

General Layout of the Nervous System

Complexity of human brain



- Average human brain weighs about 1.3kg
- A network of neurons
 - 100 billion neurons
 - Each neuron having about 1000 synaptic connections
 - Total 100 trillion connections

How is the nervous system organized overall?

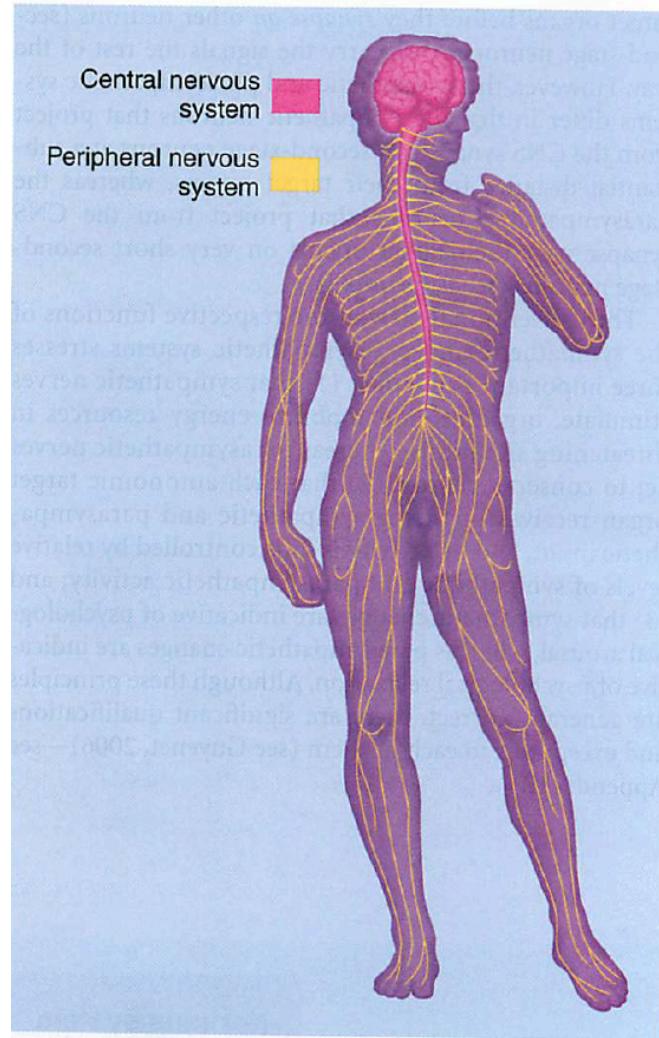
Today we will learn.....

- **General layout of the nervous system**
- **Structures protecting the nervous system**
- **Cellular components of the nervous system**
- **Anatomy of major structures of the nervous system (brain and spinal cord)**

General Layout of the Nervous System

Nervous system is divided into two main divisions

- Central Nervous System (CNS)
 - Brain (inside the skull)
 - Spinal Cord (inside the spine)
- Peripheral Nervous System (PNS)
 - outside of the skull and spine
 - bring information into the CNS and carry signals out of the CNS
 - most of PNS nerves project from spinal cord except the 12 pairs of nerves called cranial nerves which project from the brain.



Before we learn more details.....

There are some definitions we need to remember

- **Nerve:** Collection of axons outside the CNS.
- **Tract:** Collection of axons inside the CNS.

Afferent tract or nerves : carries information into a region of interest

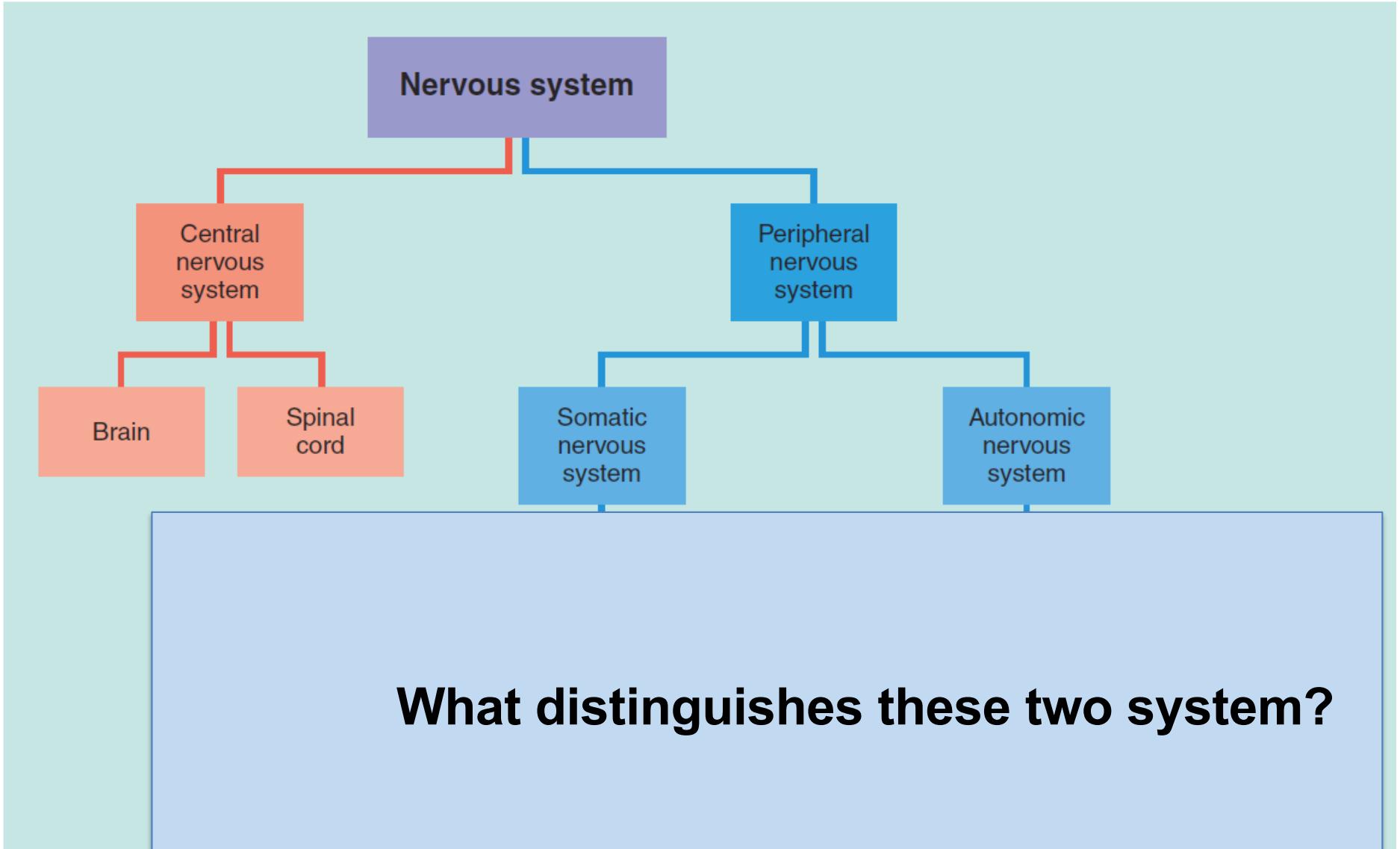
Efferent tract or nerves : carries information away from a region of interest

