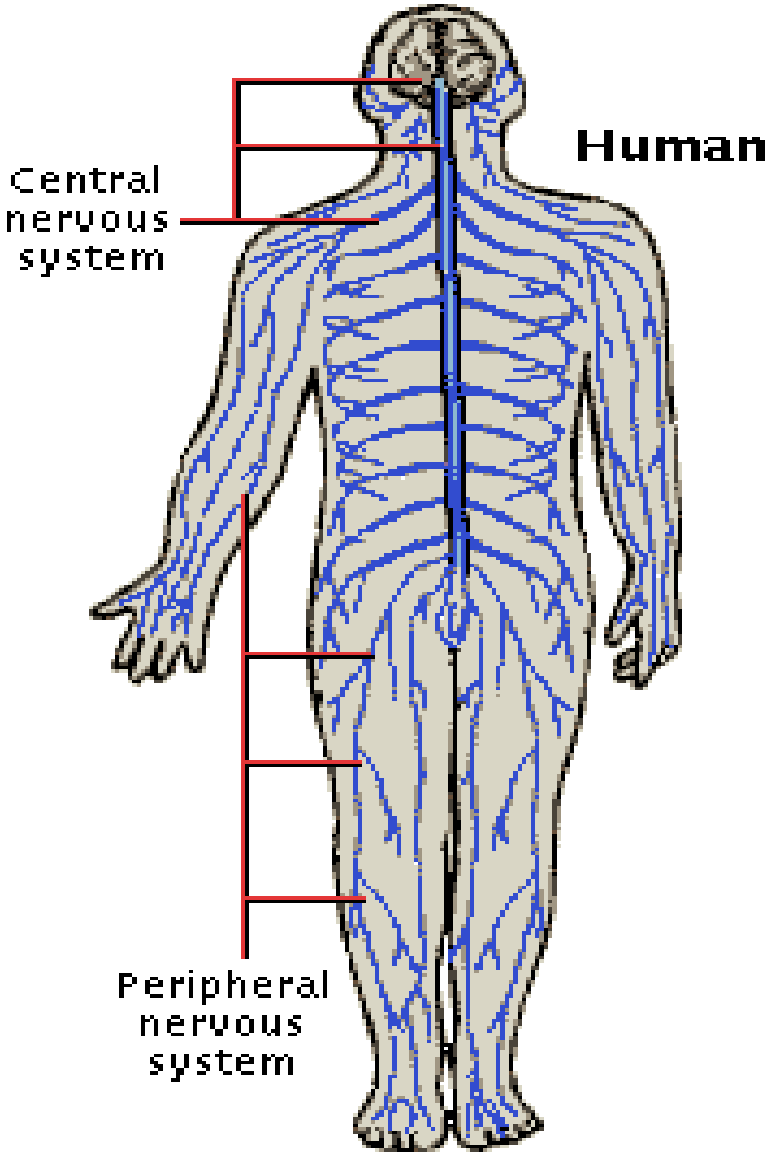
The Nervous System



Martha Assimakopoulou
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.

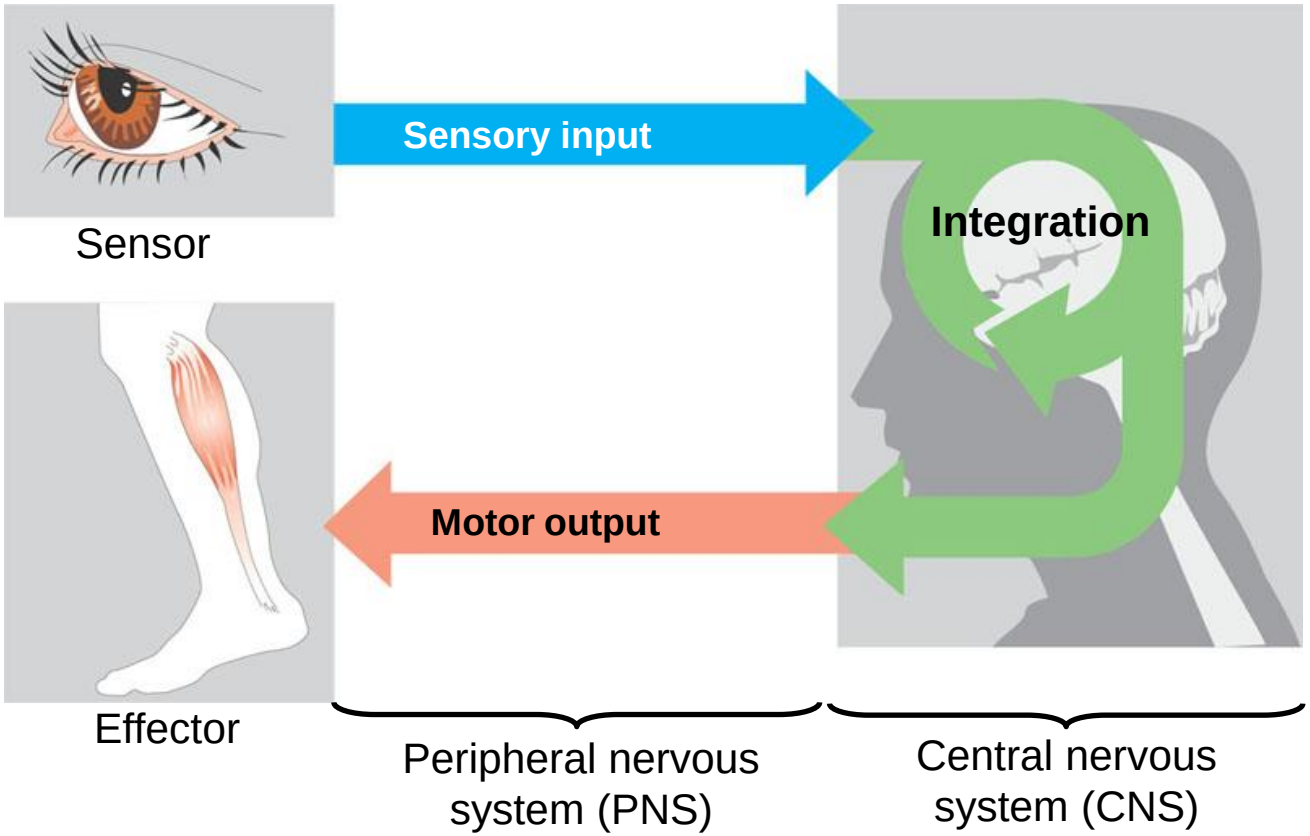


Figure 48.3

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.

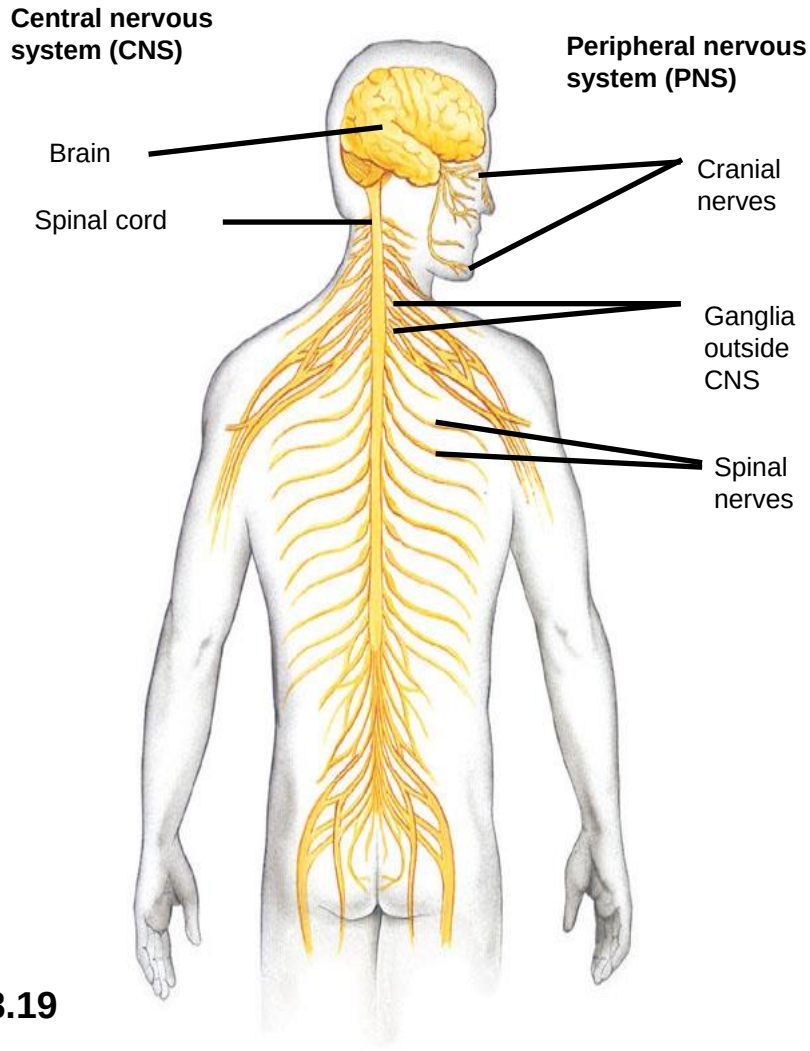
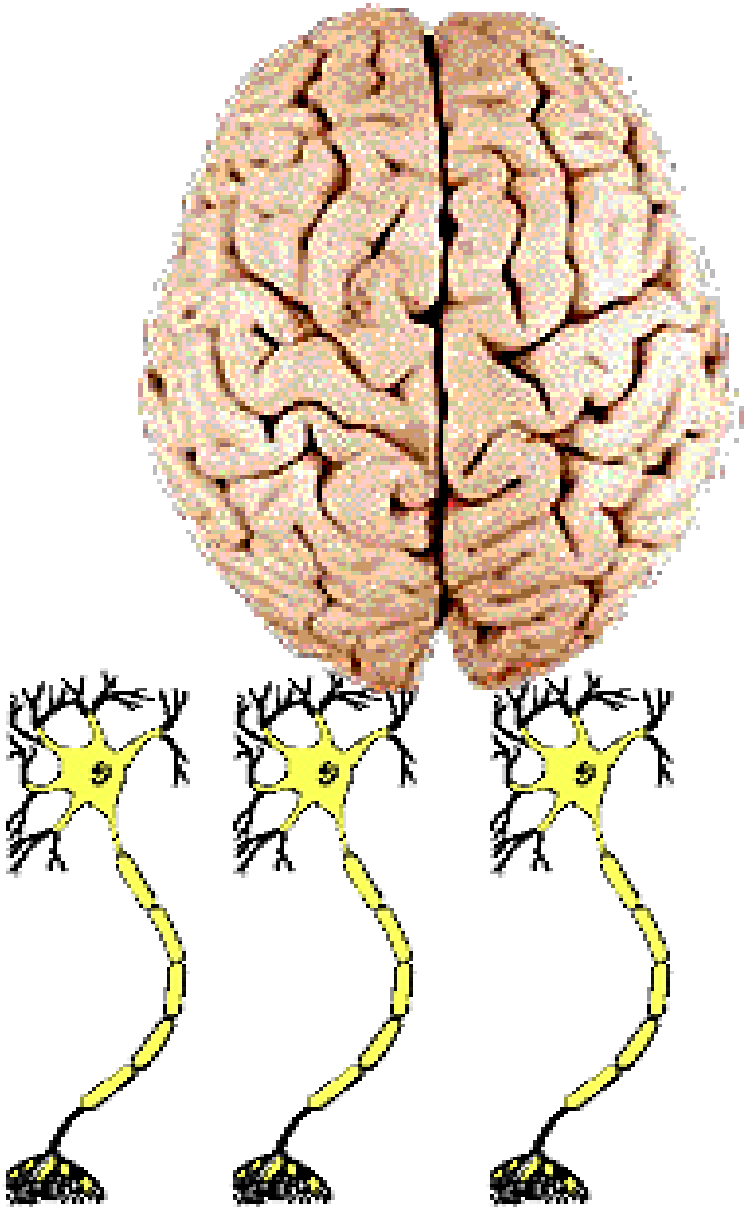


Figure 48.19

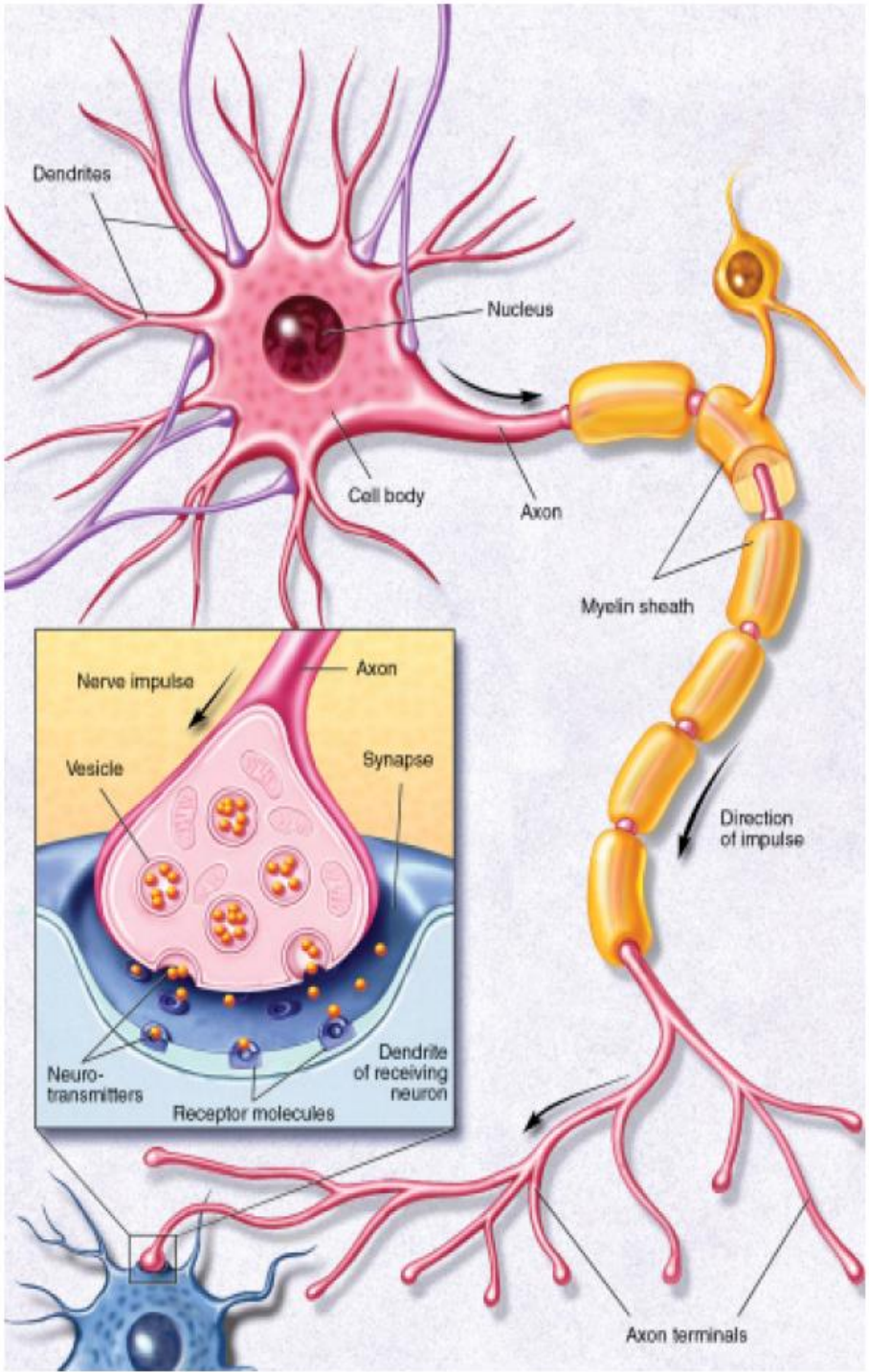
Command and Control Center

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



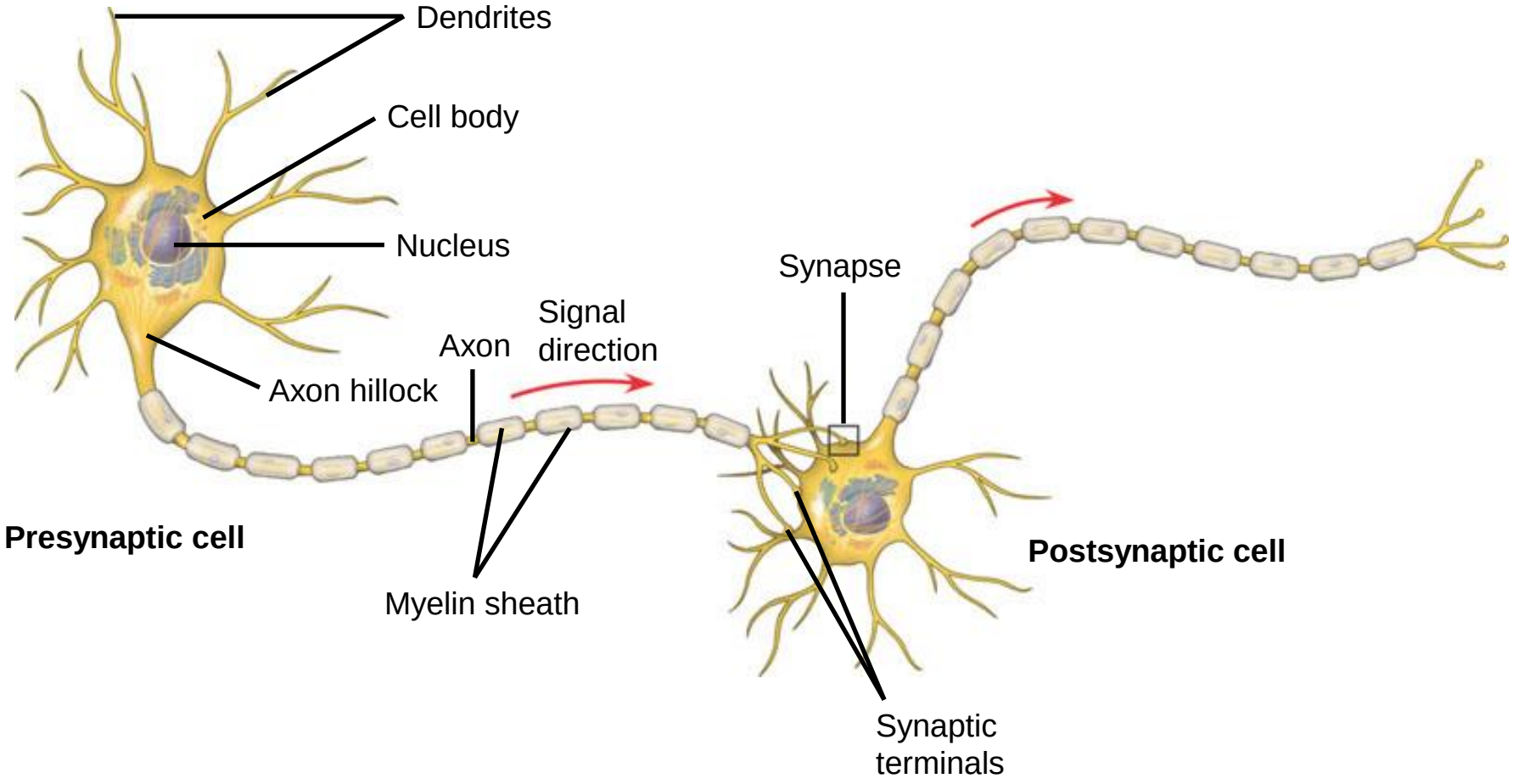
The neuron

- 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.

