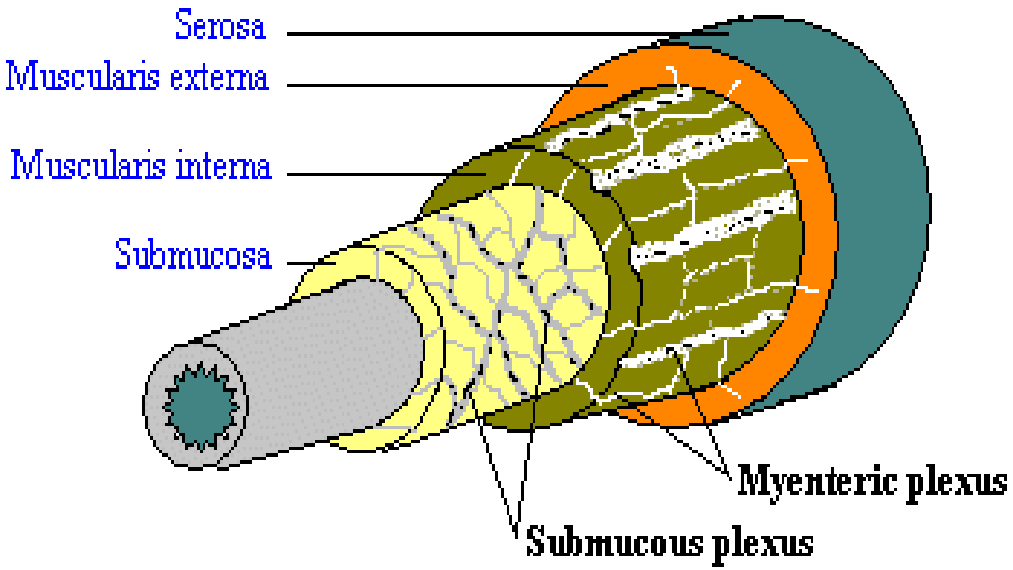

**The *sympathetic division* correlates with the "fight-or-flight" response.**

**The *parasympathetic division* promotes a return to self-maintenance functions.**

# Disorders of the Autonomic Nervous System: Hypertension

- Hypertension – high blood pressure
  - Can result from overactive sympathetic vasoconstriction

- The **enteric division**
  - controls the activity of the digestive tract, pancreas, and gallbladder.



# Interesting Facts !!!

- The left side of the brain controls the right side of the body.
- The right side of the brain controls the left side of the body.
- The brain is full grown by age 6.
- It weighs about 1,4-1,5 kg.
- The brain is made mostly of water (85%).
- Nerves are like telephone lines that send messages. These messages move through the body faster than you can blink your eyes.

***Thank you.***