Neurons are often found as a cluster

- **Ganglion (pl. ganglia):** A cluster of neuron cell bodies outside the CNS
- **Nucleus:** A cluster of neuron cell bodies inside the CNS

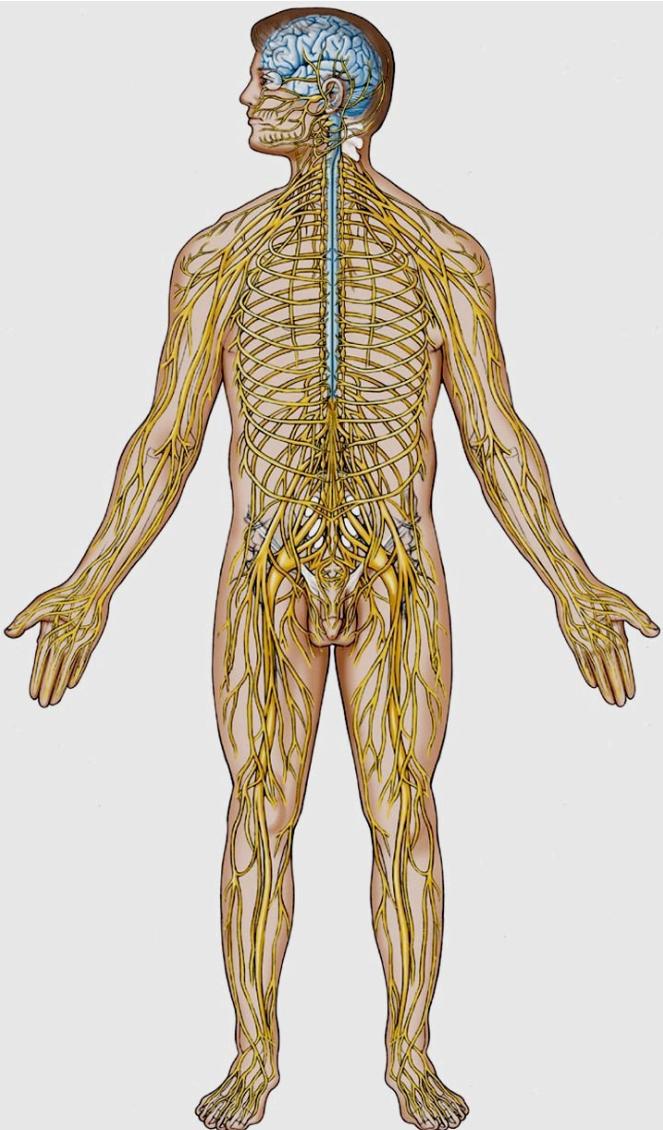
General Layout of the Nervous System

PNS is further divided into two subdivisions:
Somatic nervous system and **autonomic nervous system**



Anatomy of Somatic Nervous System

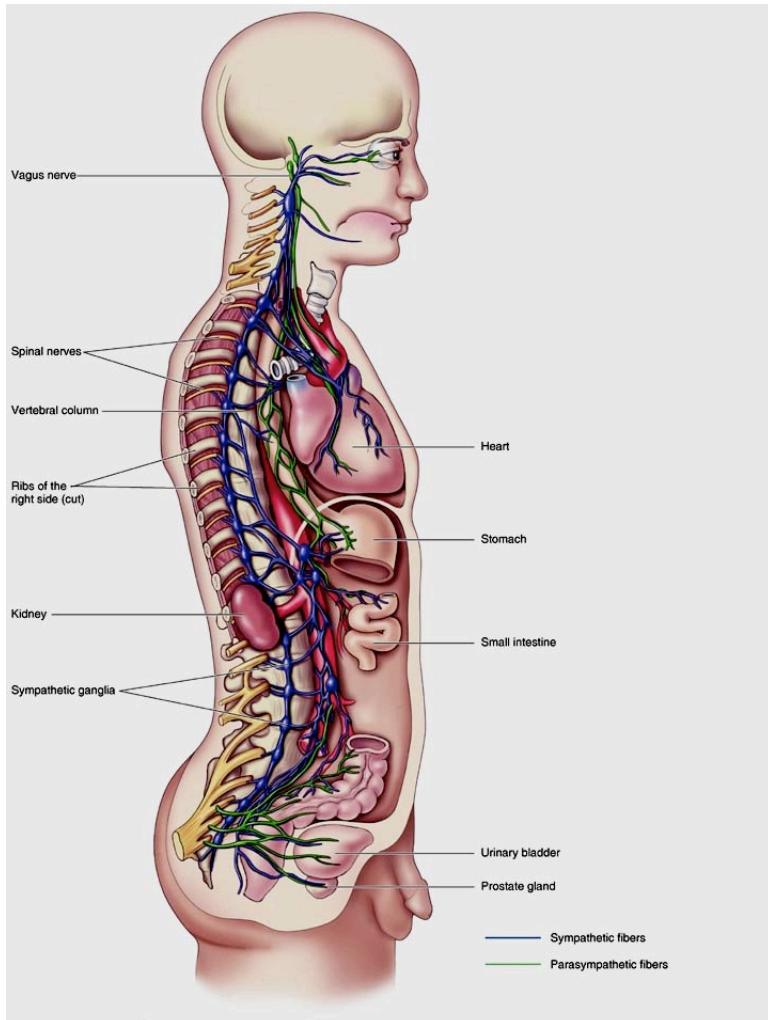
Somatic nervous system interacts with the **body's external environment through body surface and skeletal muscles**