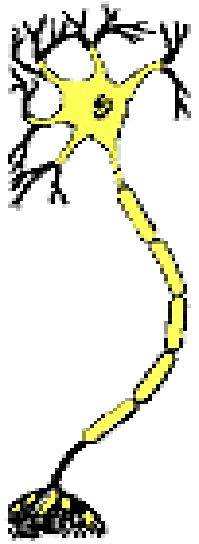


Neuron Structure (1)

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

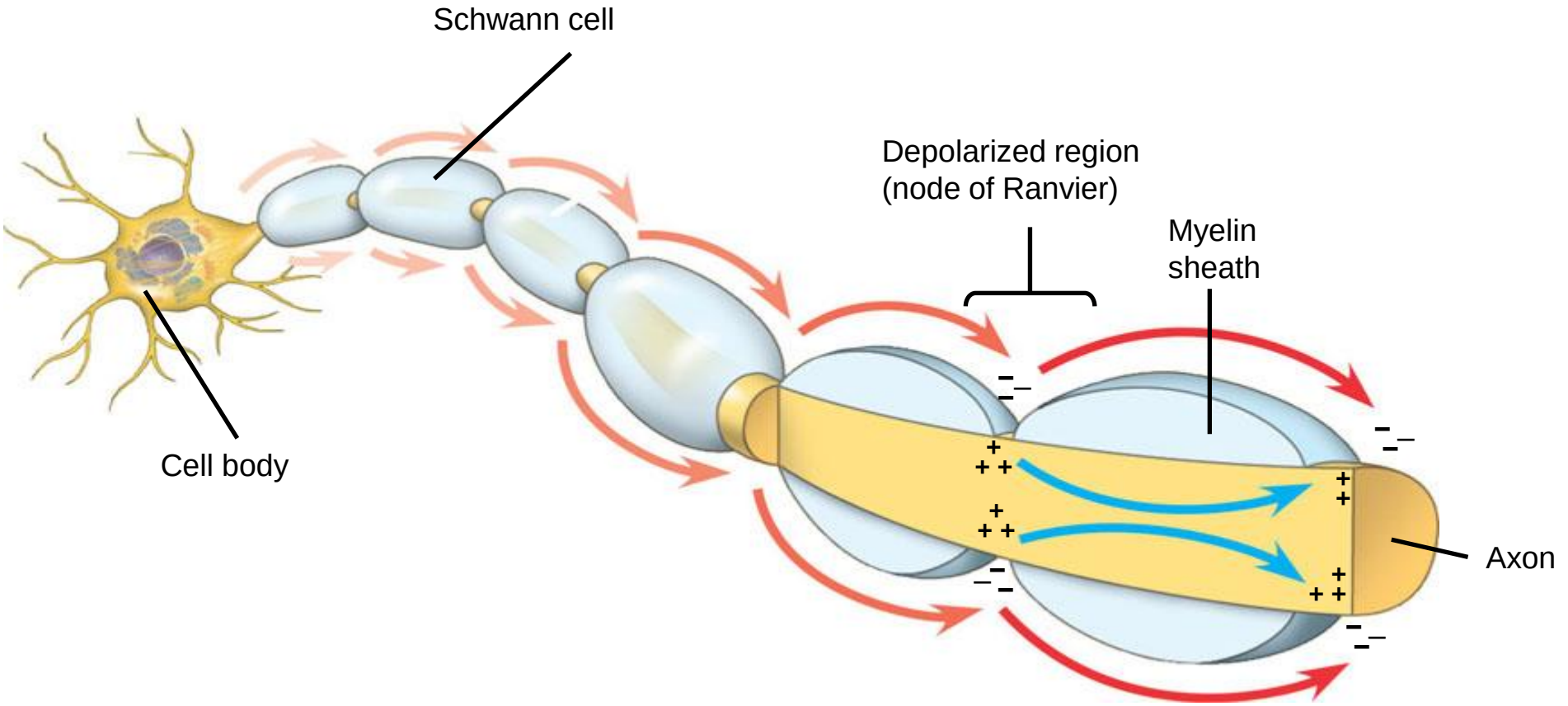


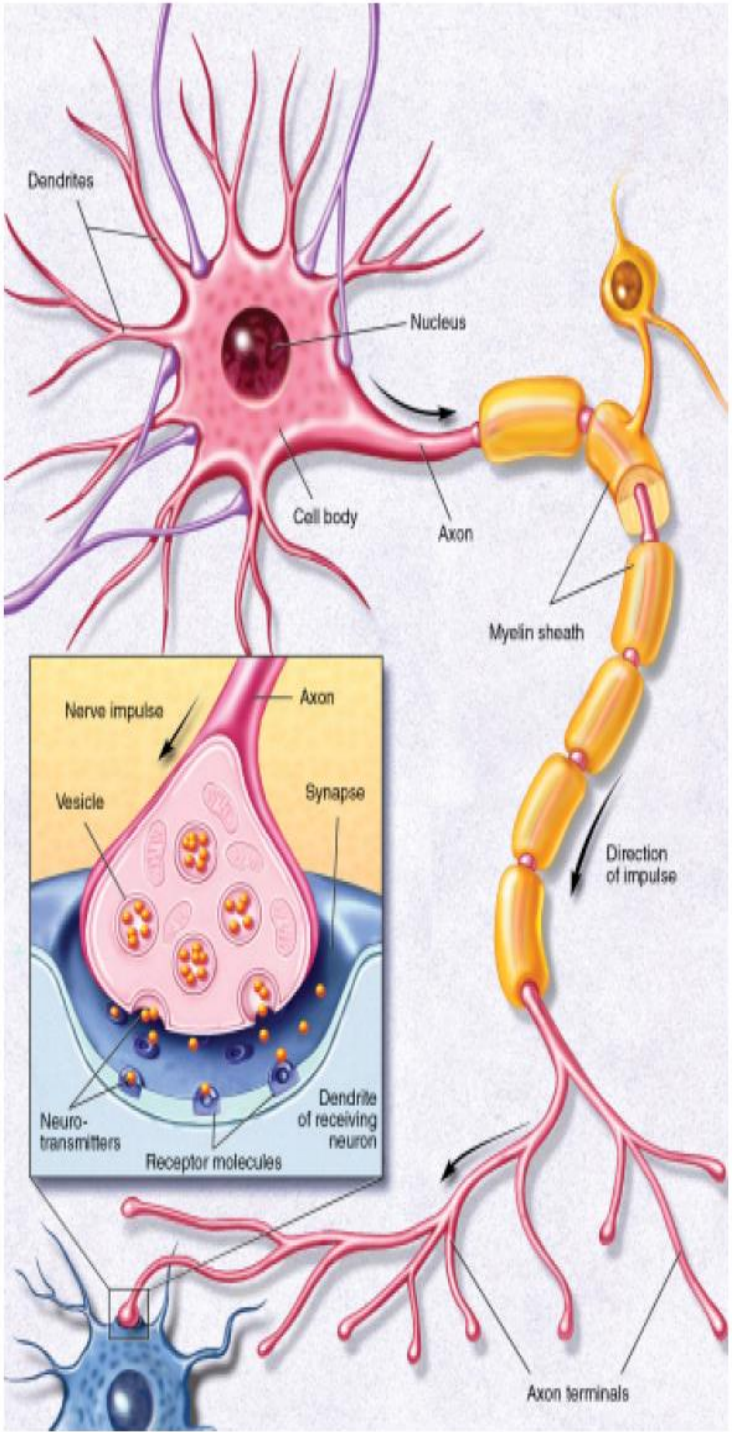
Neuron Structure (2)



- 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.

- 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.





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.

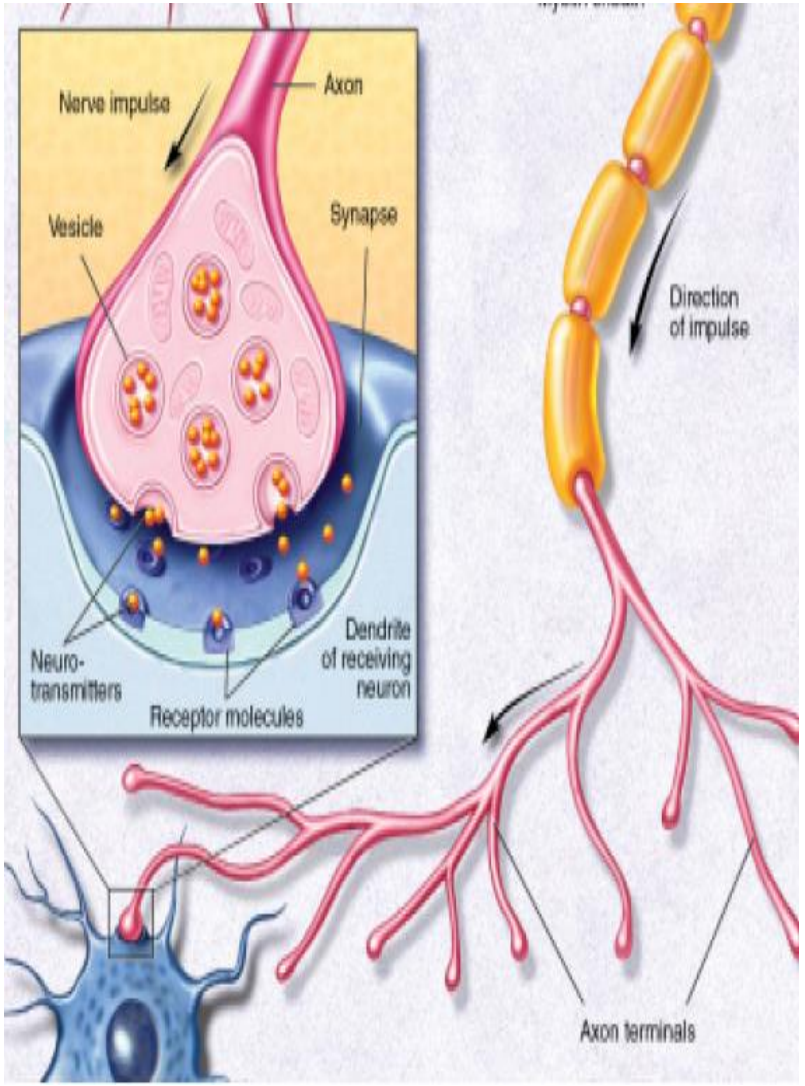
The point of virtual contact is known as the synapse.

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.

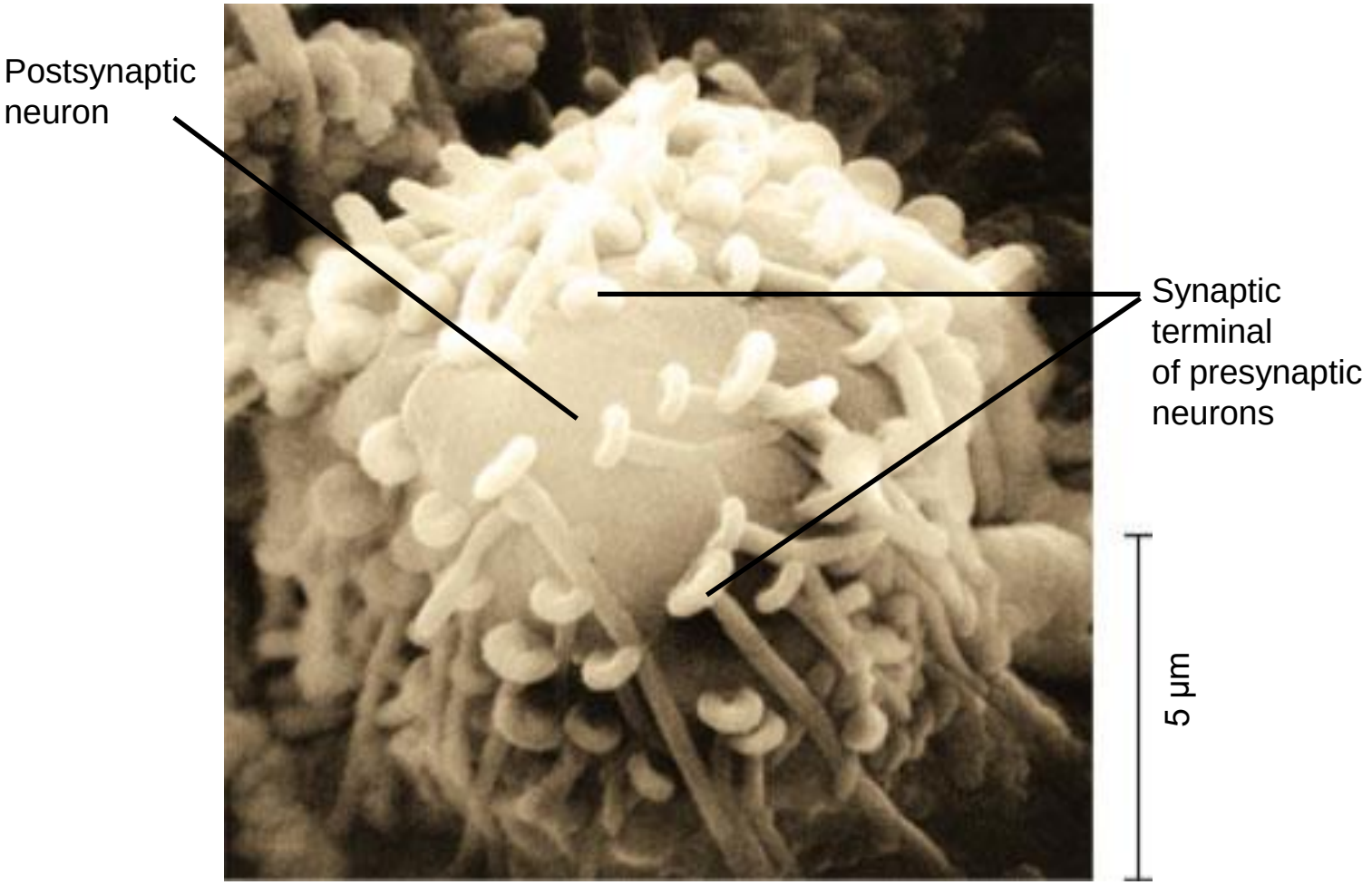
The dendrites and cell body are covered with synapses formed by the ends of axons of other neurons.



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



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

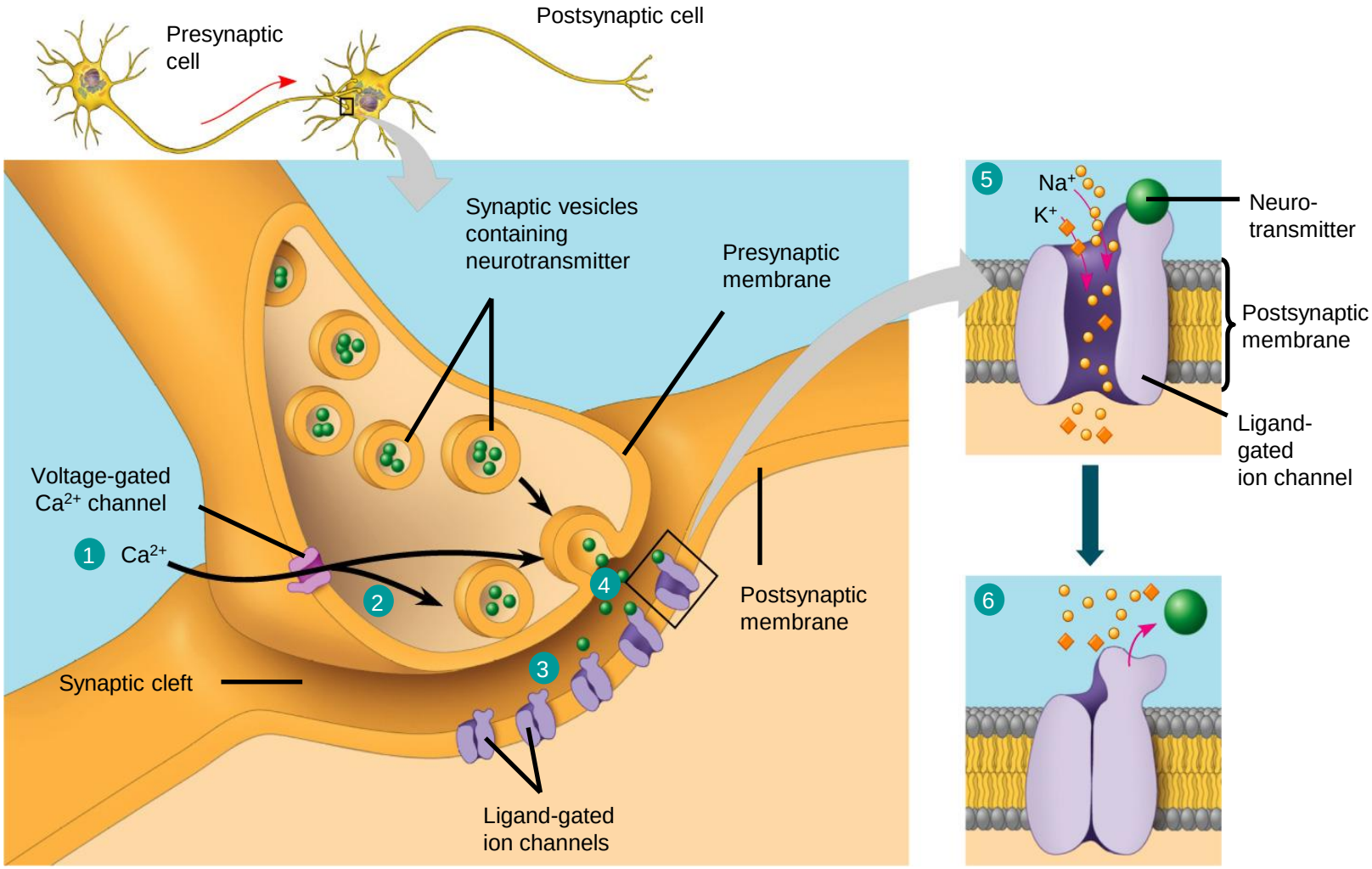
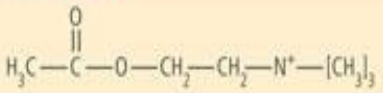
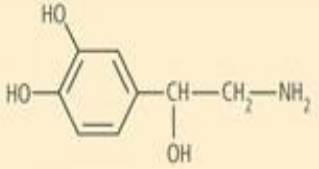
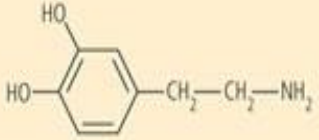
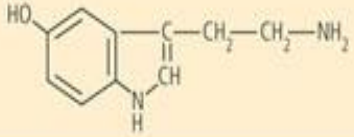
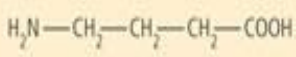
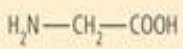
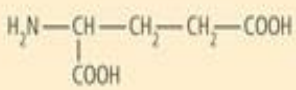
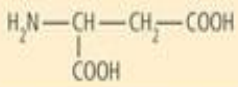
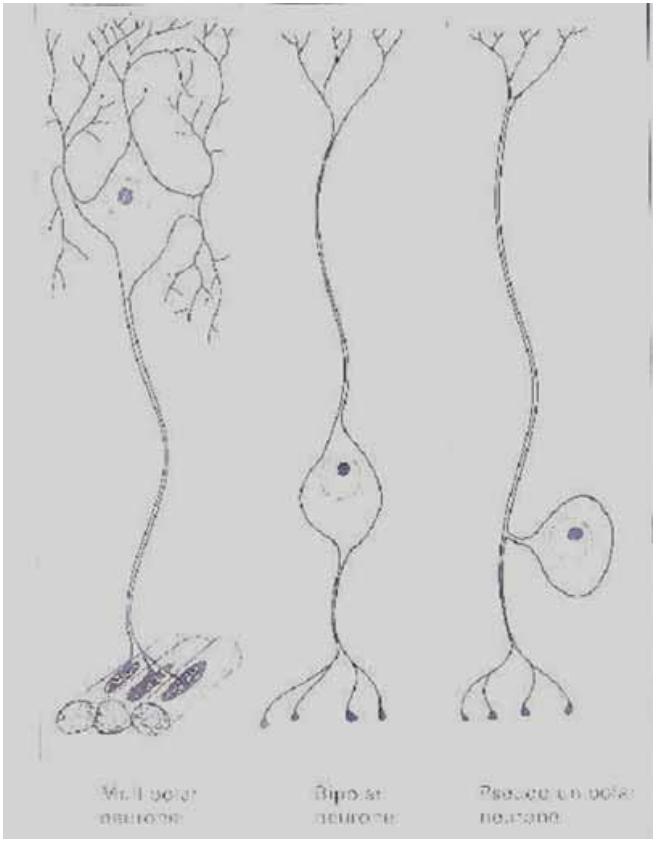


Figure 48.17

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

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



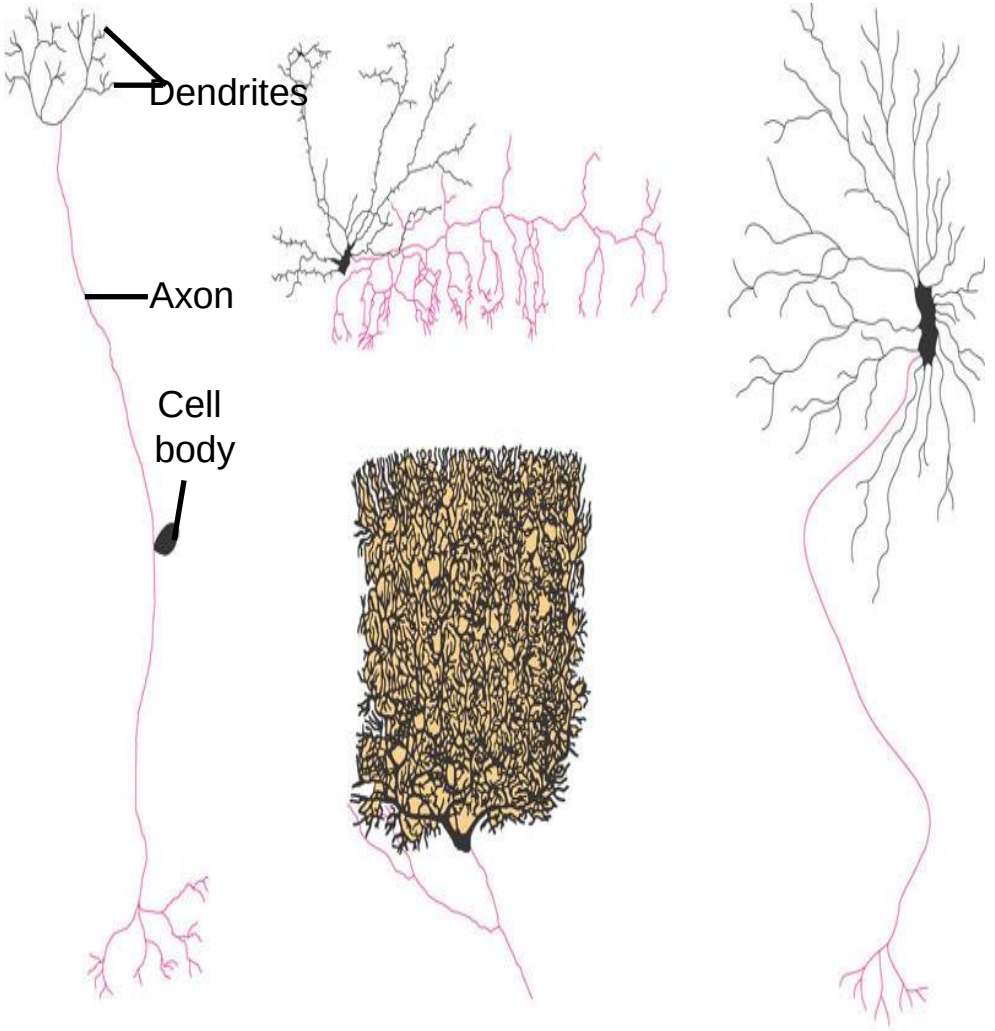
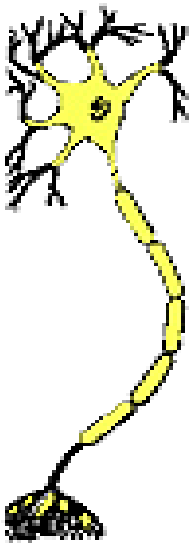
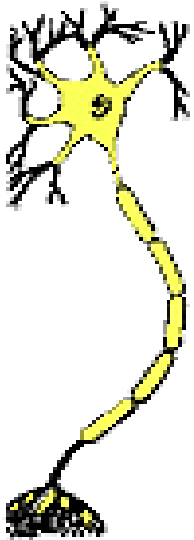