- Receives sensory information from **sensory organs** (e.g., skin, eyes, ear, etc.) and controls movements of **skeletal muscles**
 - Afferent nerves carry information from various body parts close to external environment to the CNS – (i.e. sensory nerves)
 - Efferent nerves carry information from the CNS to the skeletal muscle – (i.e. motor nerves)

Anatomy of Autonomic Nervous System

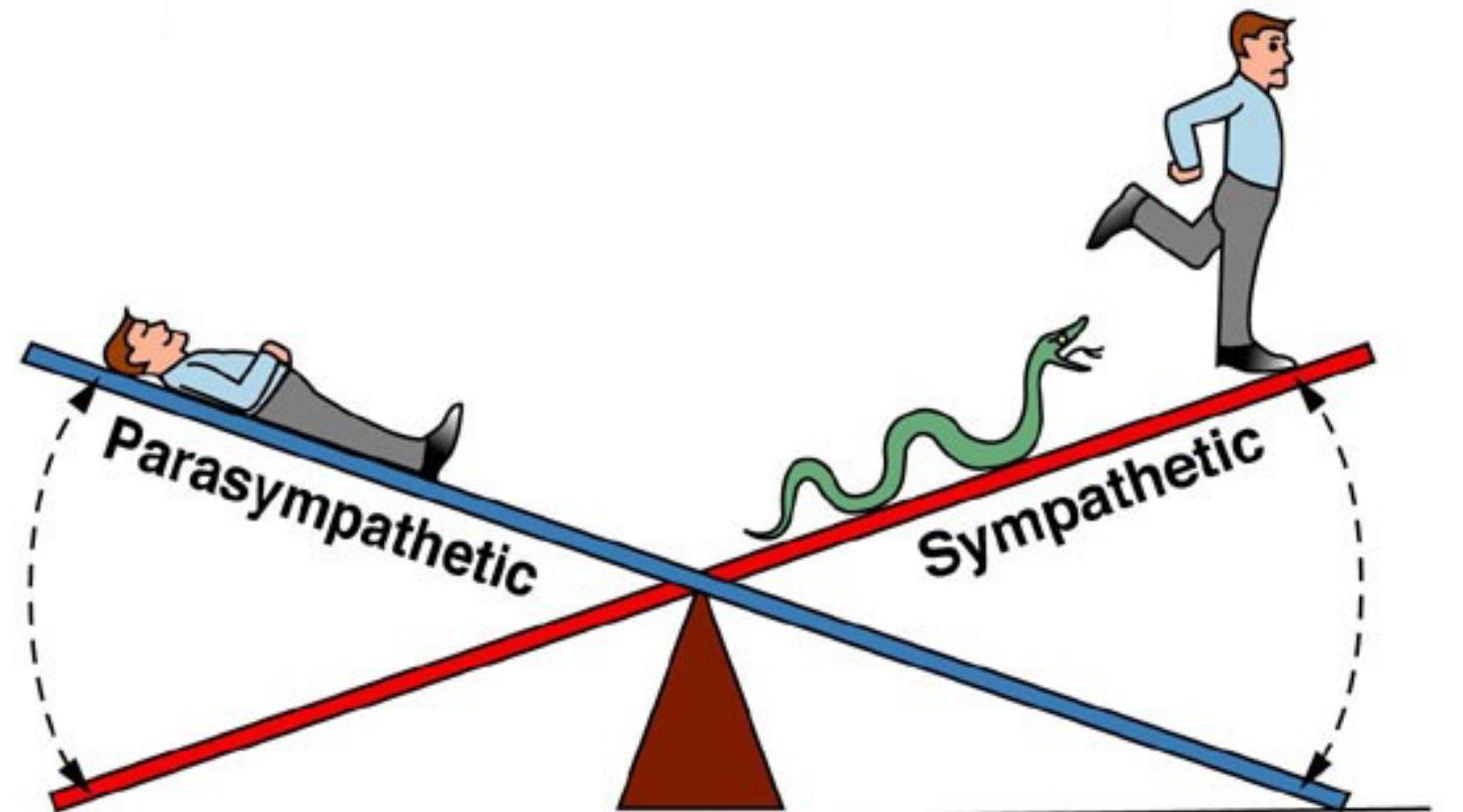
In contrast, autonomic nervous system interacts with the body's internal environment (internal organs)



- **Afferent** nerves carry sensory signals from internal organs to the CNS – **sensory nerves**
- **Efferent** nerves carry motor signals from the CNS to internal organs – **motor nerves**
 - *Operates without direct control by our consciousness*
- **Autonomic efferent motor nerves** are divided into **two systems** based on their structure and function.
 - **Sympathetic division**
 - **Parasympathetic division**

Sympathetic VS. parasympathetic division

Functional difference



Rest-and-digest:
Parasympathetic
activity dominates.

Fight-or-flight:
Sympathetic activity
dominates.

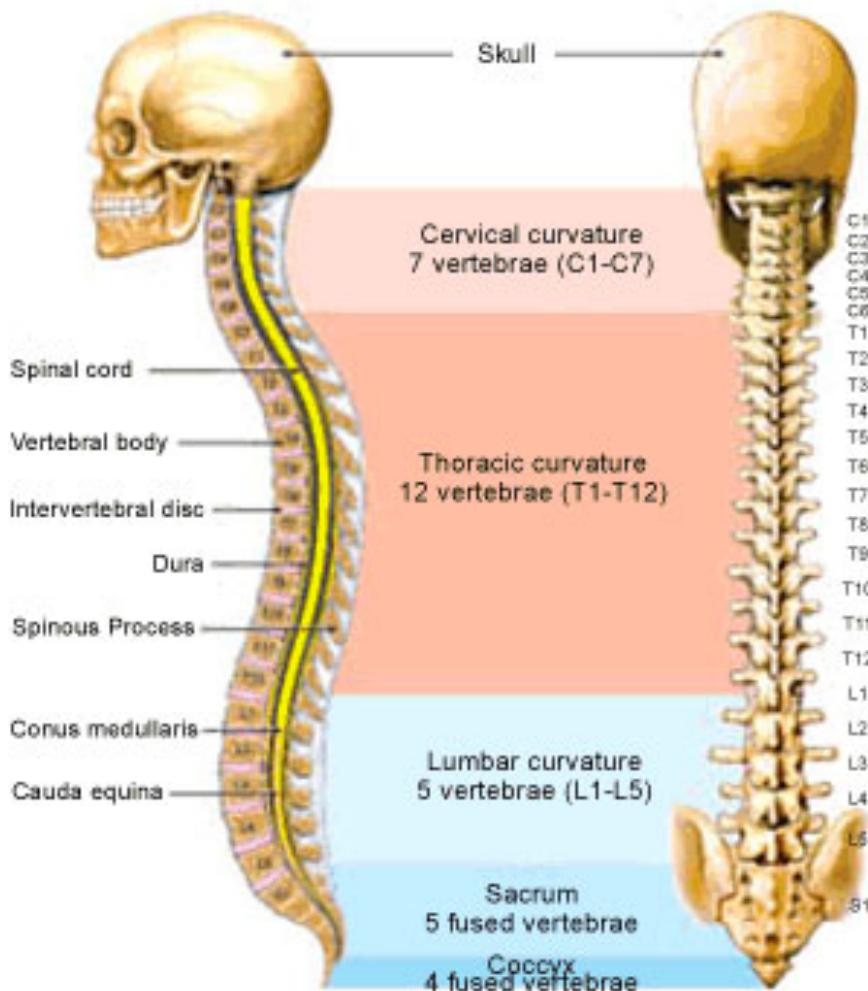
Sympathetic VS. parasympathetic division

Structural difference

- Sympathetic nerves and parasympathetic nerves emerge from different positions along the spine
- Need to know the basic anatomy of the spine

Anatomy of Autonomic Nervous System

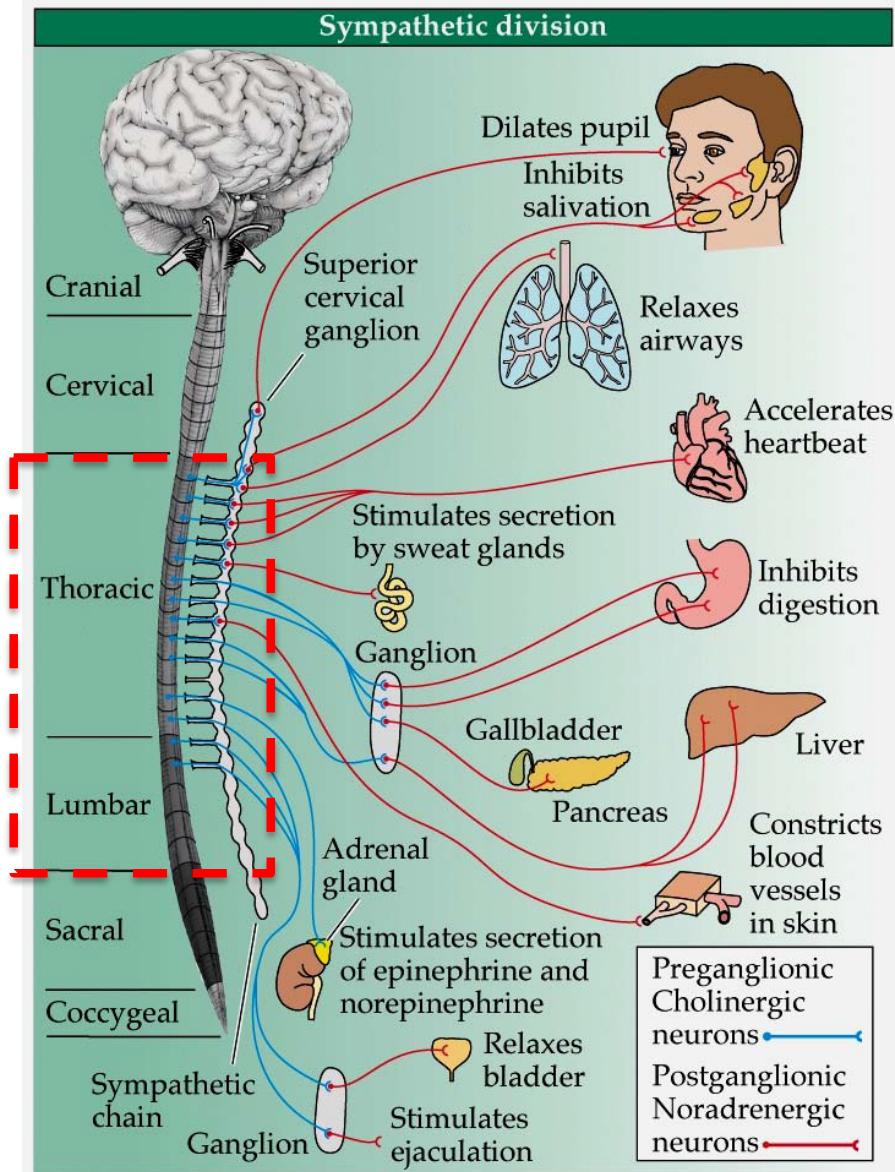
Human spine is composed of 33 bones called vertebrae.