Figure 48.6a–c (a) Sensory neuron (b) Interneurons (c) Motor neuron

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

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

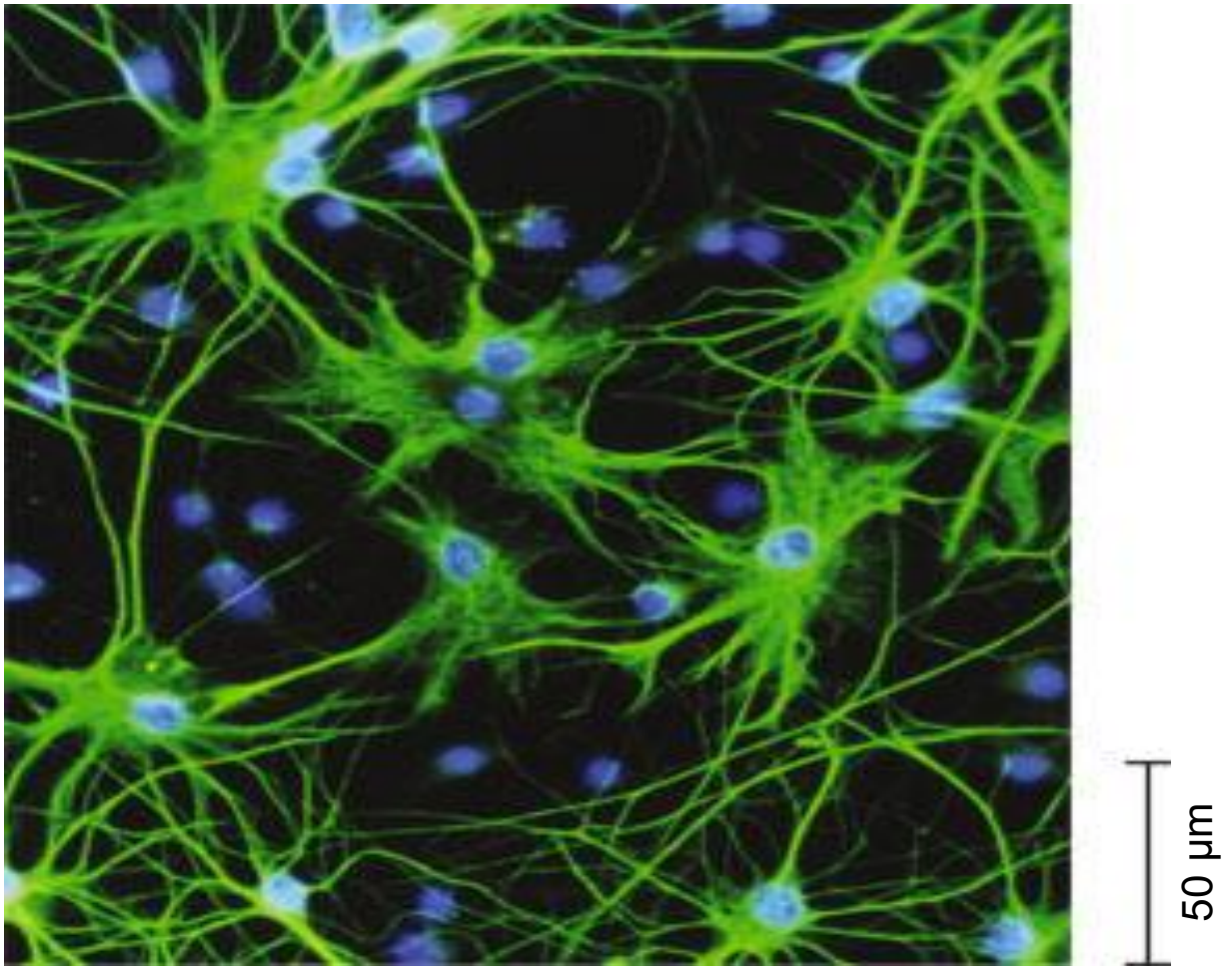




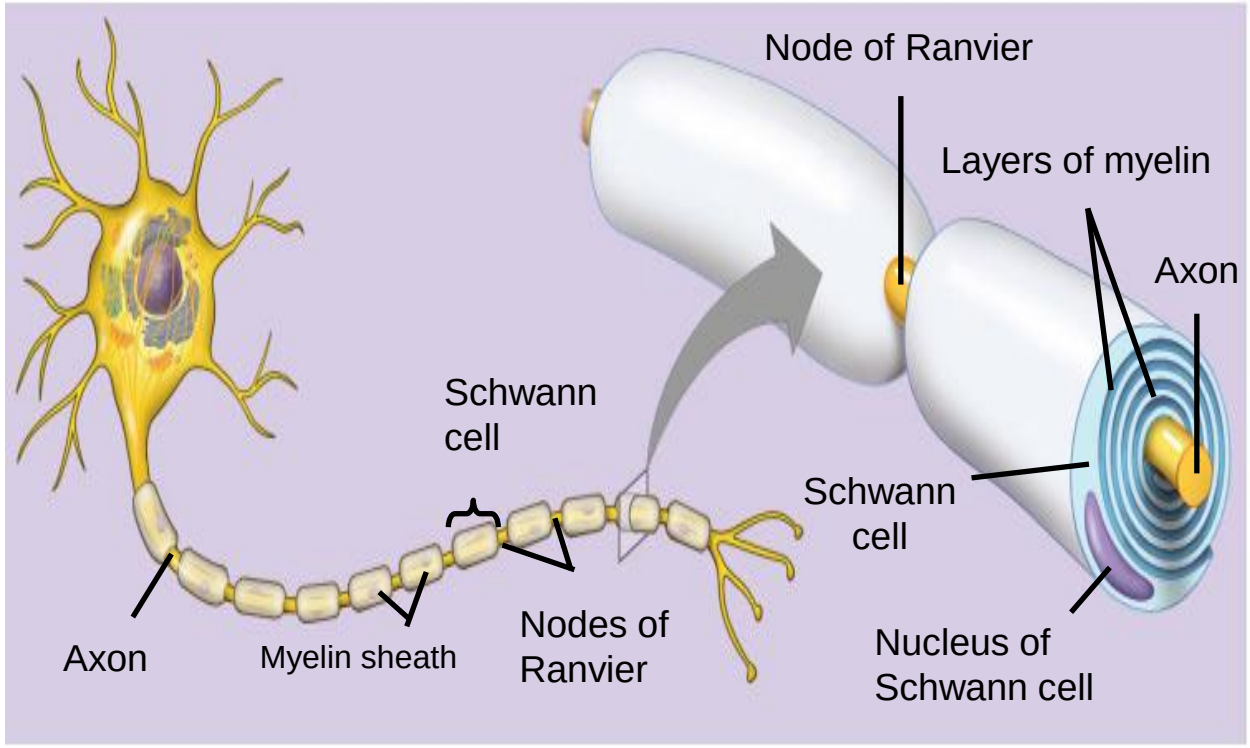
Supporting Cells (Glia)

- 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.



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



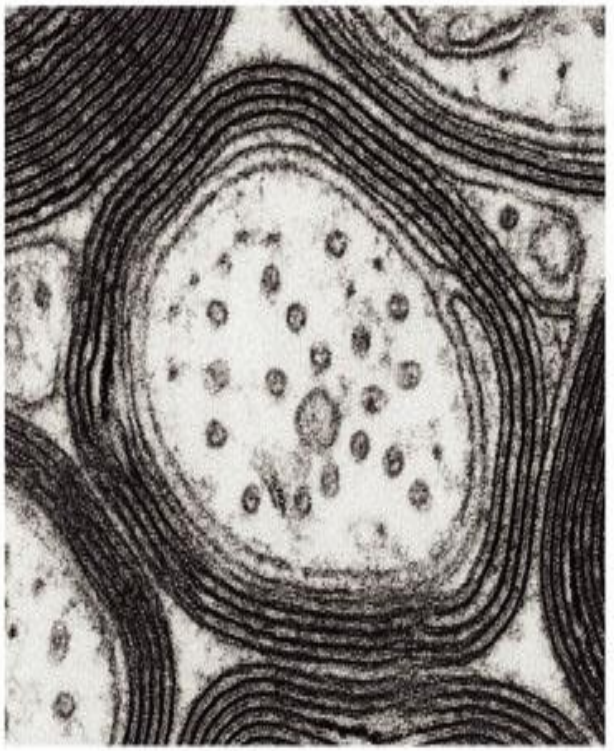
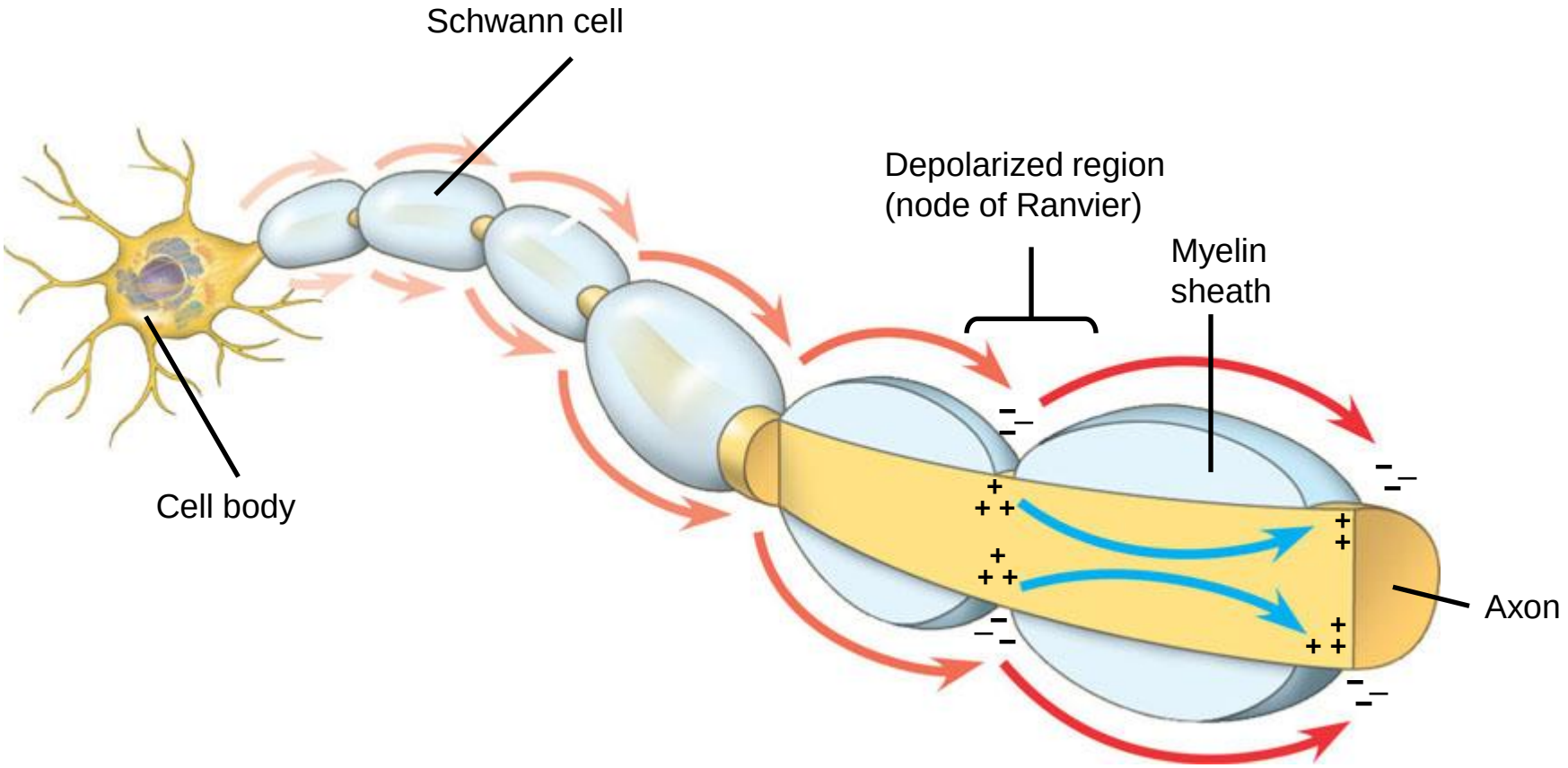
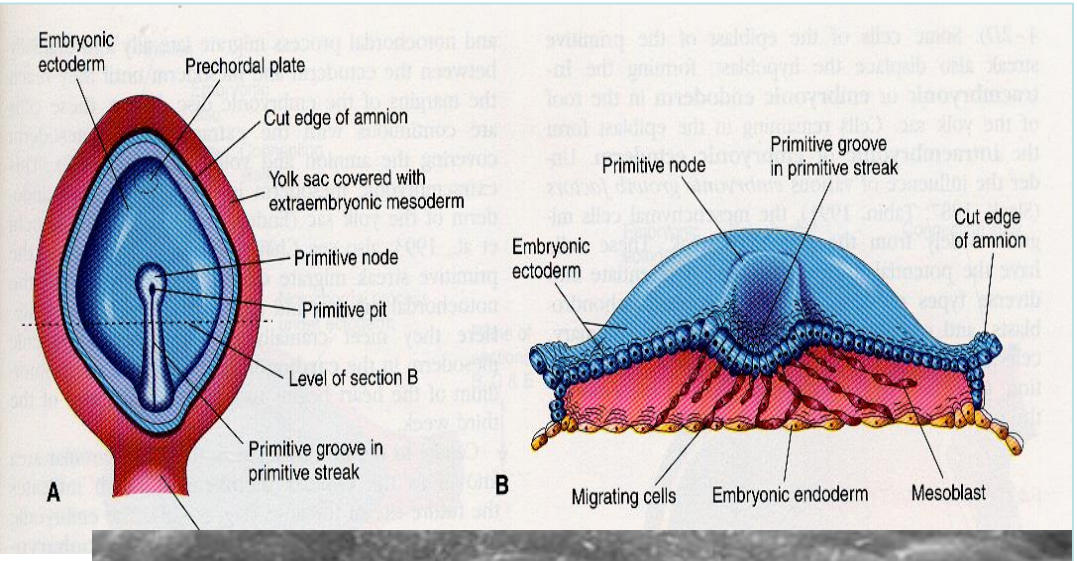


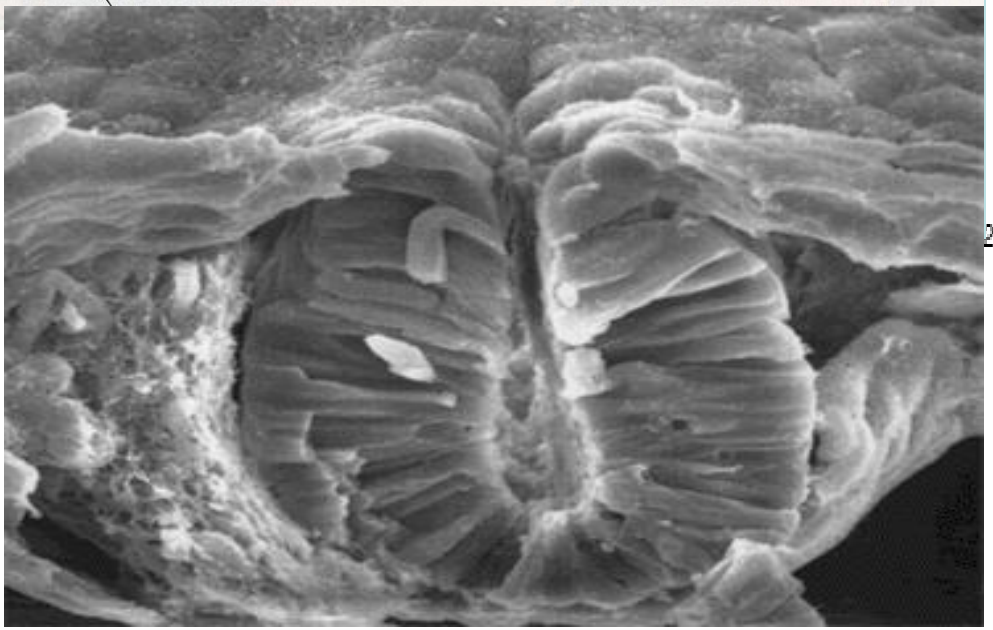
Figure 48.8

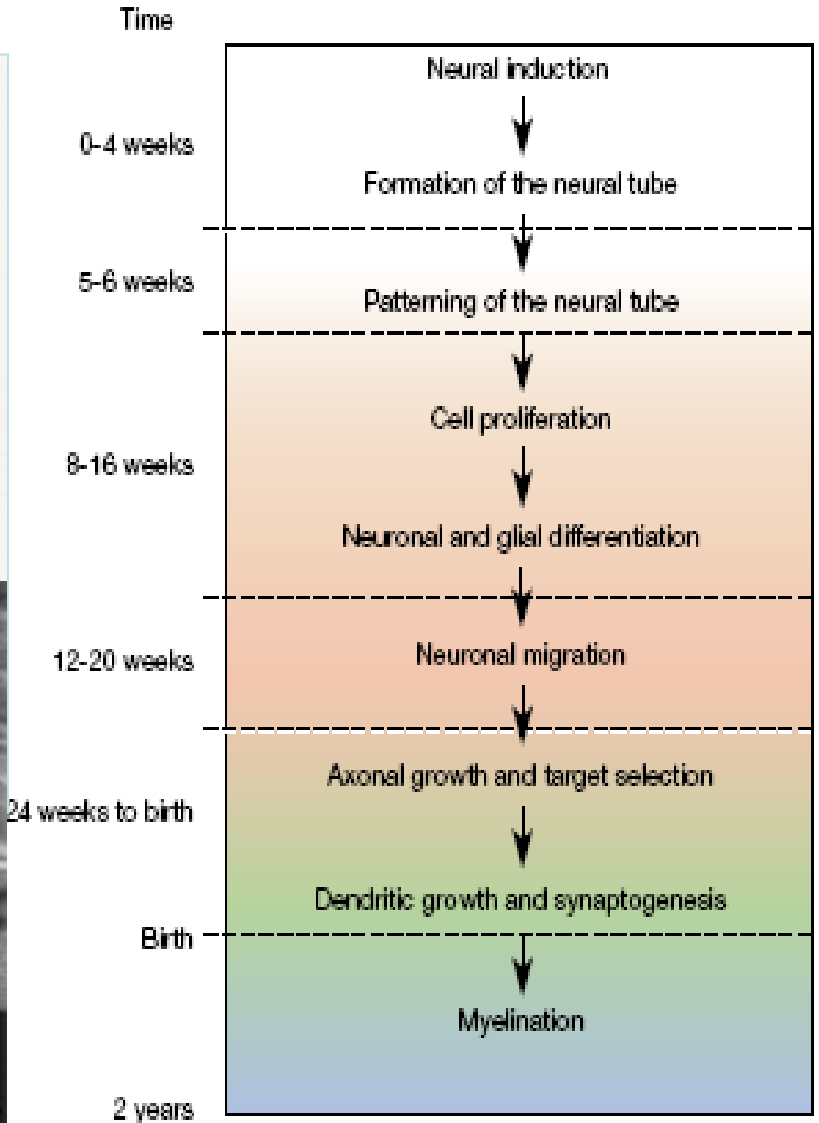
- The myelin sheath speeds the transmission of electrical signals along the axon.