- Cervical spine - 7 vertebrae in the neck.
- Thoracic spine - 12 vertebrae in the upper back.
- Lumbar spine - 5 vertebrae in lower back.
- Sacrum spine - 5 fused vertebrae.
- Coccyx ('käk-siks) spine - 4 fused vertebrae.

Anatomy of Autonomic Nervous System

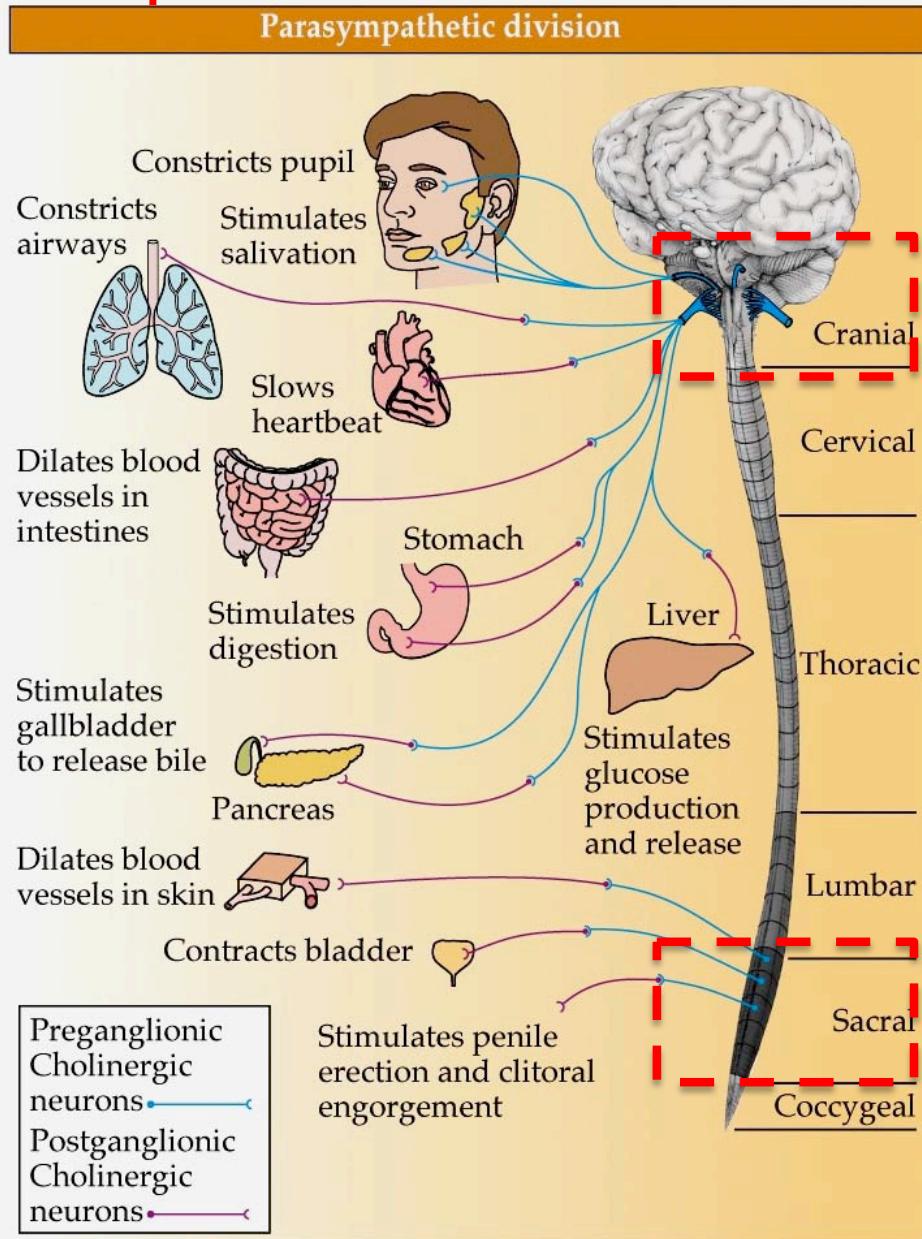
Sympathetic motor nerves project from spinal motor neurons in the middle portion of the spinal cord (the lumbar and thoracic spine regions).



- Prepares body for vigorous activity in threatening situations (“Fight or flight”)
 - increases heart rate
 - facilitates breathing
 - increases sweating
 - dilates pupil
 - inhibits digestion
 - And many others.....
 - Collectively increases arousal level

Anatomy of Autonomic Nervous System

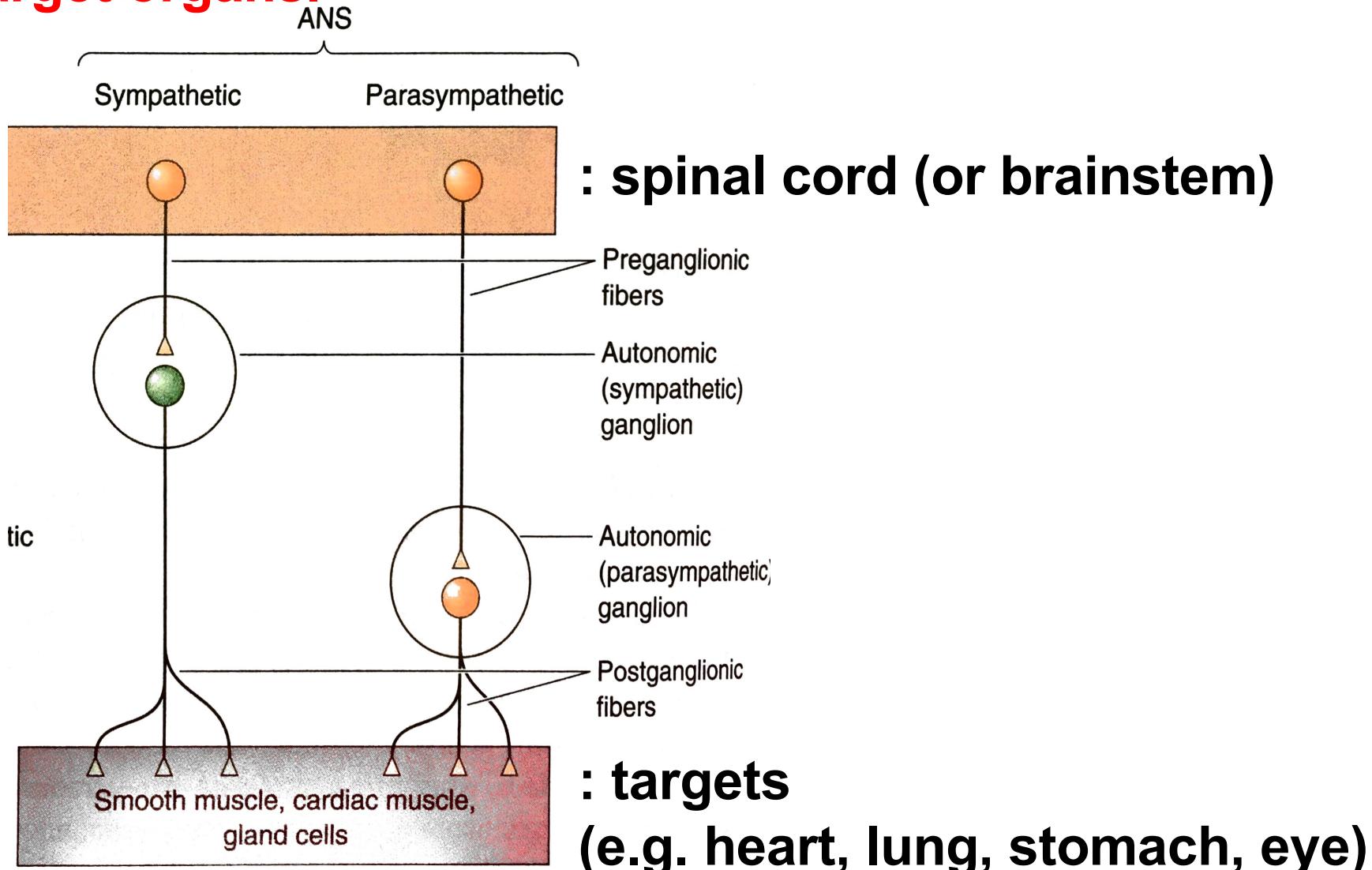
Parasympathetic motor nerves project from the brain and the sacral regions of the spinal cord.



- **promotes vegetative, nonemergency responses in various organs (“Rest and restore/digest” – leads to psychological relaxation)**
 - Decreases heart rate
 - Decreases breathing
 - Constricts pupil
 - Stimulate digestion