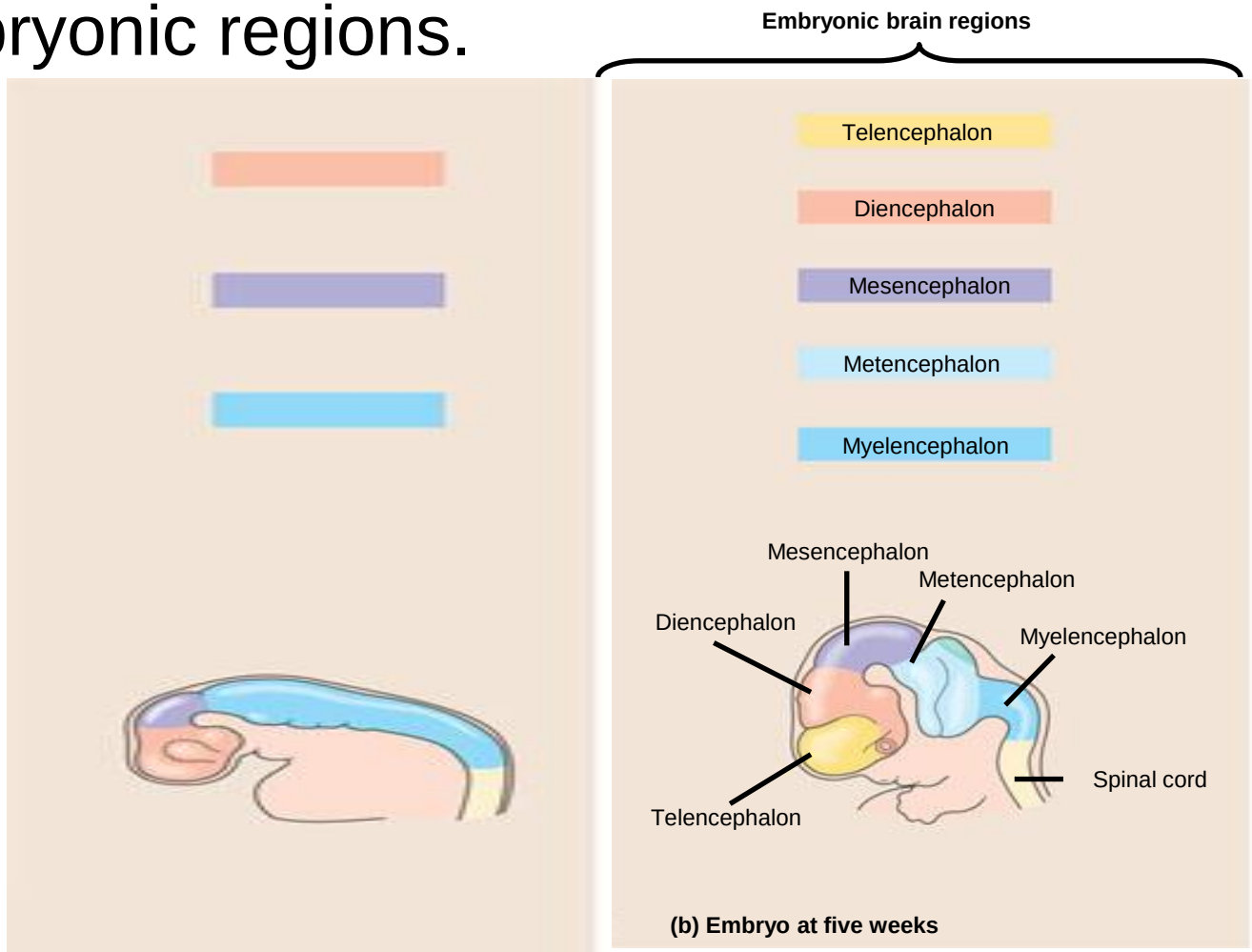
Embryonic Development of the Brain



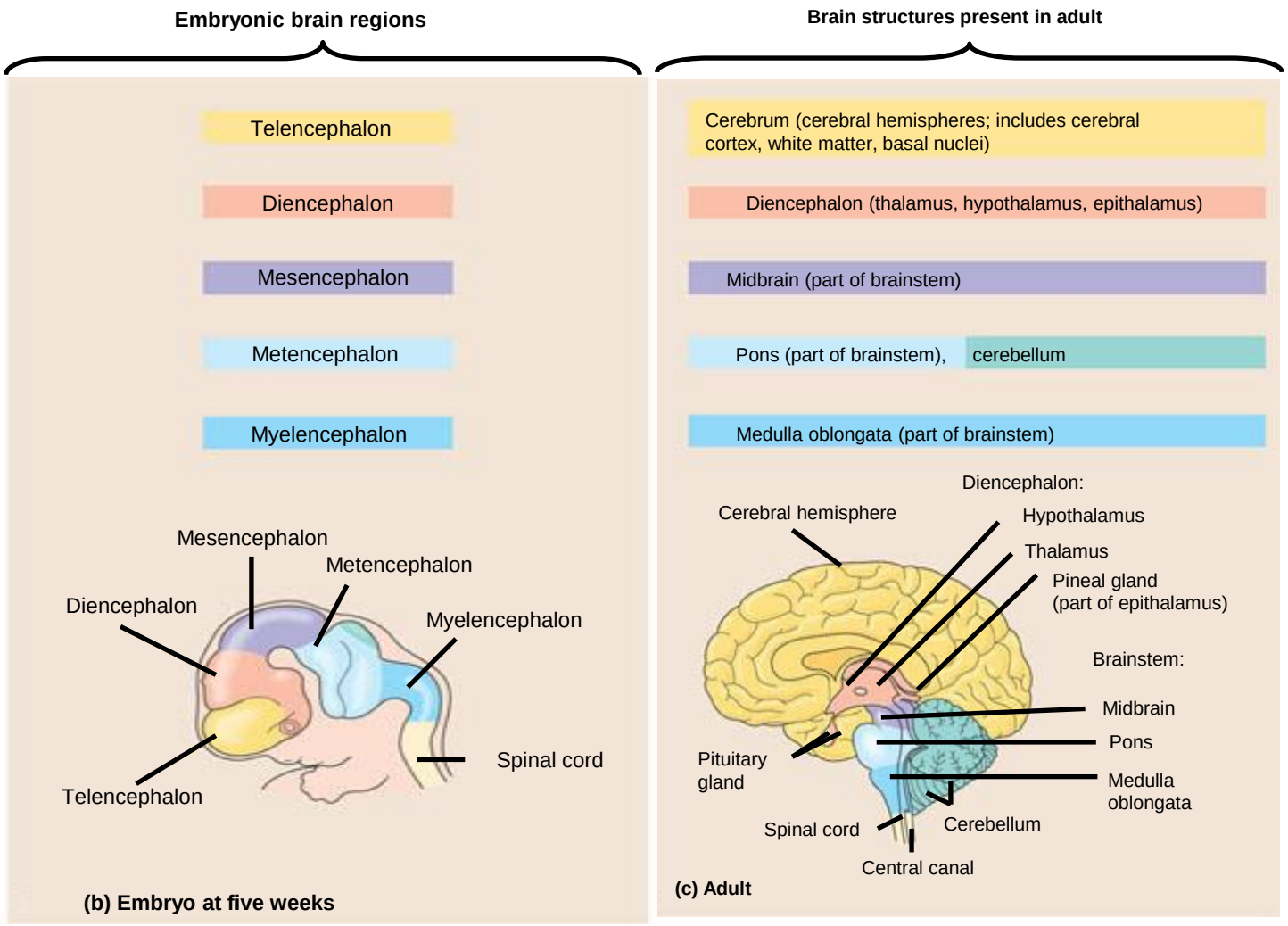




- By the fifth week of human embryonic development
  - five brain regions have formed from the three embryonic regions.



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



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.

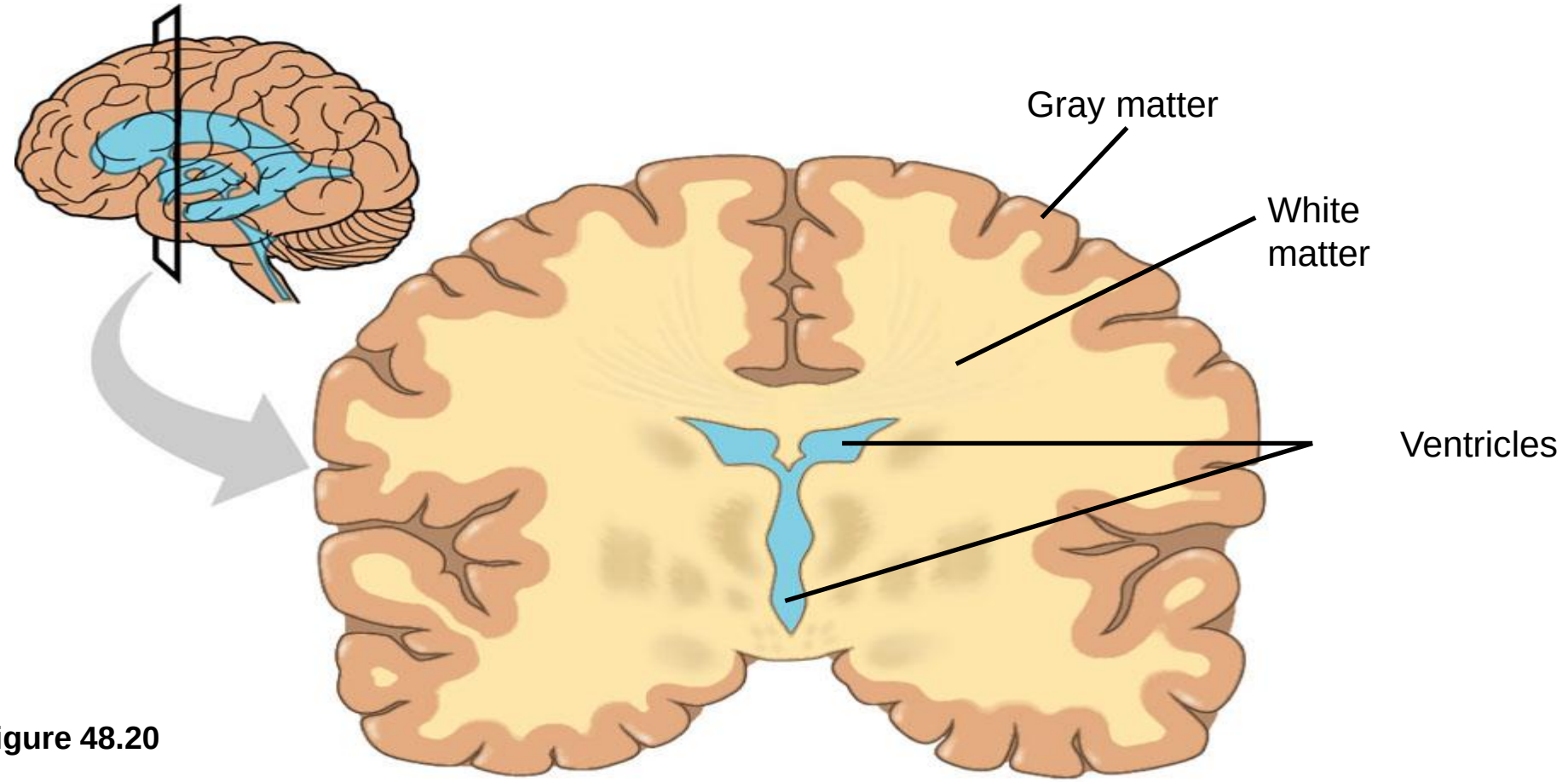
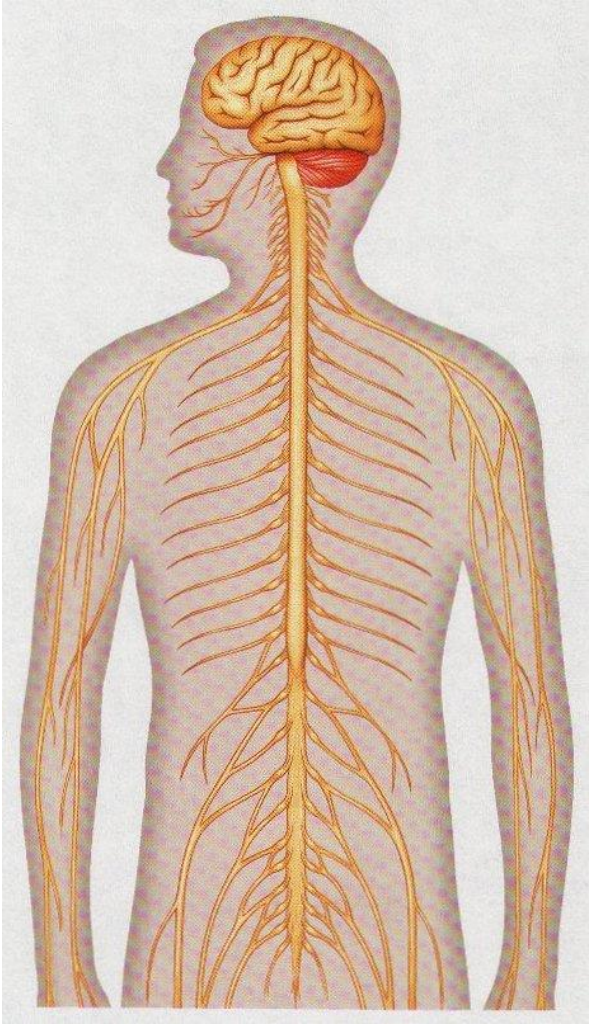


Figure 48.20

Central Nervous System (CNS)

- Brain and Spinal Cord

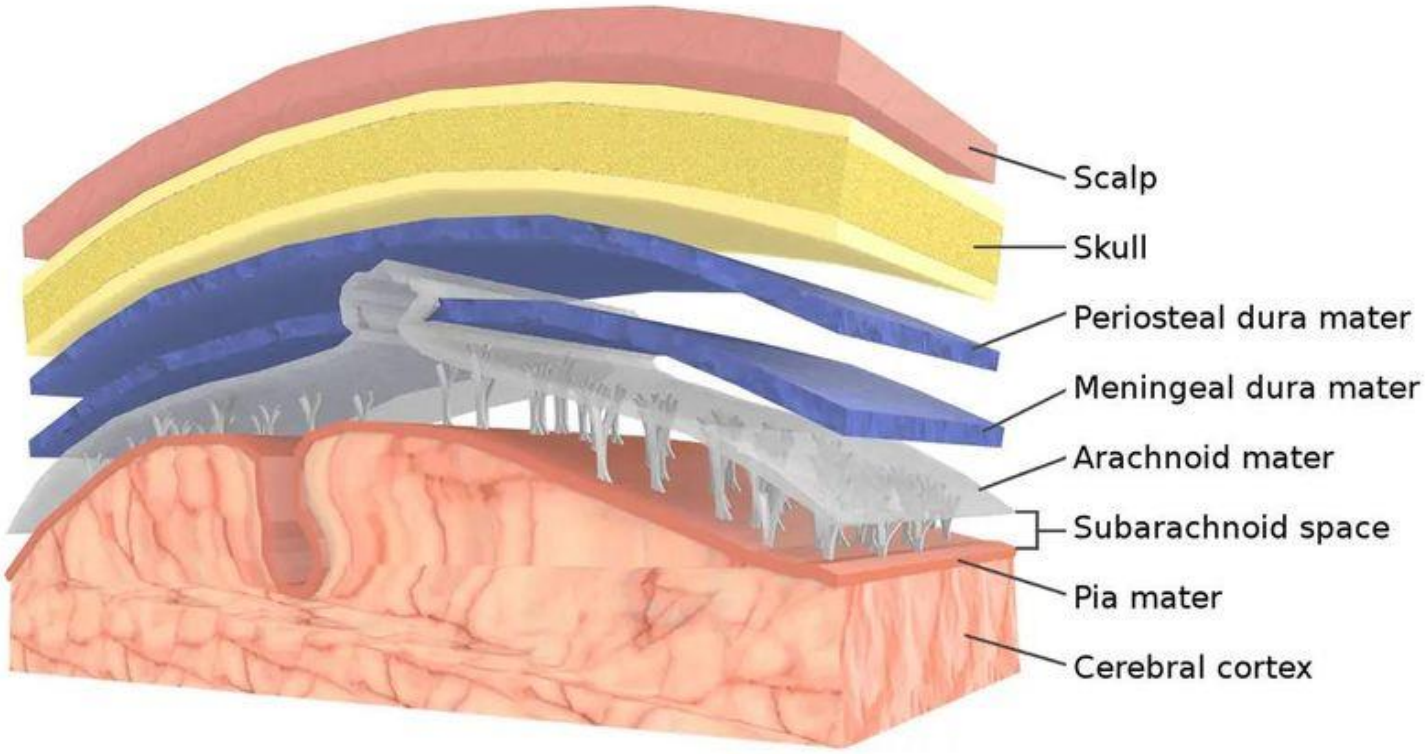
"Command Central"



e human brain
otograph by Fred Hossler/Getty Images

NATIONA
GEOGRAP

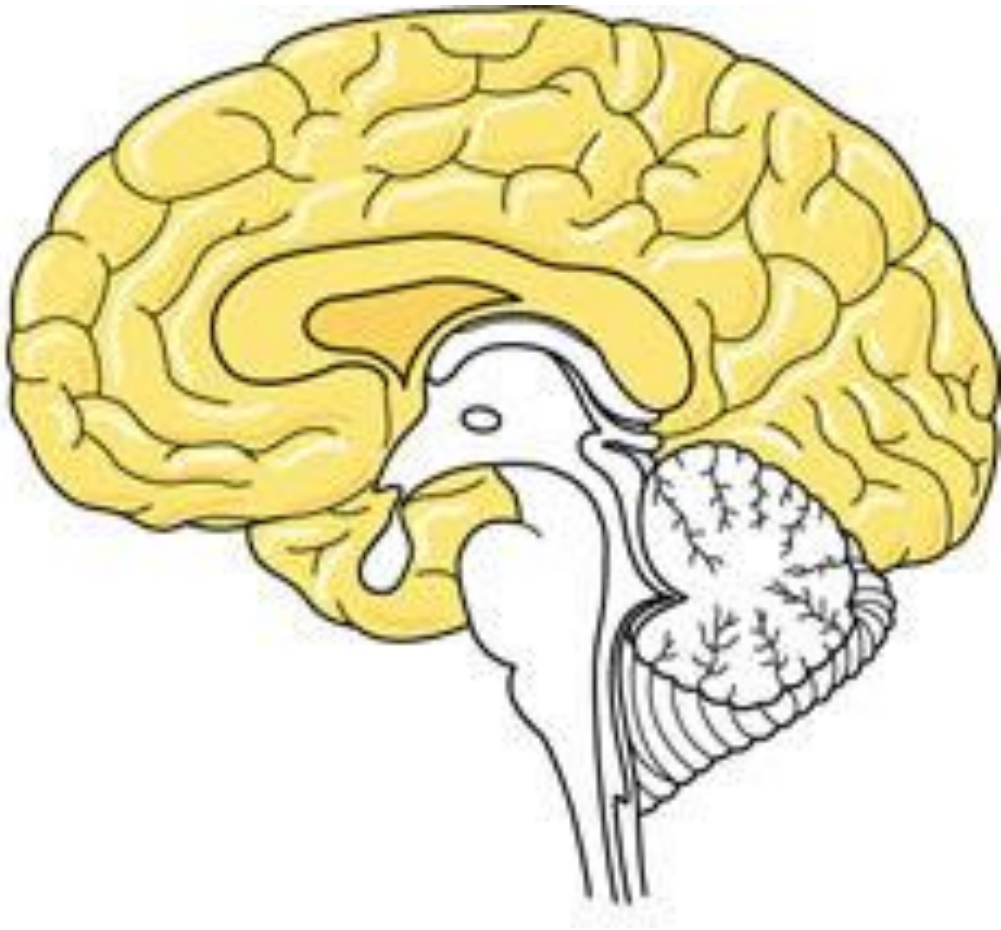
Meninges



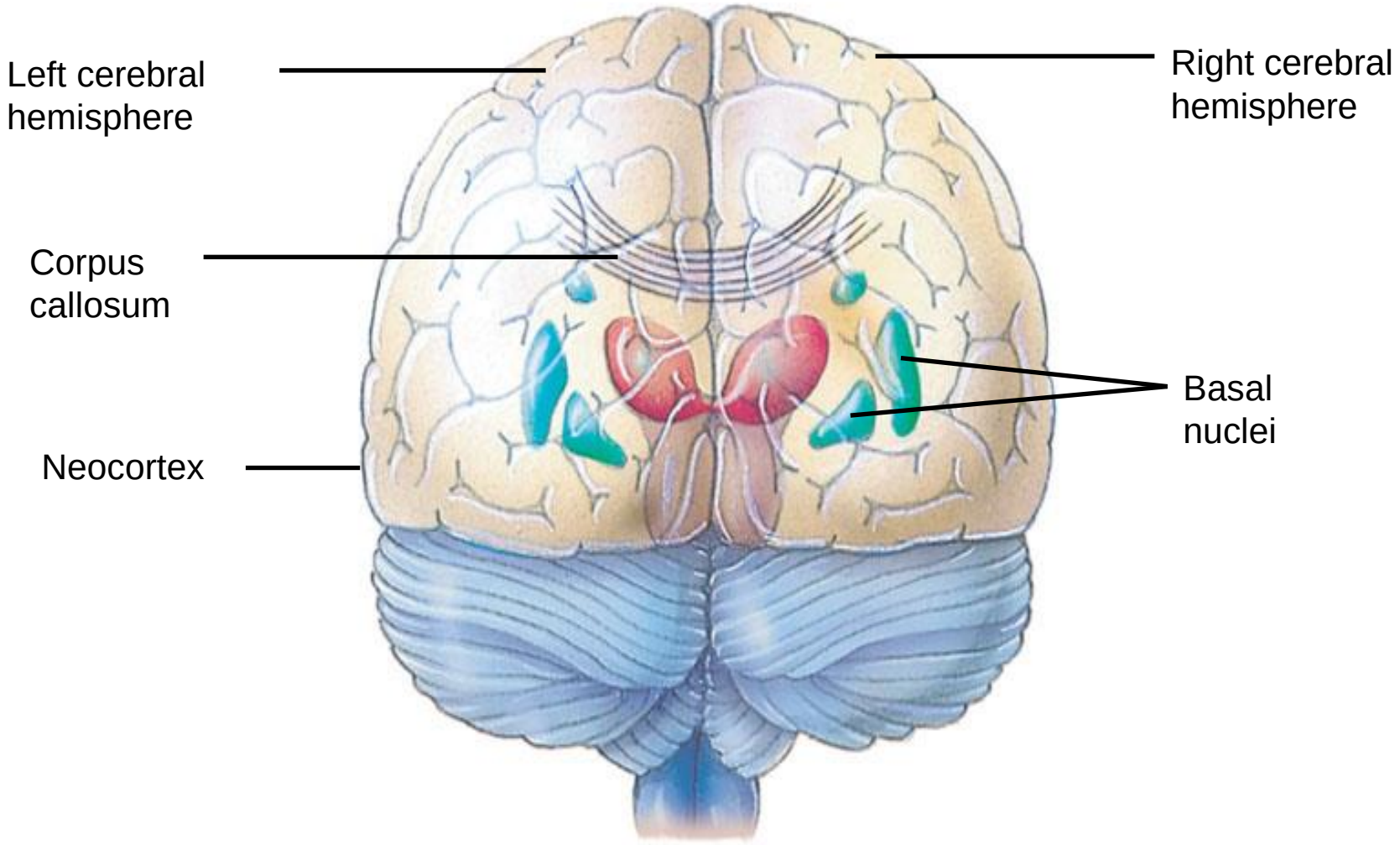
The meninges refer to the membranous coverings of the brain and spinal cord. There are three layers of meninges, known as the dura mater, arachnoid mater and pia mater.