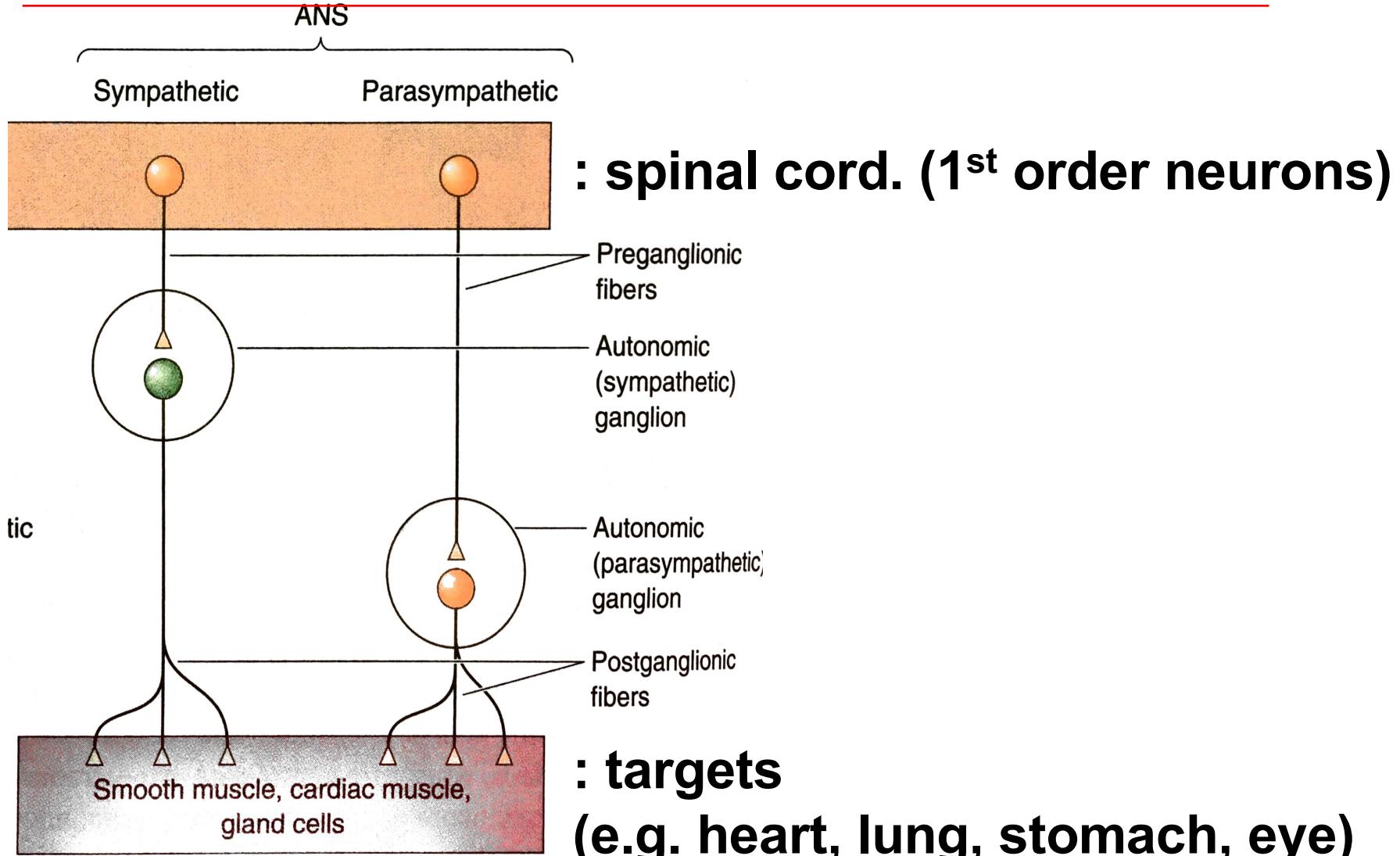
Autonomic nerve system circuit

Autonomic motor nerves control muscles and glands in the target organs.



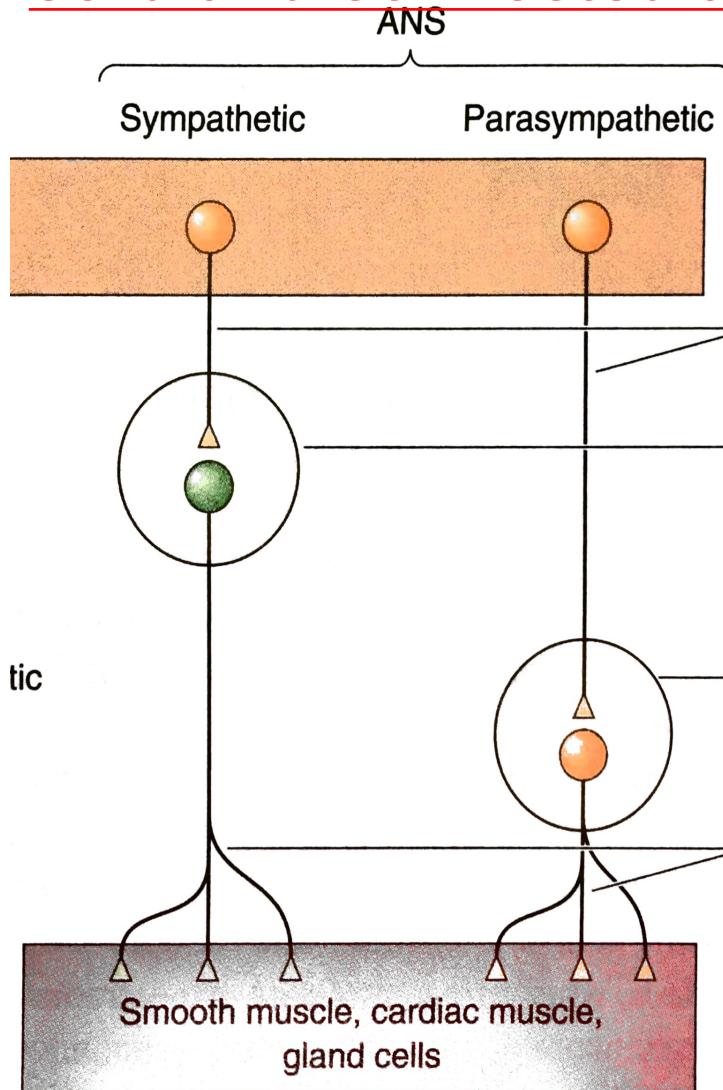
Autonomic nerve system circuit

- Starter neurons (i.e. first order neurons) are in the spinal cord and connected to the second order neurons



Autonomic nerve system circuit

- **Starter neurons (i.e. first order neurons) are in the spinal cord and connected to the second order neurons**



: spinal cord

Preganglionic
fibers
Autonomic
(sympathetic)
ganglion

Autonomic
(parasympathetic)
ganglion
Postganglionic
fibers

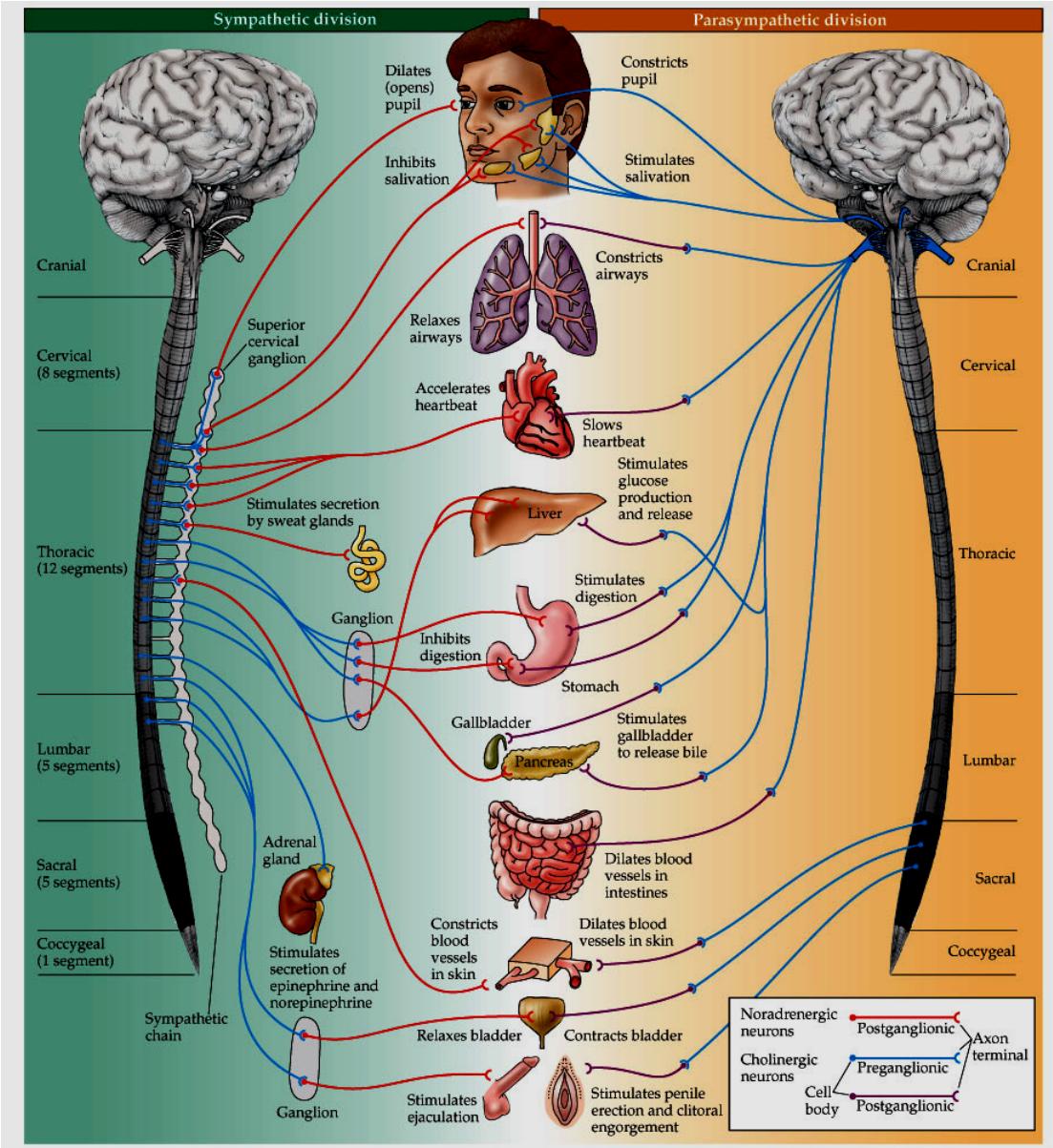
Smooth muscle, cardiac muscle,
gland cells