The Cerebrum

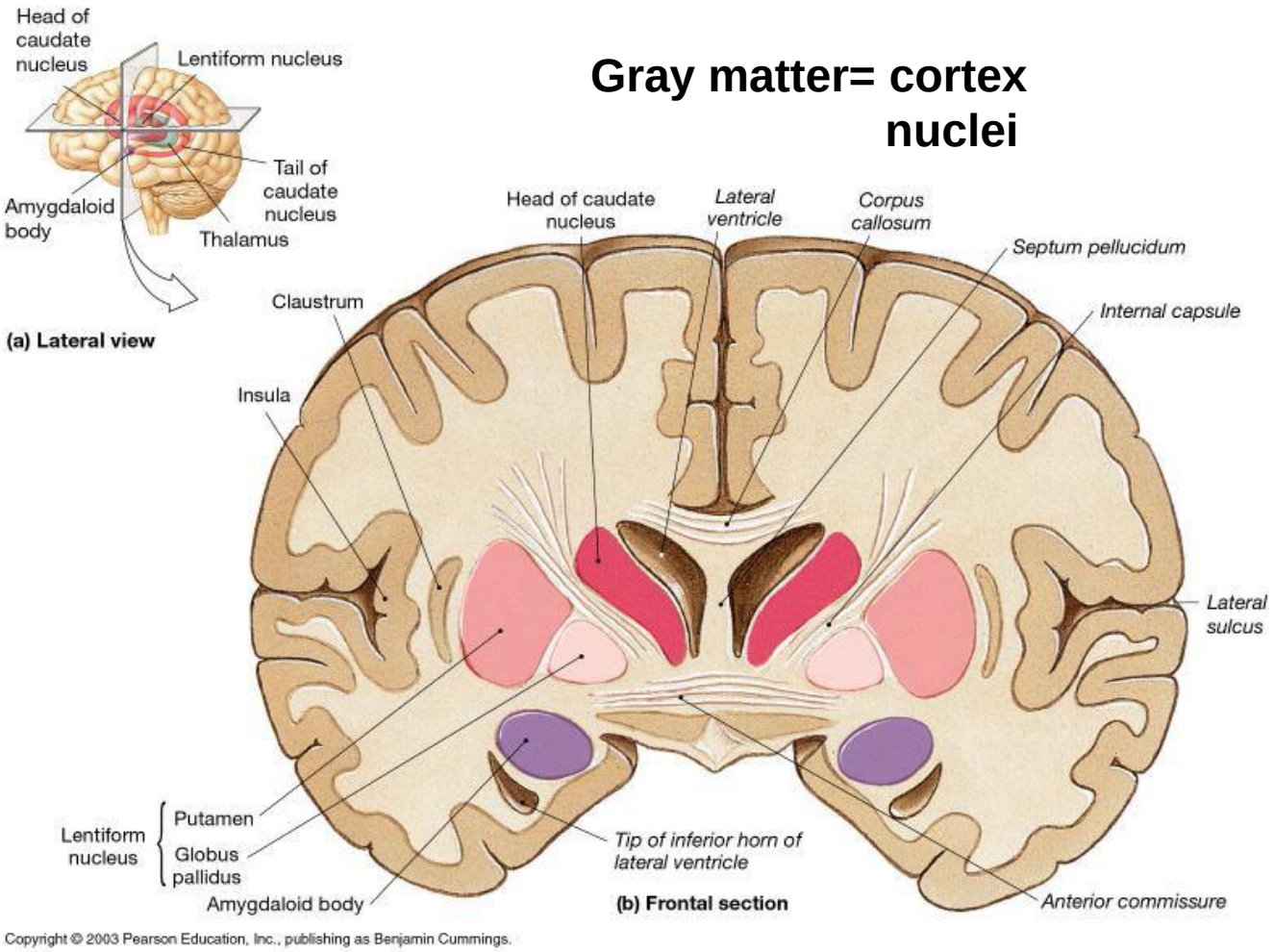
- The cerebrum
  - develops from the embryonic telencephalon.



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

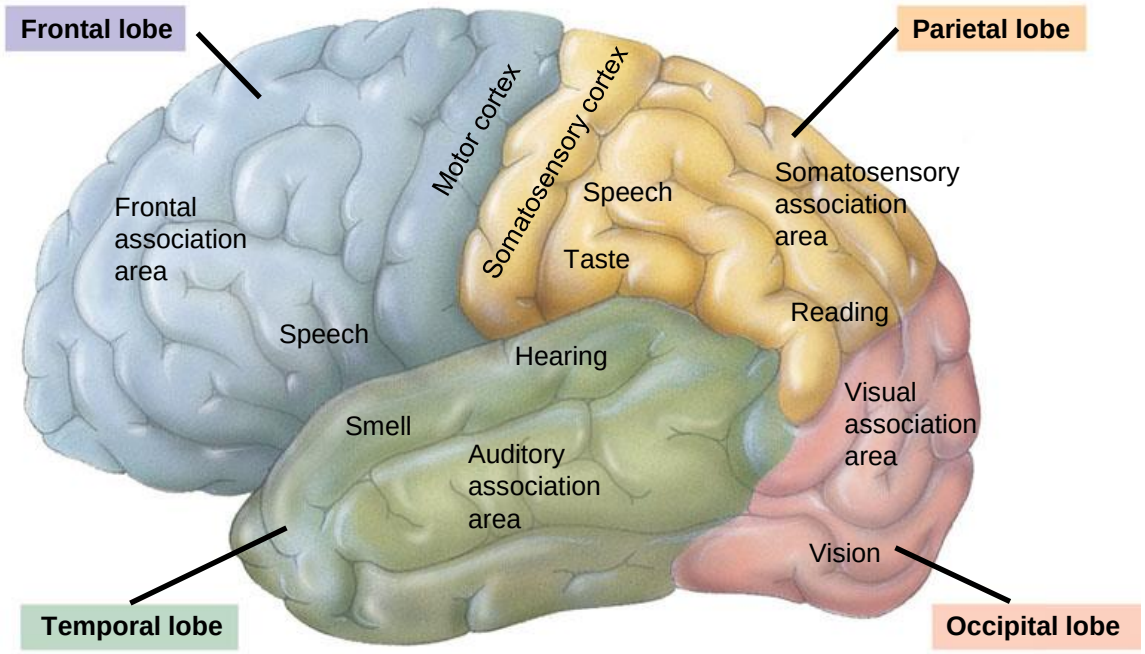


Gray matter= cortex nuclei



Each side of the cerebral cortex has four lobes:

- Frontal, parietal, temporal, and occipital.



- 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.

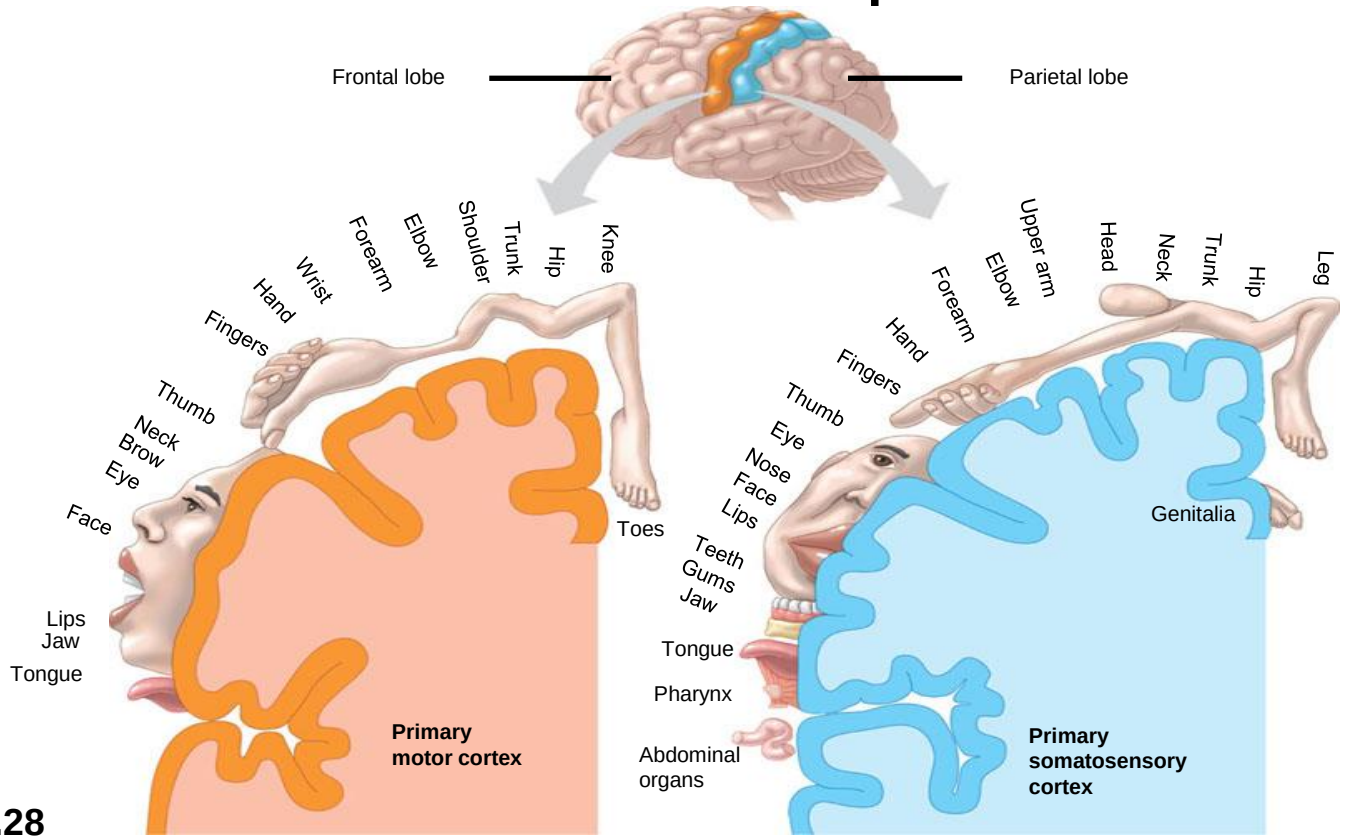


Figure 48.28

The frontal lobe

- The frontal lobe is located beneath the frontal bone of the calvaria and is the most anterior region of the cerebrum. It is separated from the parietal lobe posteriorly by the **central sulcus** and from the temporal lobe inferoposteriorly by the **lateral sulcus**.
- The association areas of the frontal lobe are responsible for: higher intellect, personality, mood, social conduct and language (dominant hemisphere side only).

The parietal lobe

- The parietal lobe is found below the parietal bone of the calvaria, between the frontal lobe anteriorly and the occipital lobe posteriorly, from which it is separated by the central sulcus and **parieto-occipital sulcus**, respectively. It sits superiorly in relation to the temporal lobe, being separated by the lateral sulcus.
- Its cortical association areas contribute to the control of language and calculation on the dominant hemisphere side, and **visuospatial functions** (e.g. 2-point discrimination) on the non-dominant hemisphere side

The temporal lobe

- The temporal lobe is beneath the temporal bone of the calvaria inferior to the frontal and parietal lobes, from which it is separated by the **lateral sulcus**.
- The cortical association areas of the temporal lobe are accountable for memory and language – this includes hearing as it is the location of the **primary auditory cortex**.

The occipital lobe

- The occipital lobe is the most posterior part of the cerebrum situated below the occipital bone of the calvaria. Its inferior aspect rests upon the **tentorium cerebelli**, which segregates the cerebrum from the cerebellum. The **parieto-occipital sulcus** separates the occipital lobe from the parietal and temporal lobes anteriorly.
- The primary visual cortex (V1) is located within the occipital lobe and hence its cortical association area is responsible for vision.

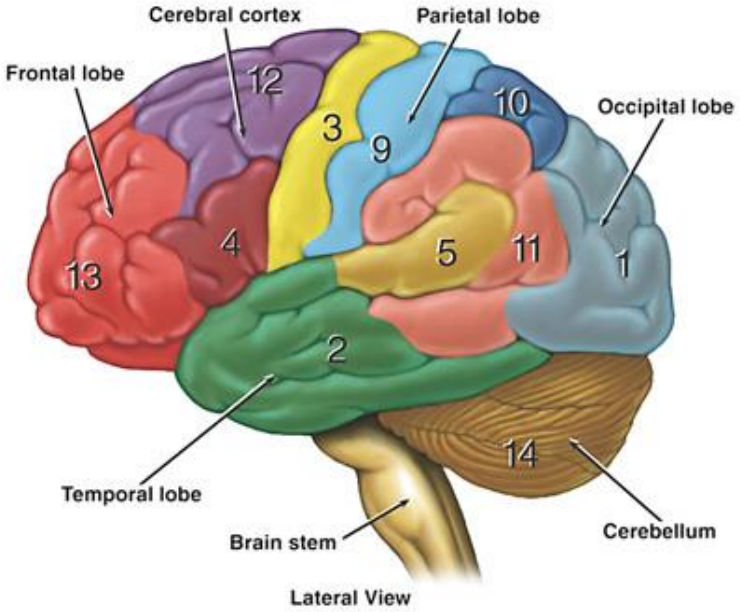
- During brain development, in a process called *lateralization*
  - Competing functions segregate and displace each other in the cortex of the left and right cerebral hemispheres.
- The left hemisphere
  - Becomes more adept **at language, math, logical operations, and the processing of serial sequences.**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

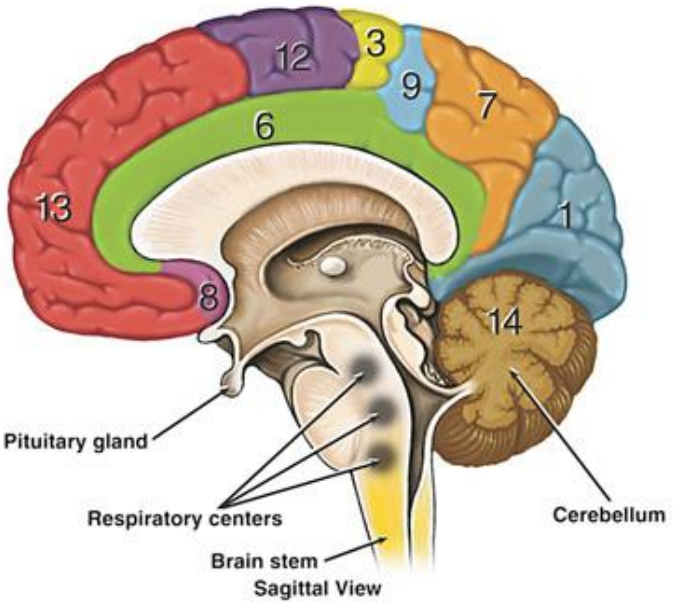
Functional Areas of the Cerebral Cortex

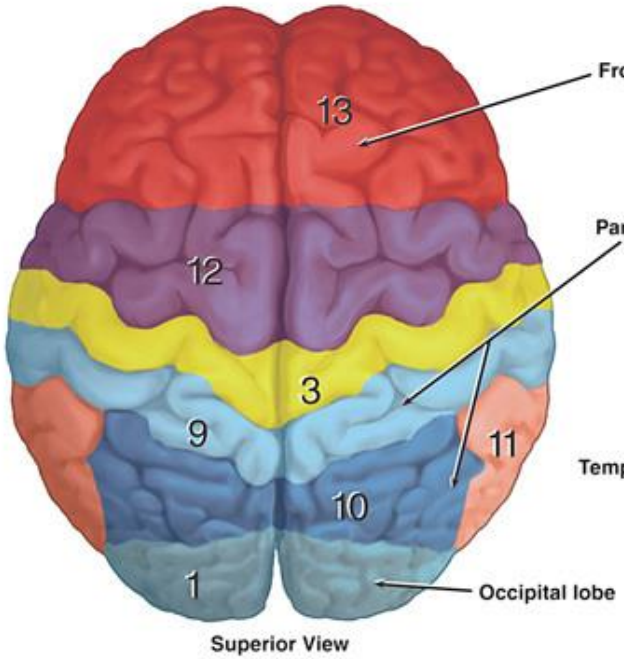
1. **Visual Area:**
   Sight
   Image recognition
   Image perception
2. **Association Area**
   Short-term memory
   Equilibrium
   Emotion
3. **Motor Function Area**
   Initiation of voluntary muscles
4. **Broca's Area**
   Muscles of speech
5. **Auditory Area**
   Hearing
6. **Emotional Area**
   Pain
   Hunger
   "Fight or flight" response
7. **Sensory Association Area**
8. **Olfactory Area**
   Smelling
9. **Sensory Area**
   Sensation from muscles and skin
10. **Somatosensory Association Area**
    Evaluation of weight, texture, temperature, etc. for object recognition
11. **Wernicke's Area**
    Written and spoken language comprehension
12. **Motor Function Area**
    Eye movement and orientation
13. **Higher Mental Functions**
    Concentration
    Planning
    Judgment
    Emotional expression
    Creativity
    Inhibition

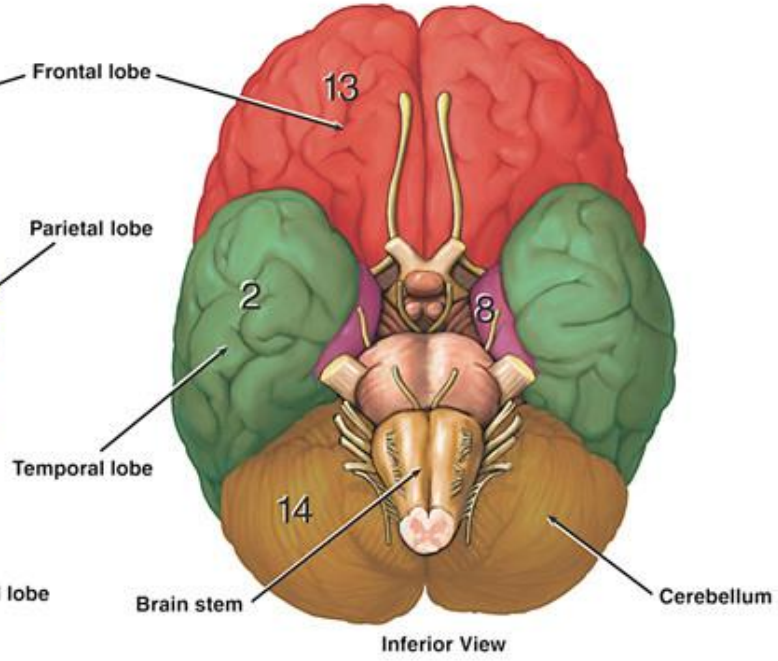
Functional Areas of the Cerebellum

14. **Motor Functions**
    Coordination of movement
    Balance and equilibrium
    Posture





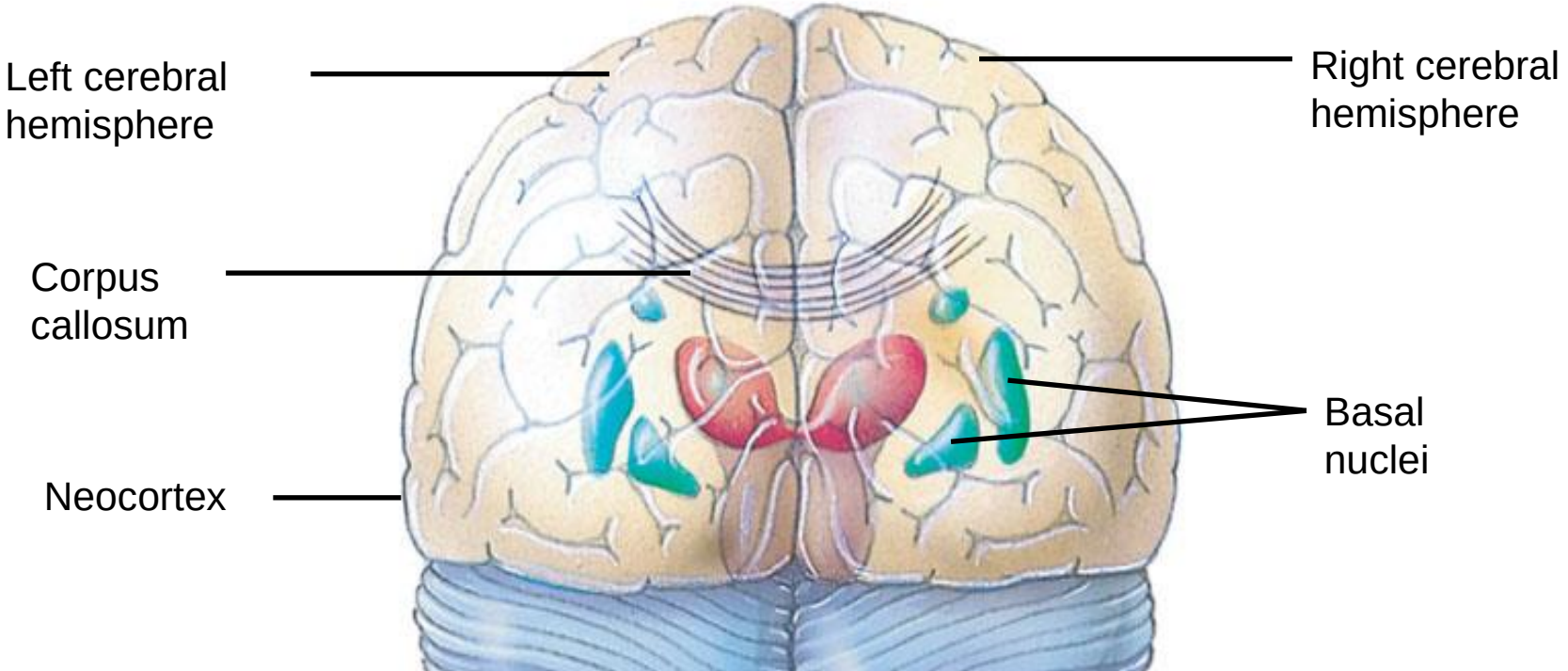




In humans, the largest and most complex part of the brain Is the cerebral cortex, where sensory information is analyzed,

motor commands are issued, and language is generated.

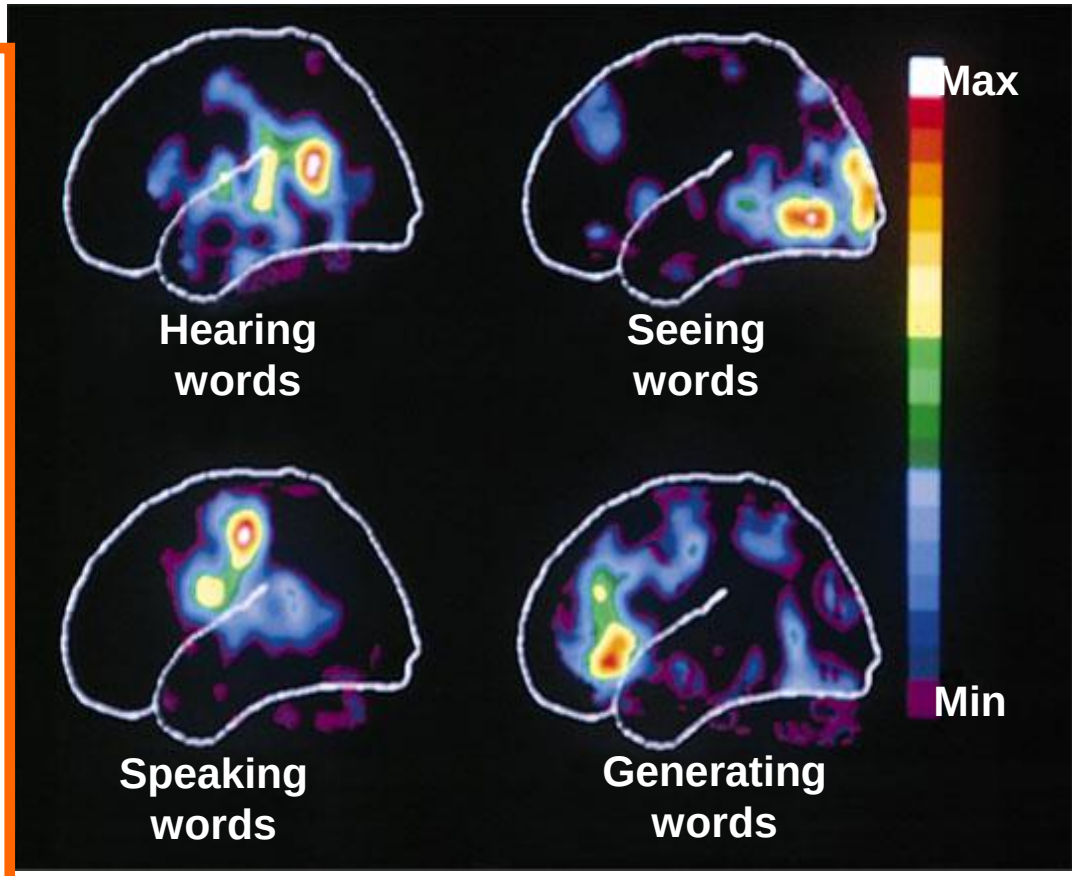
- A thick band of axons, the **corpus callosum**
  - provides communication between the right and left cerebral cortices.
- The **basal nuclei**
  - are important centers for planning and learning movement sequences.
- In mammals
  - the cerebral cortex has a convoluted surface called the neocortex.



Language and Speech

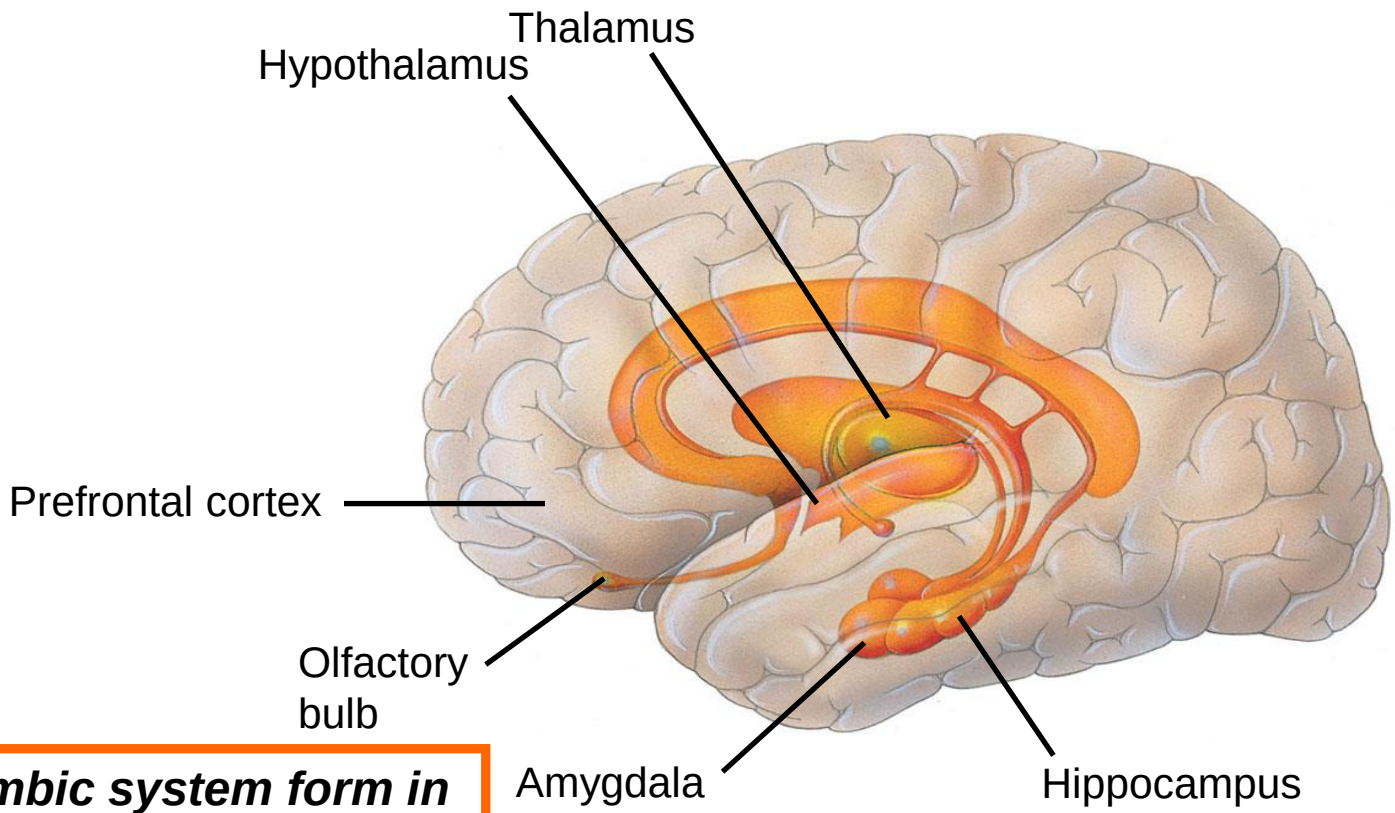
- Studies of brain activity
  - Have mapped specific areas of the brain responsible for language and speech.

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



Emotions

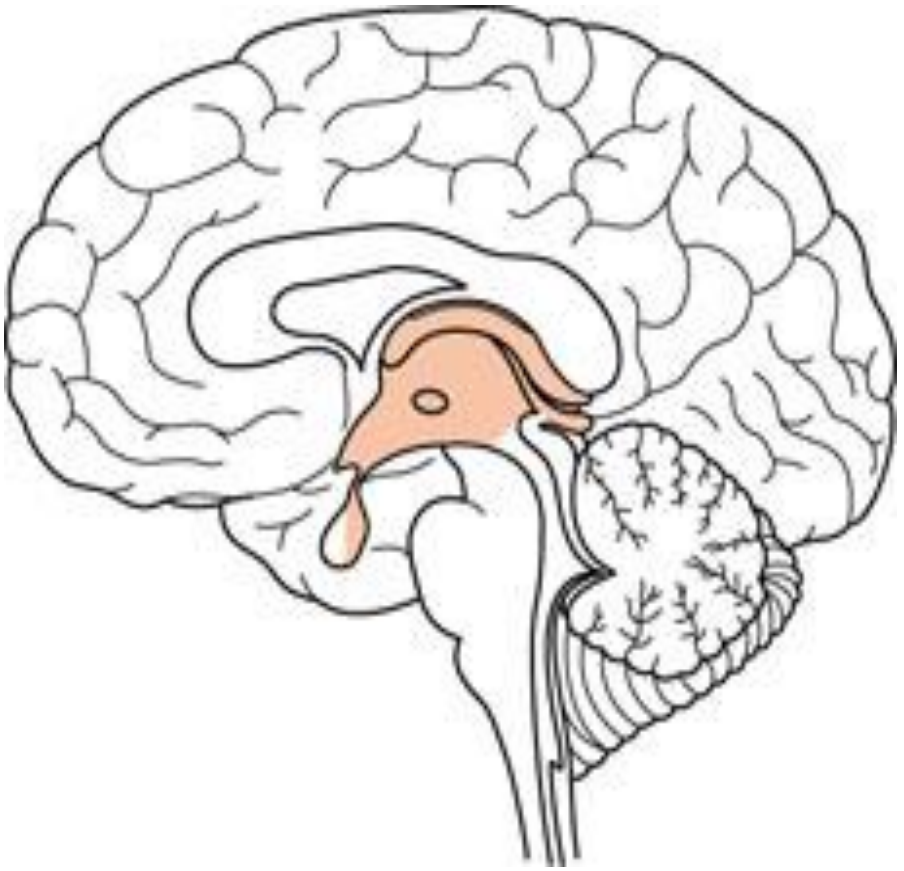
- The limbic system
  - is a ring of structures around the brainstem.



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

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.

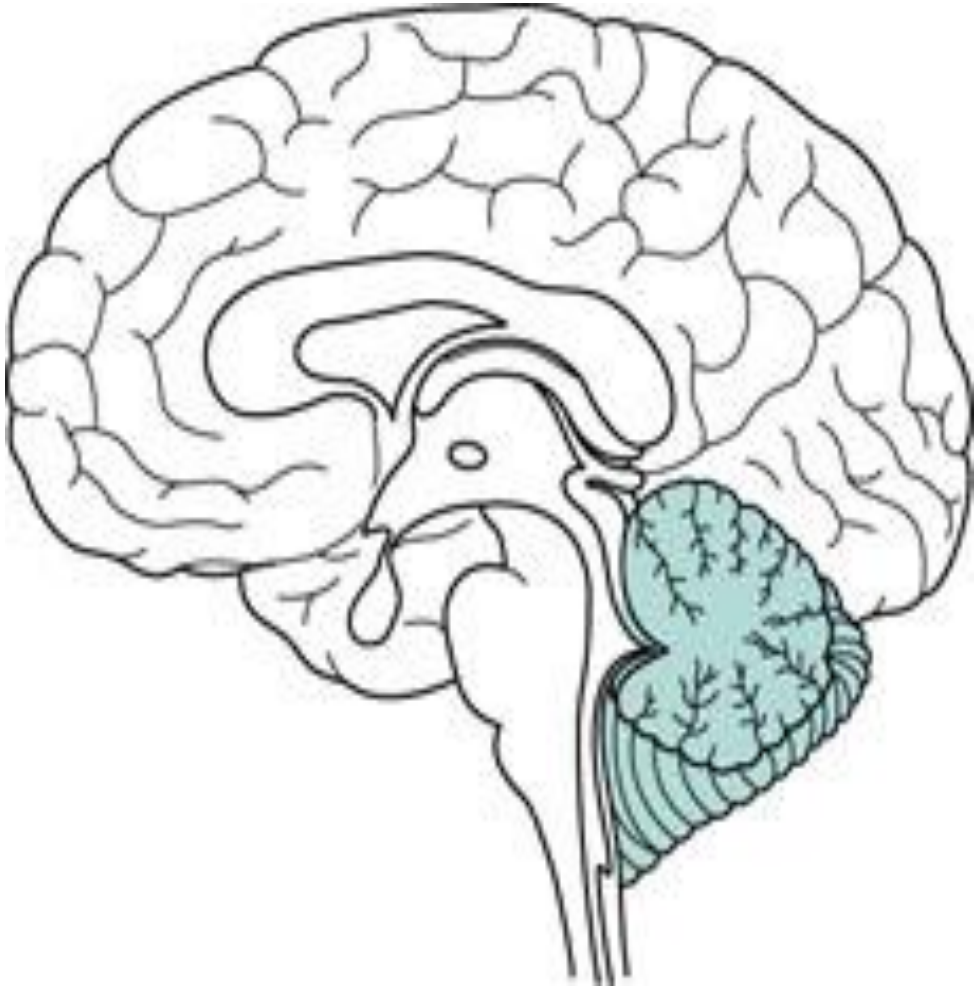
- **The thalamus**
  is the **main input center for sensory** information going to the cerebrum and the main output center for motor information leaving the cerebrum.

- The **hypothalamus** regulates

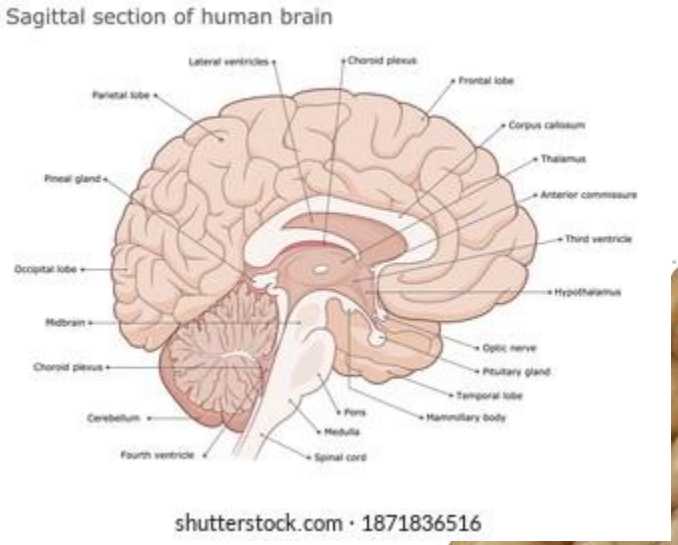
  Homeostasis
  Basic survival behaviors such as feeding, fighting, fleeing, and reproducing.

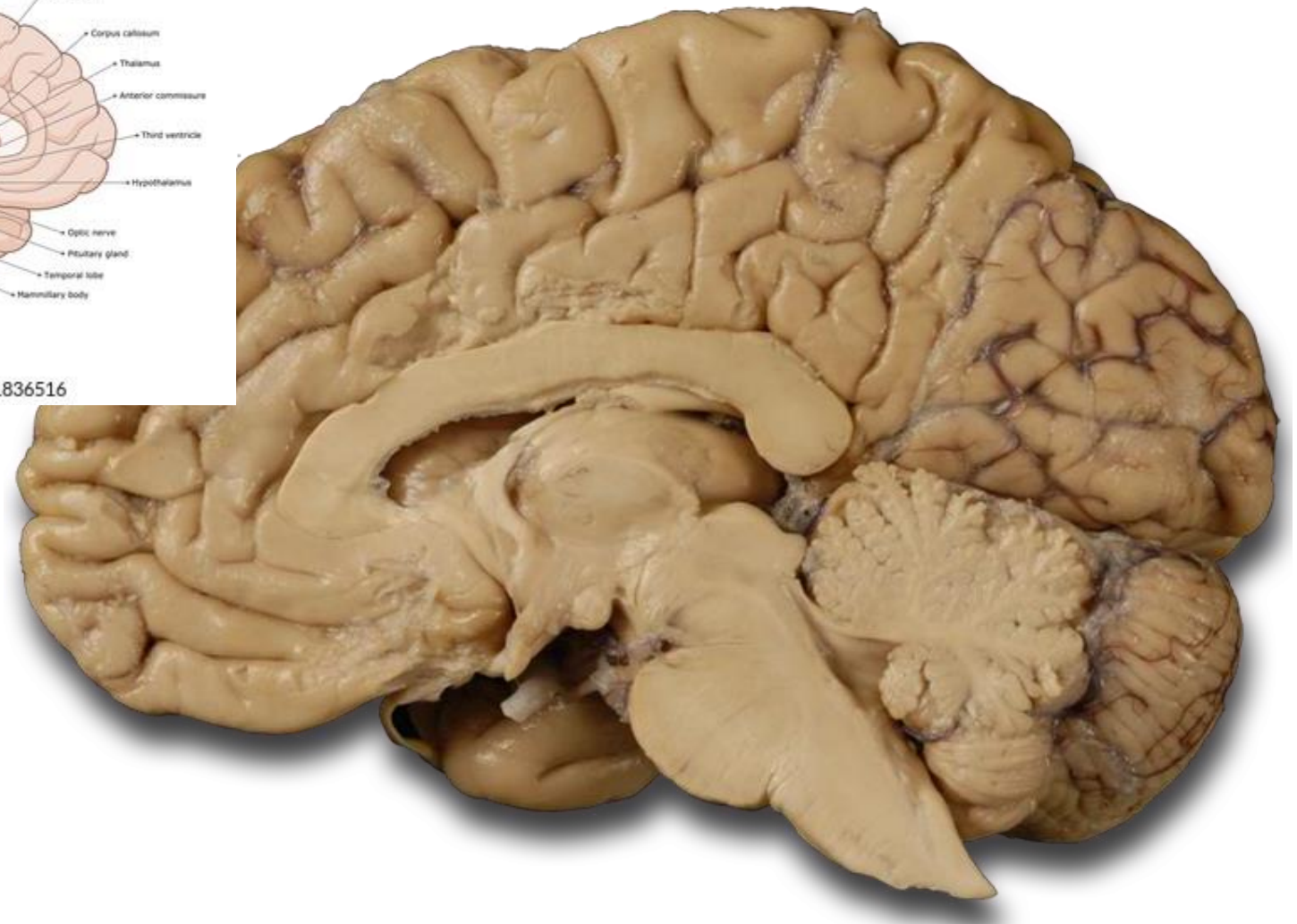
The Cerebellum

- 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.**



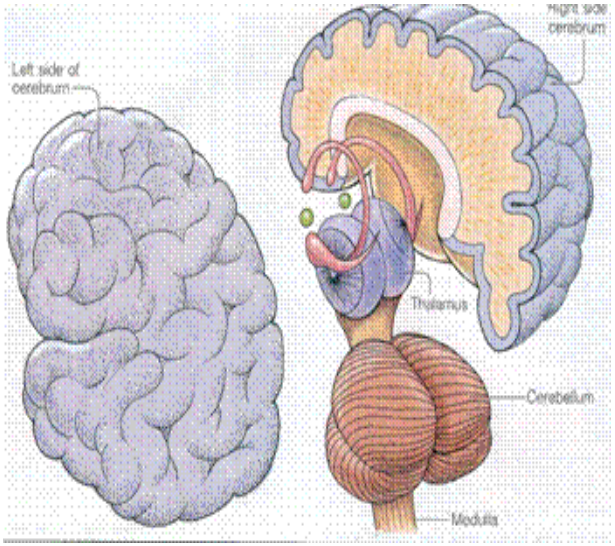
The Brain stem

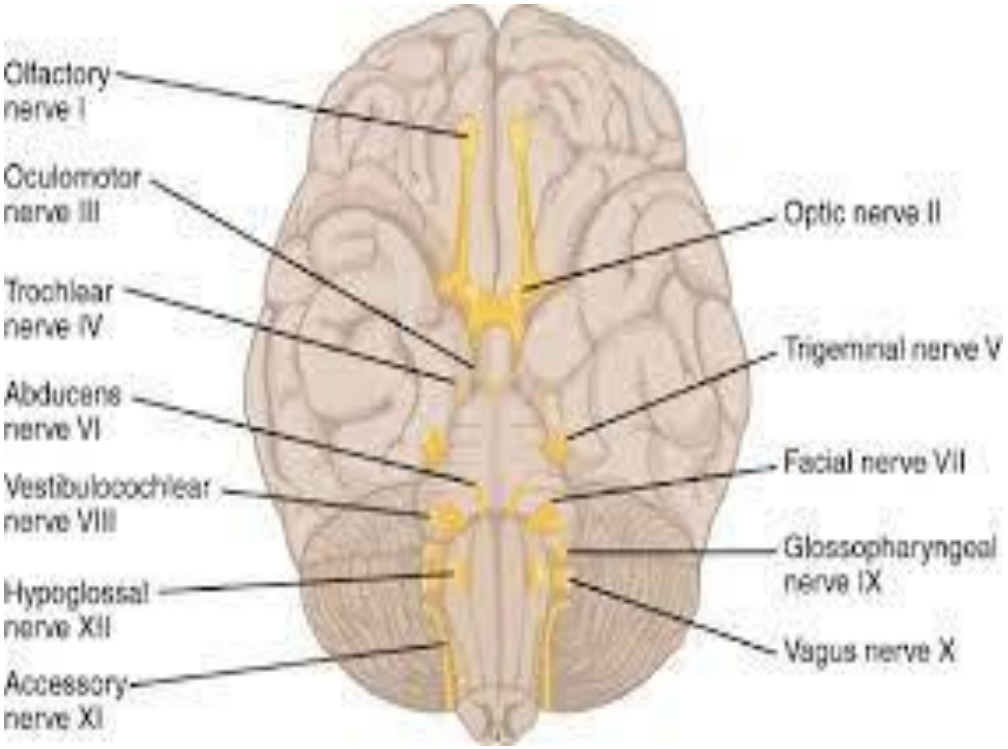




The Brain Stem connects the brain to the spinal cord

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

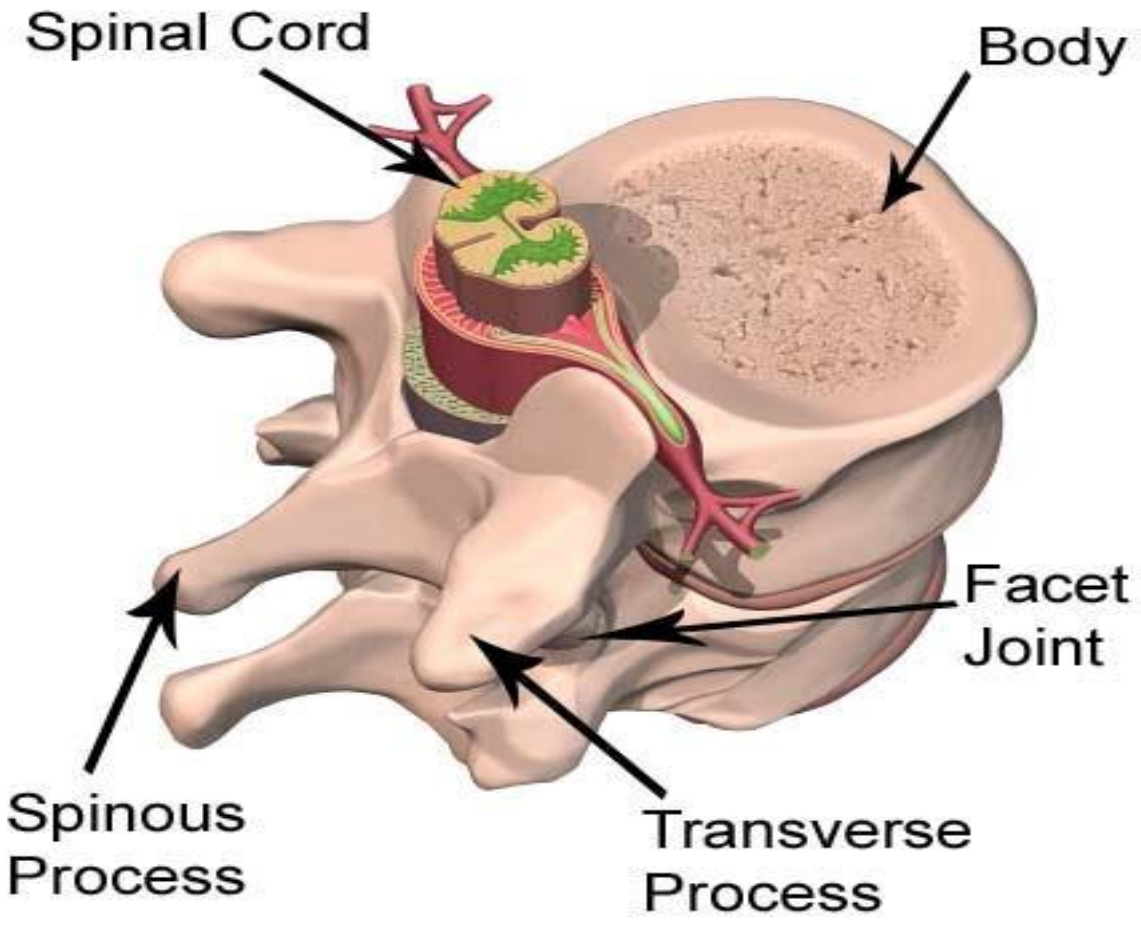


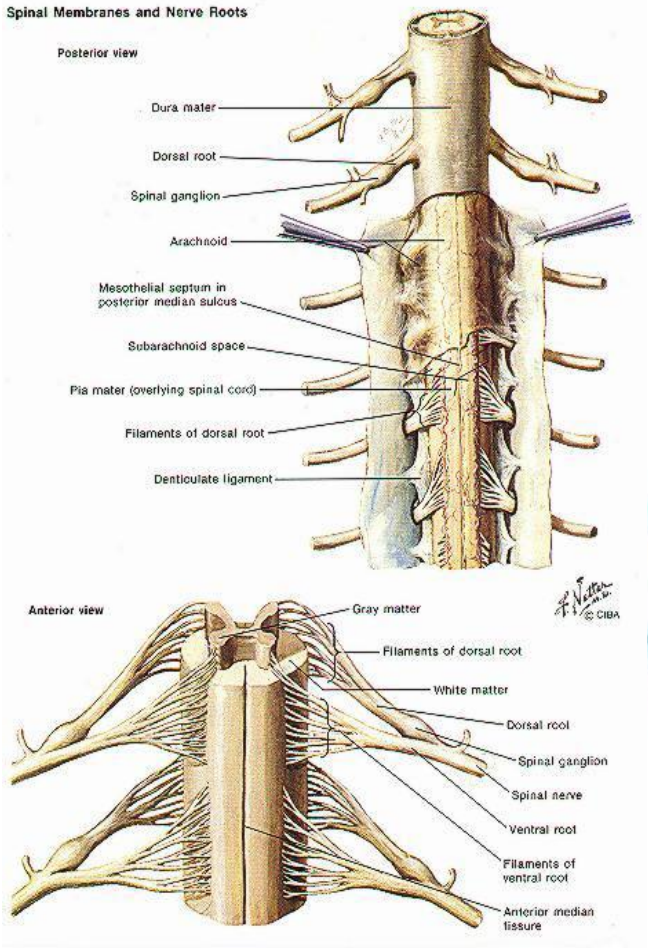


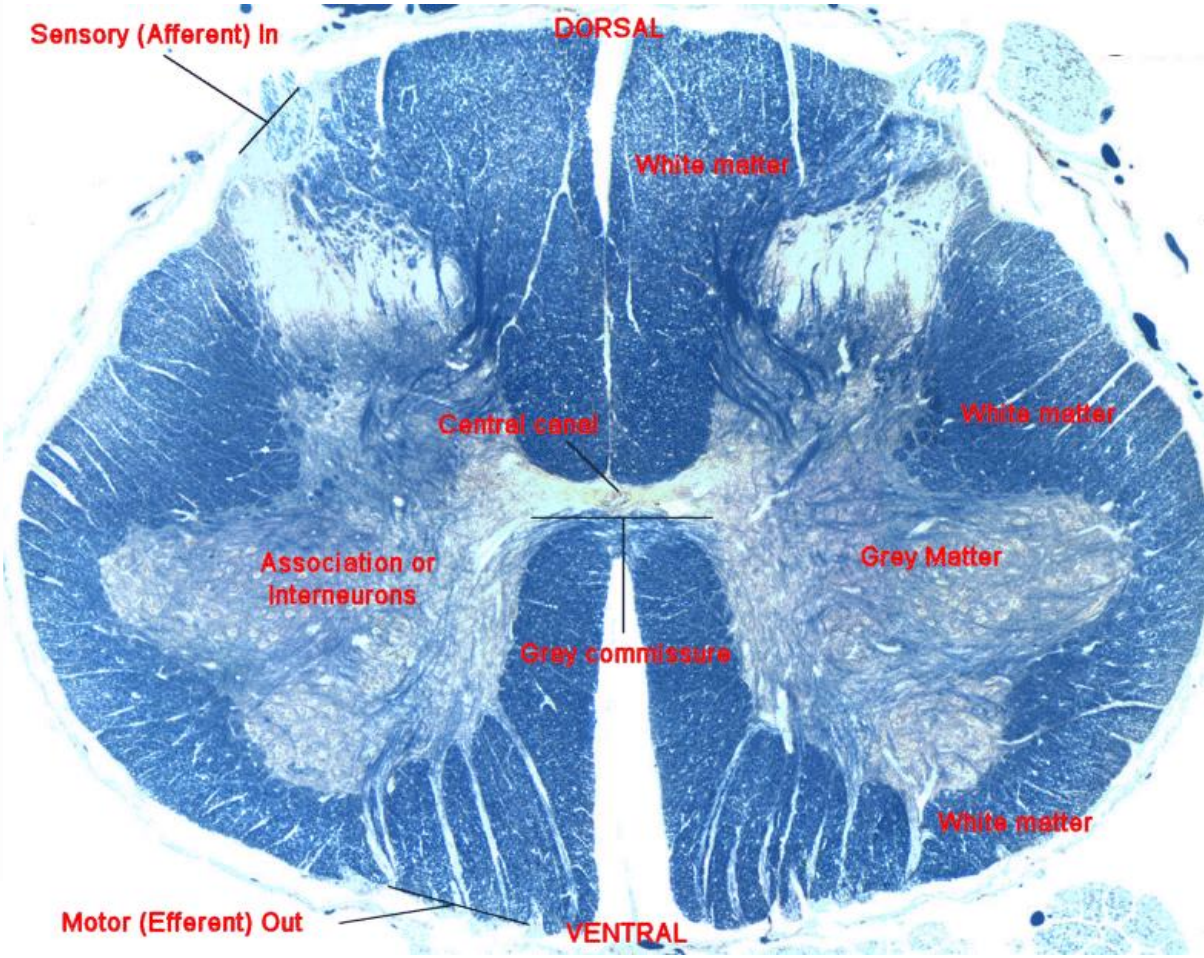
Interesting Facts !!!

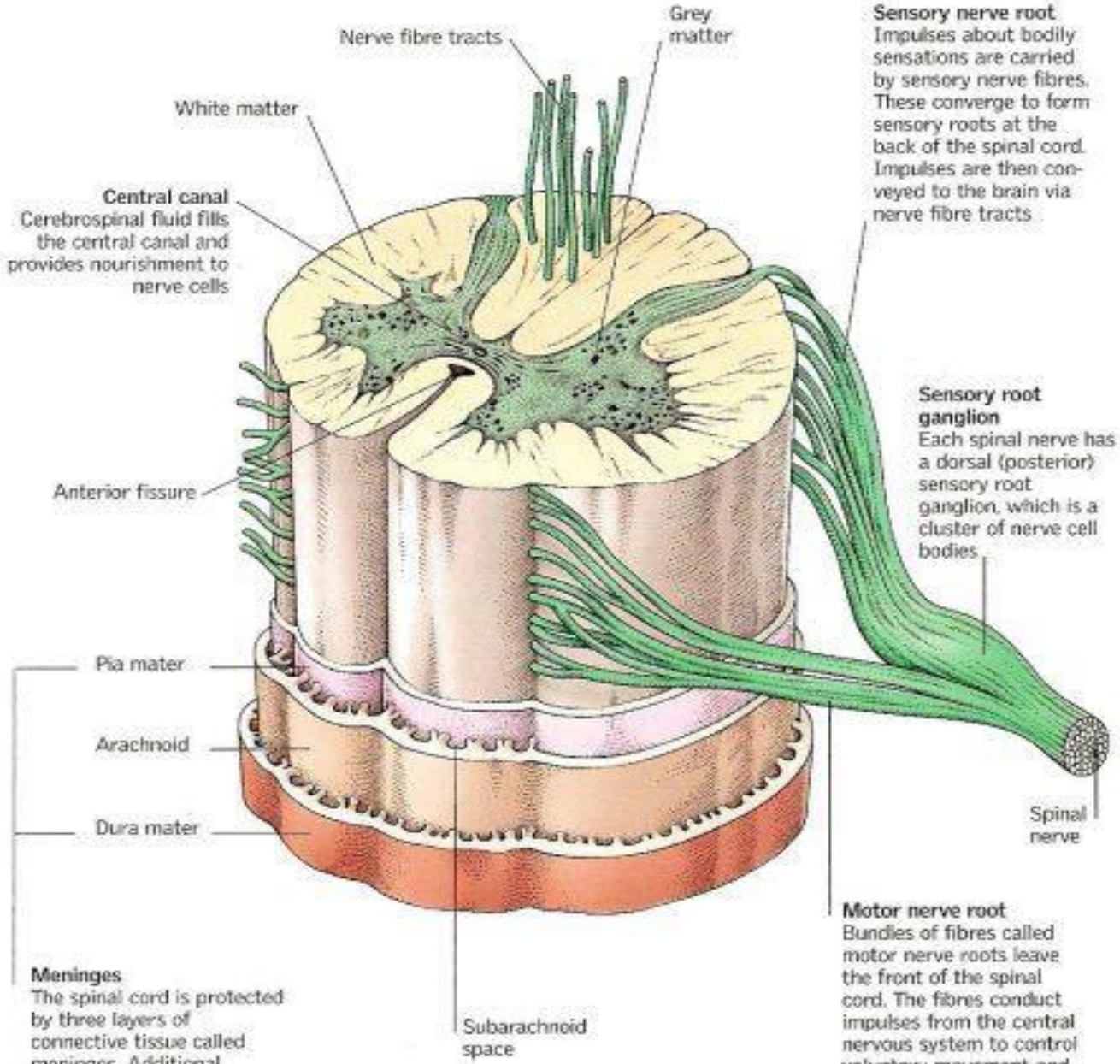
- The left side of the brain controls the right side of the body.
- The right side of the brain controls the left side of the body.
- The brain is full grown by age 6.
- It weighs about 1,4-1,5 kg.
- The brain is made mostly of water (85%).

The spinal level

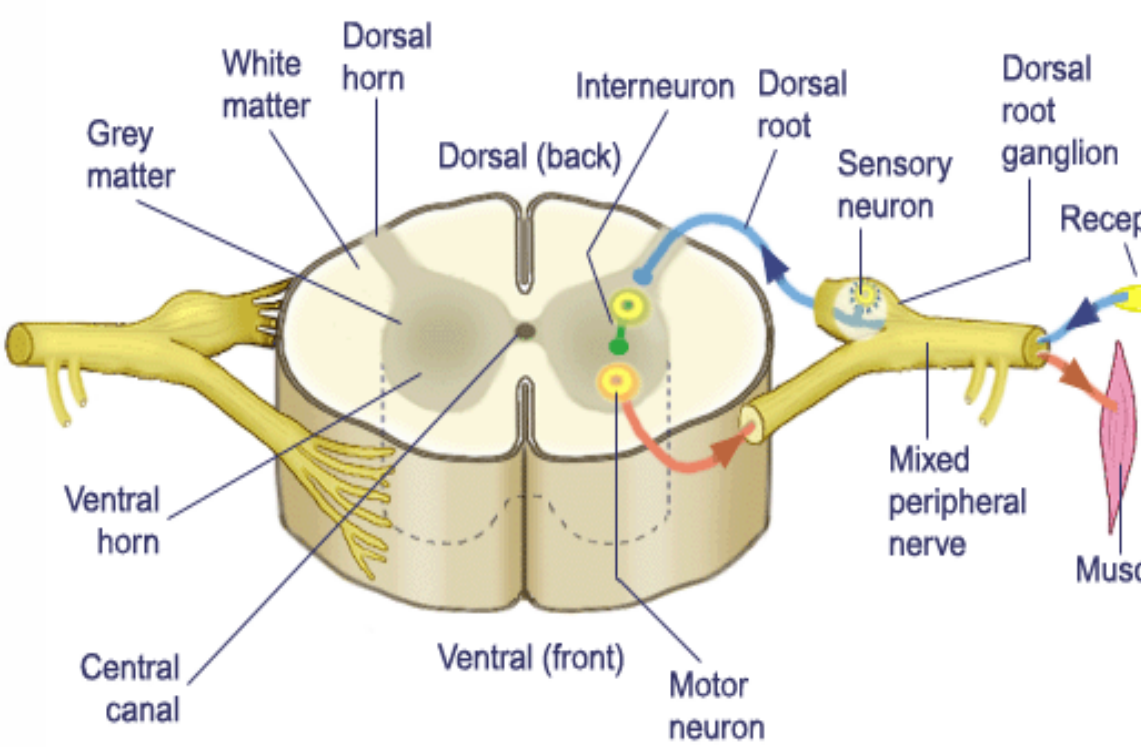


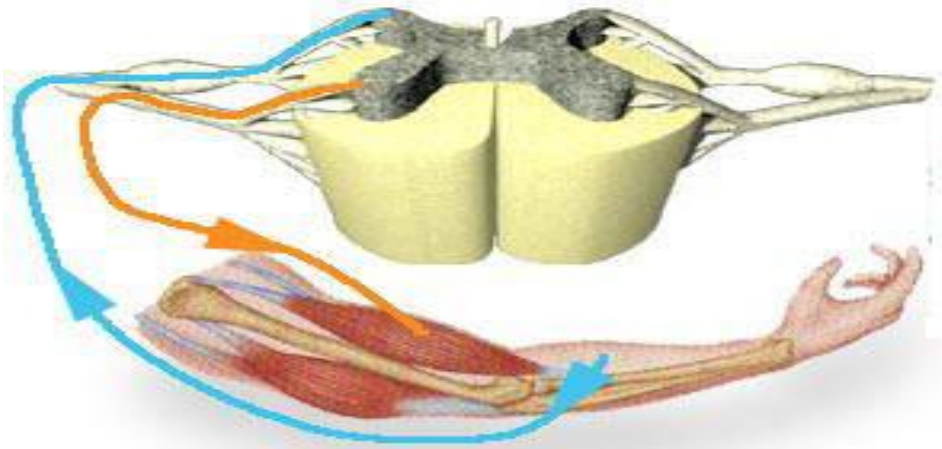

Spinal Membranes and Nerve Roots
Posterior view
Dura mater
Dorsal root
Spinal ganglion
Arachnoid
Mesothelial septum in posterior median sulcus
Subarachnoid space
Pia mater (overlying spinal cord)
Filaments of dorsal root
Denticulate ligament
Anterior view
Gray matter
Filaments of dorsal root
White matter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

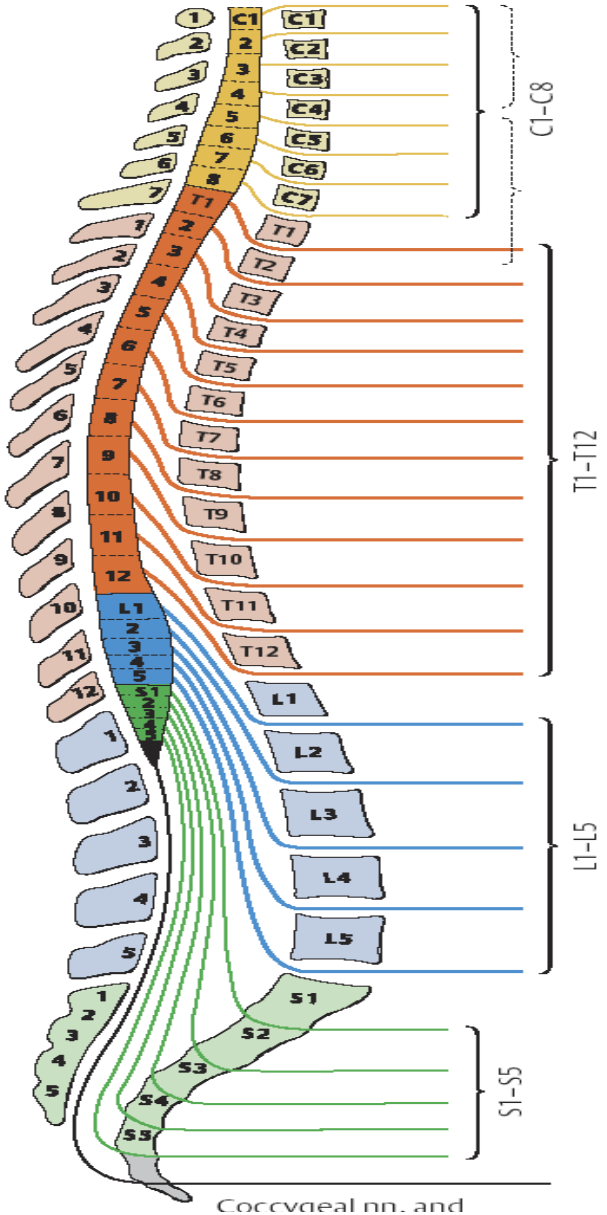

Sensory (Afferent) In
DORSAL
White matter
Central canal
White matter
Association or Interneurons
Grey Matter
Grey commissure
White matter
Motor (Efferent) Out
VENTRAL



Structure of spinal cord

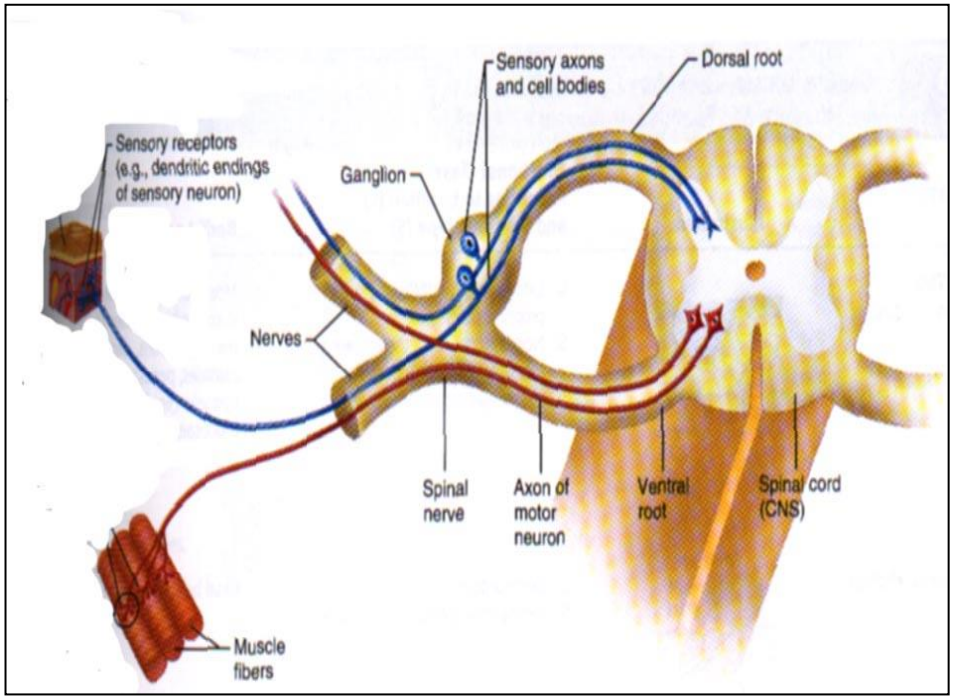

Grey matter
White matter
Dorsal horn
Dorsal (back)
Interneuron
Dorsal root
Sensory neuron
Dorsal root ganglion
Recep
Ventral horn
Central canal
Ventral (front)
Motor neuron
Mixed peripheral nerve
Musc




C1
C2
C3
C4
C5
C6
C7
C1–C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T1–T12
L1
L2
L3
L4
L5
L1–L5
S1
S2
S3
S4
S5
S1–S5
Coccygeal nn. and

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.



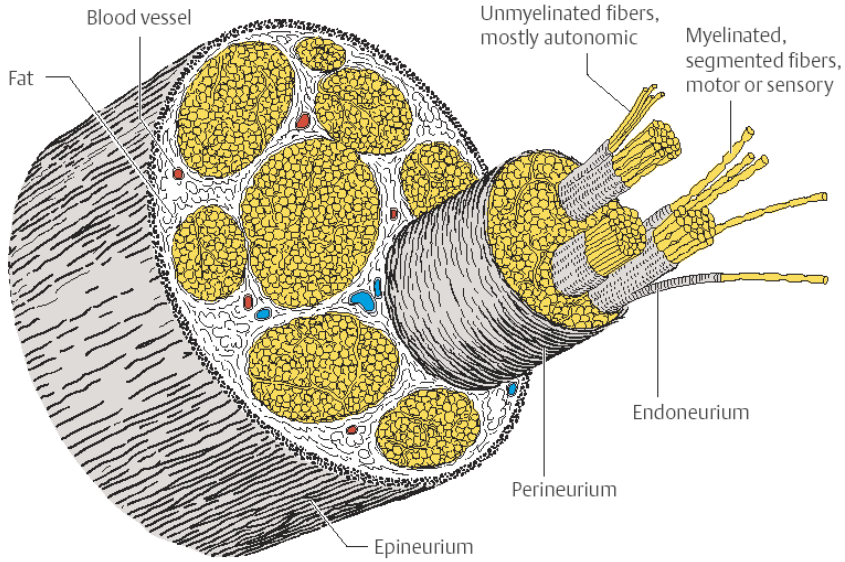


Fig. 2.3 **Cross section of a mixed peripheral nerve**

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

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.**

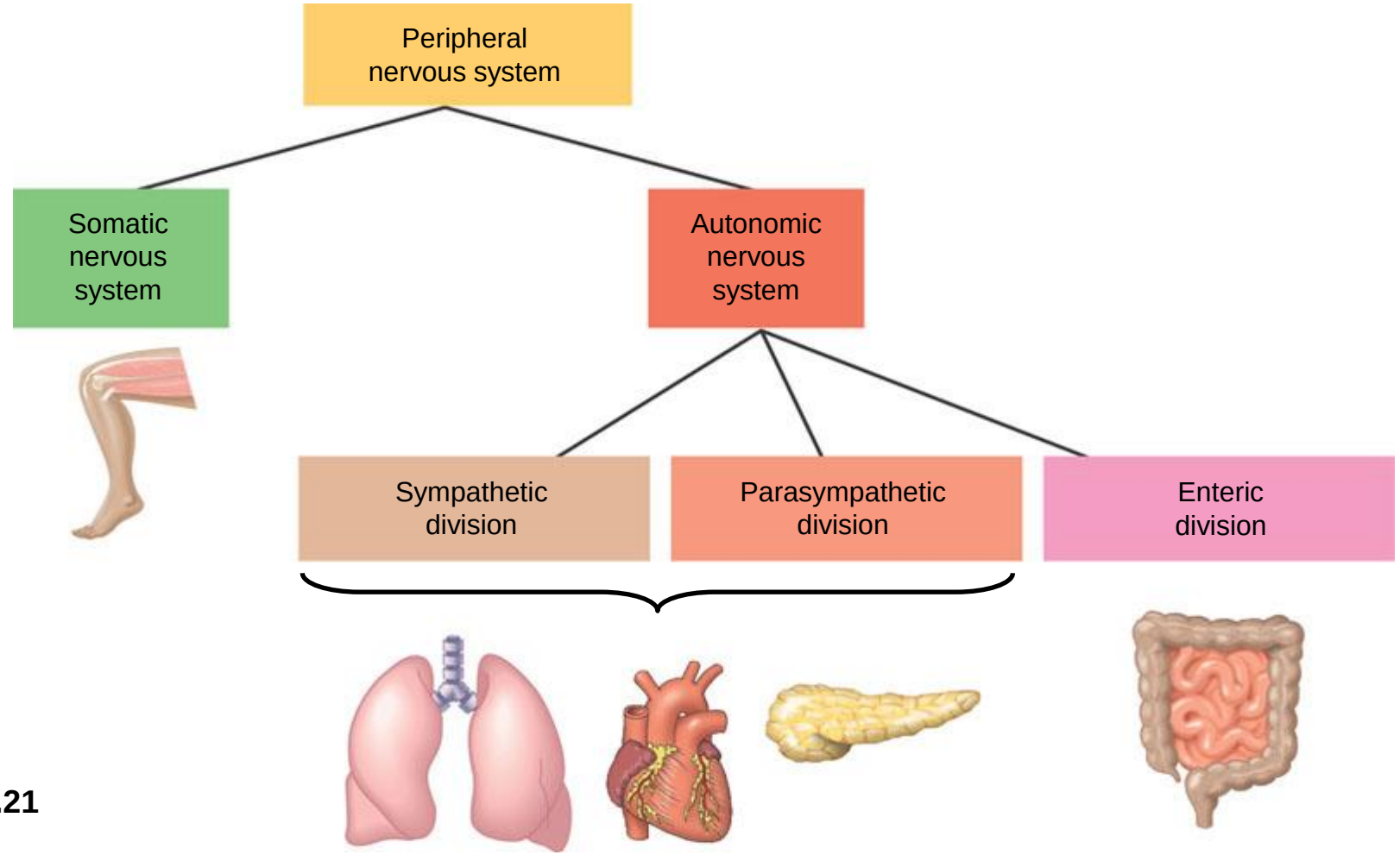
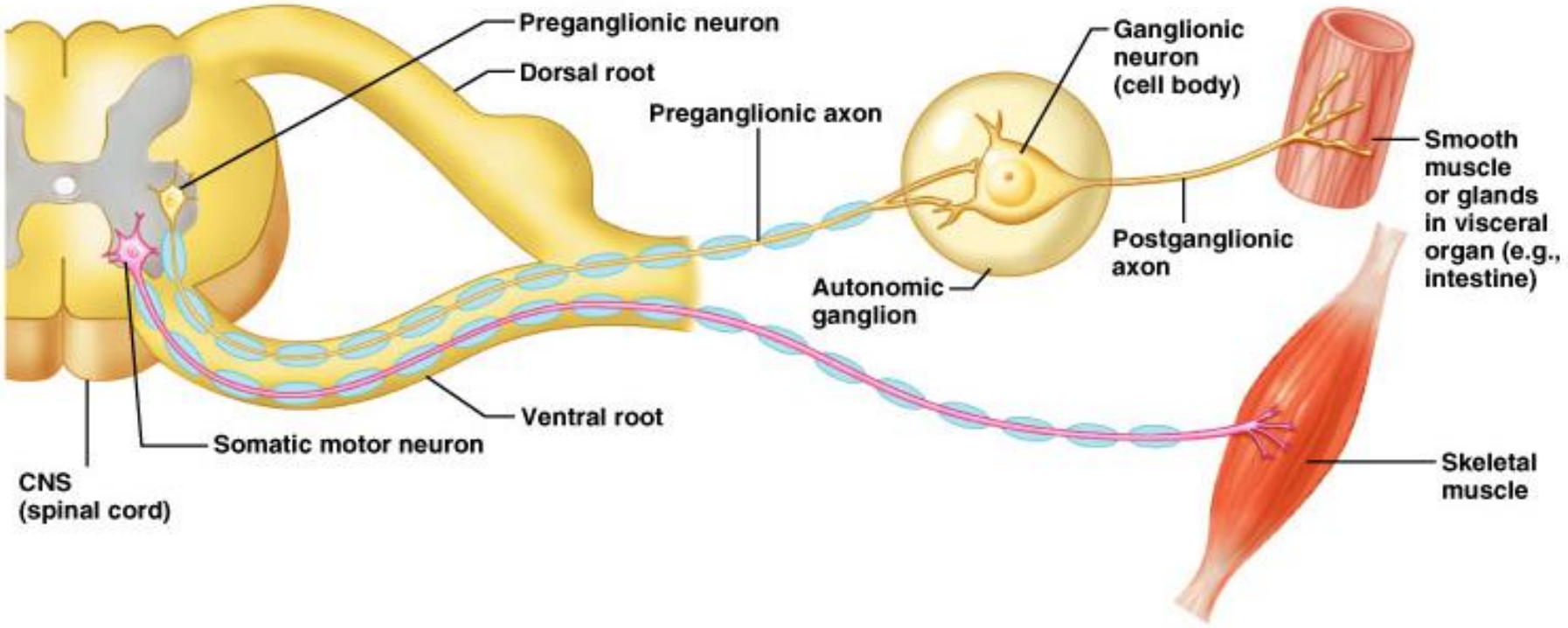


Figure 48.21

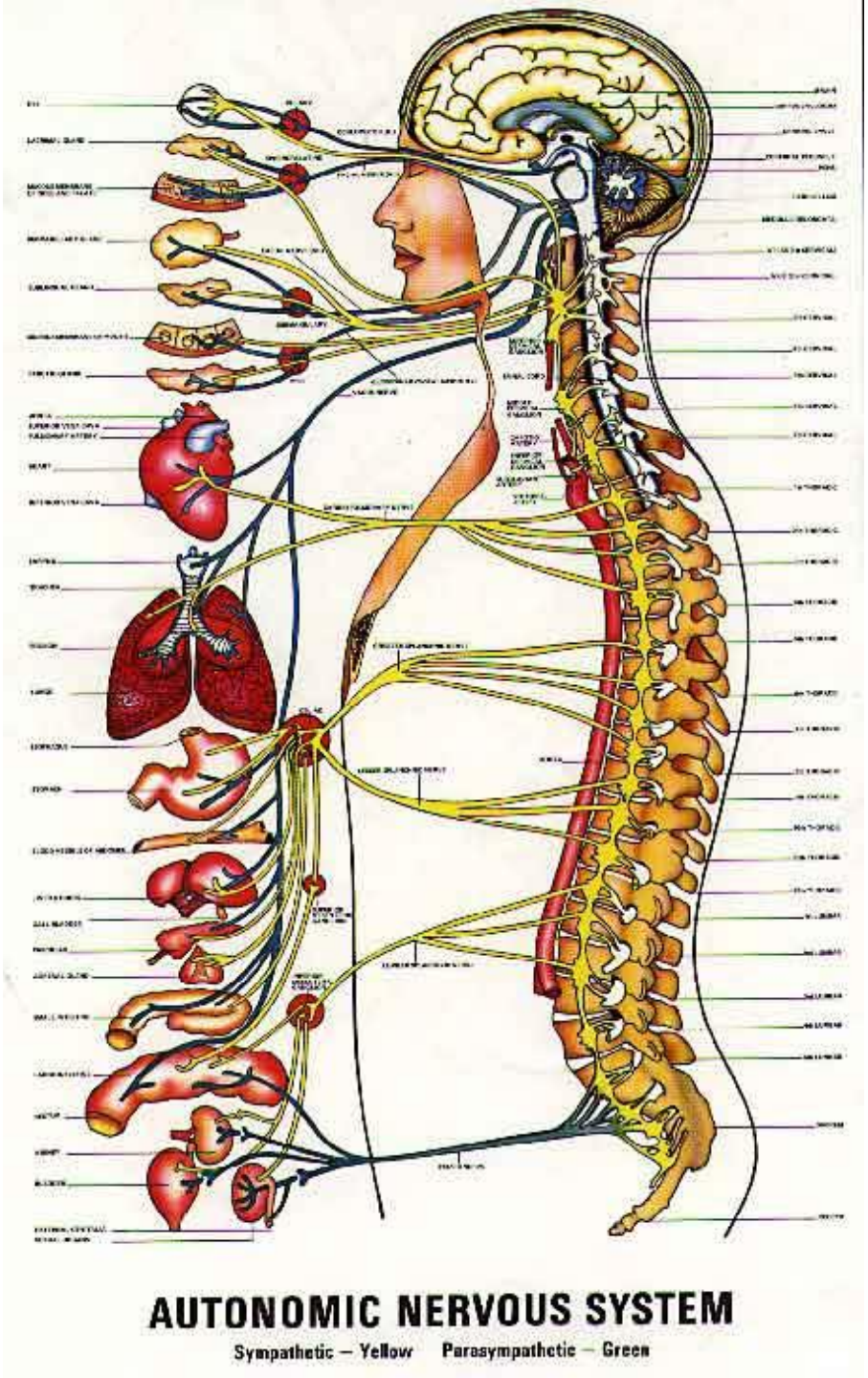
- The somatic nervous system
  - carries signals to skeletal muscles
- The autonomic nervous system
  - regulates the internal environment, in an involuntary manner,
  - is divided into the sympathetic, parasympathetic, and enteric divisions

Autonomic and Somatic Motor Systems



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

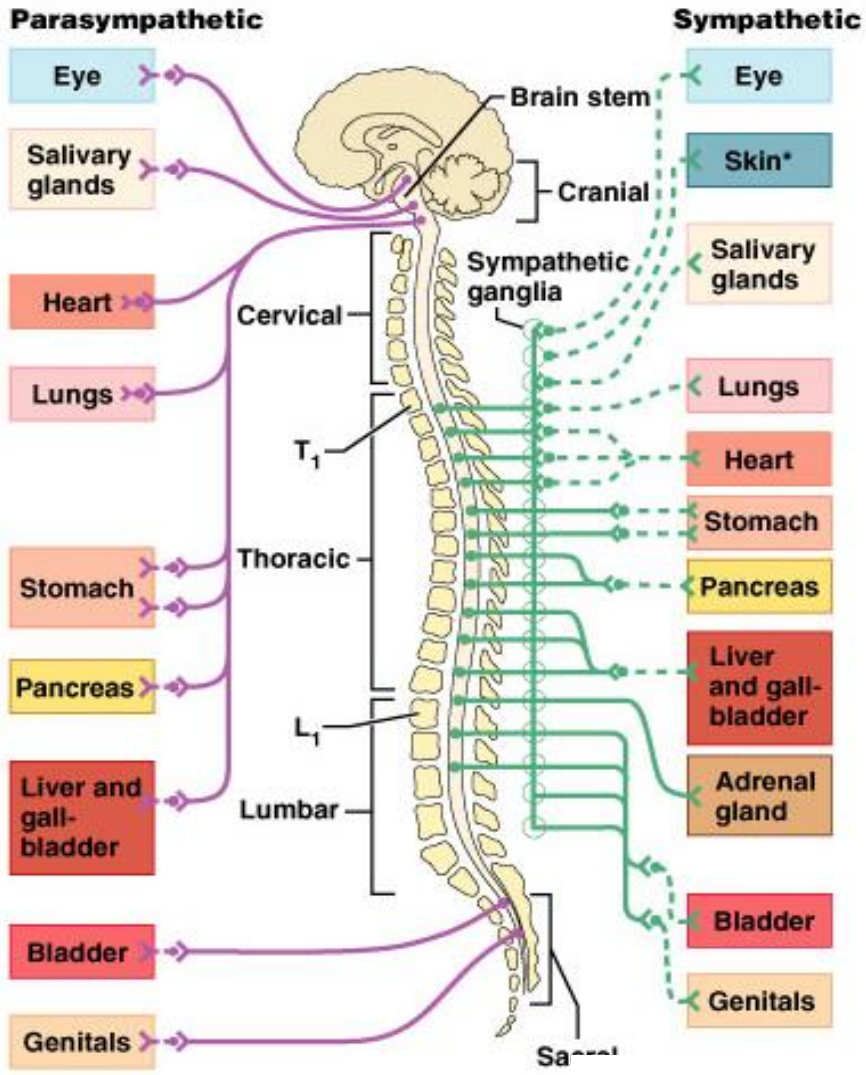


The *sympathetic division* correlates with the "fight-or-flight" response.

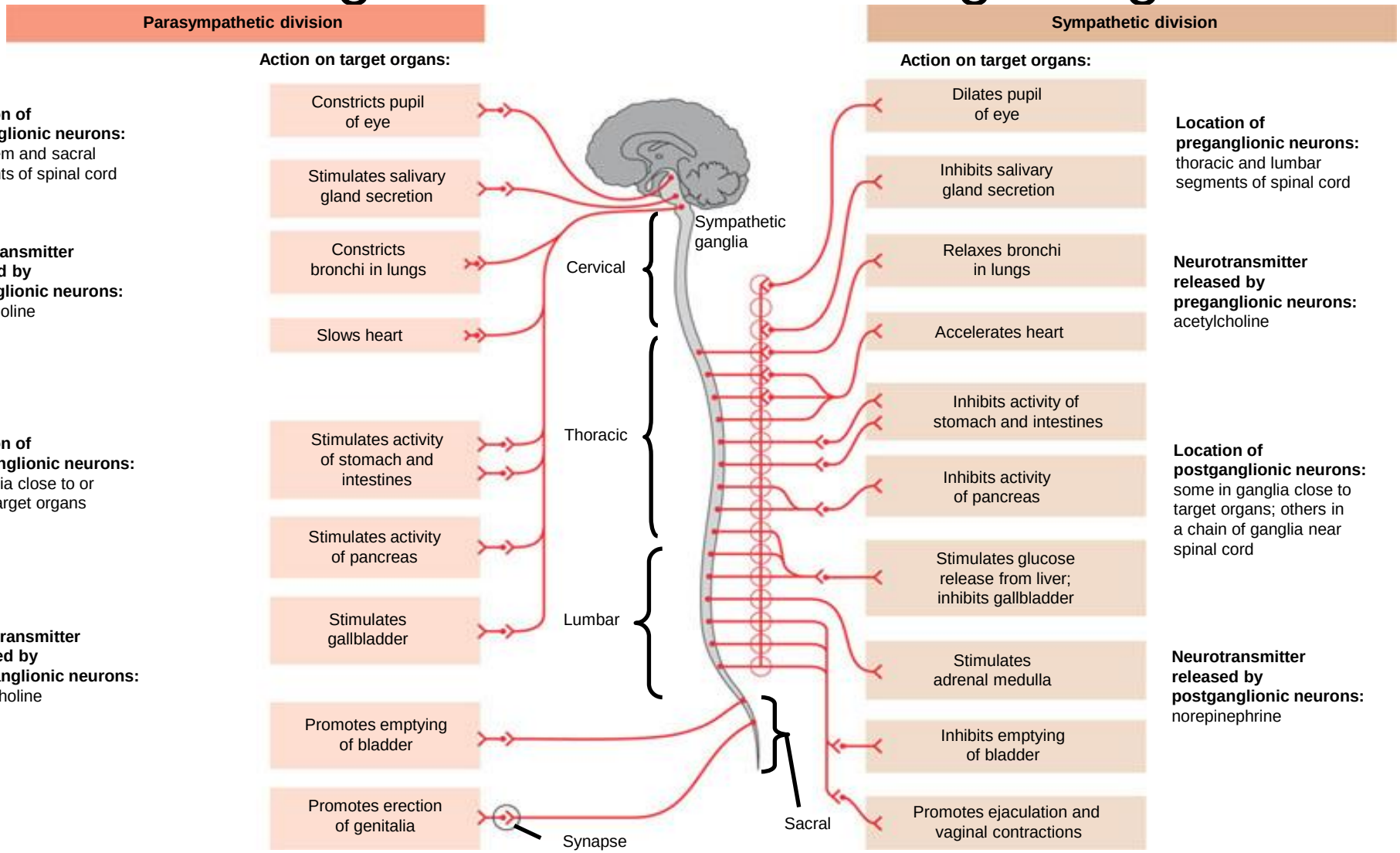
The *parasympathetic division* promotes a return to self-maintenance functions.

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



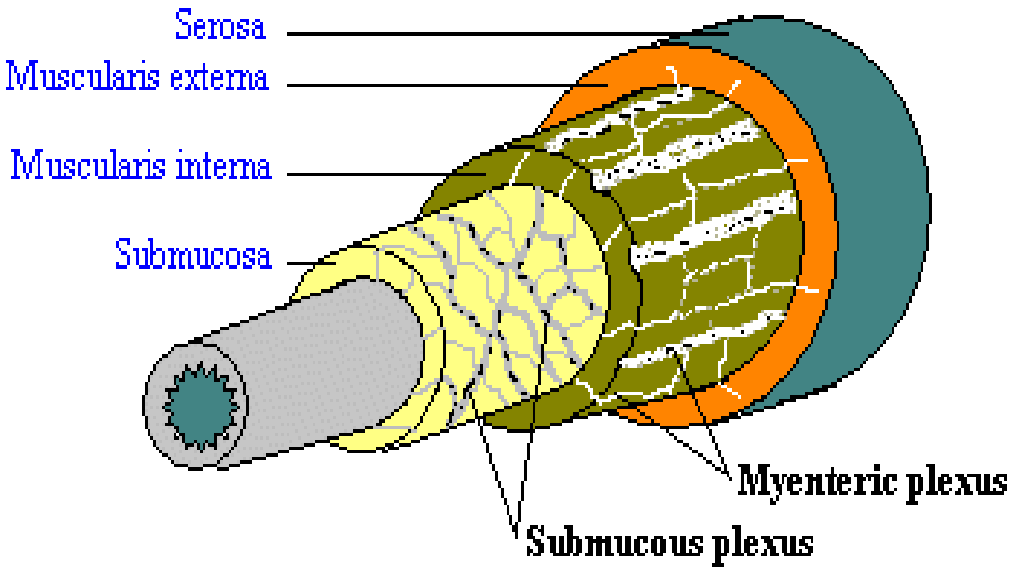
The **sympathetic and parasympathetic divisions** have antagonistic effects on target organs.



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.



References

Mayo Clinic, Medical Neurosciences/Ιατρικές Νευροεπιστήμες, 5η έκδοση/1η ελληνική έκδοση, Εκδόσεις Γκότσης, 2015