: targets
(e.g. heart, lung, stomach, eye)

- **Second order neurons of the sympathetic system are near the spinal cord**

- **Second order neurons of the parasympathetic system are near the target organs**

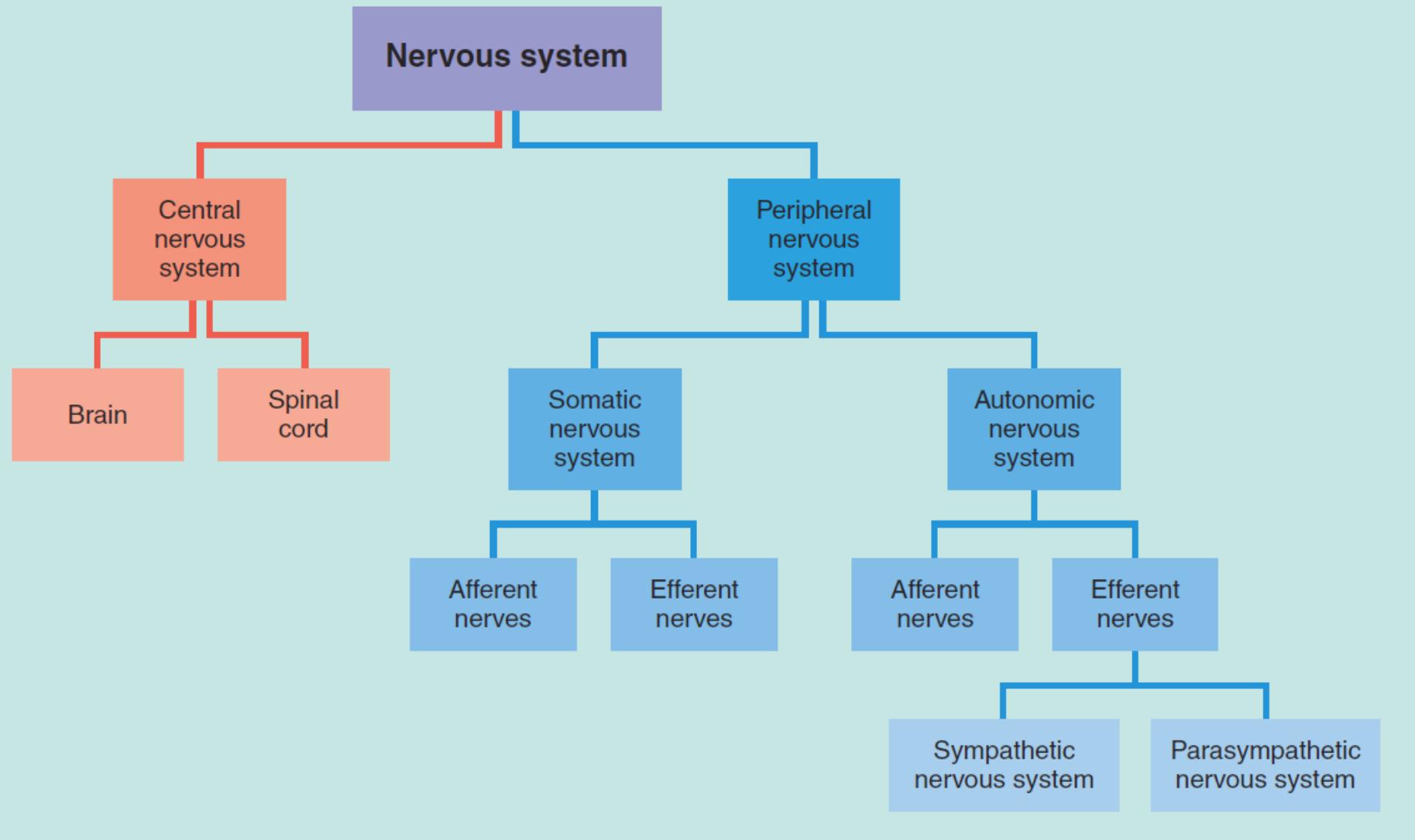
Anatomy of Autonomic Nervous System



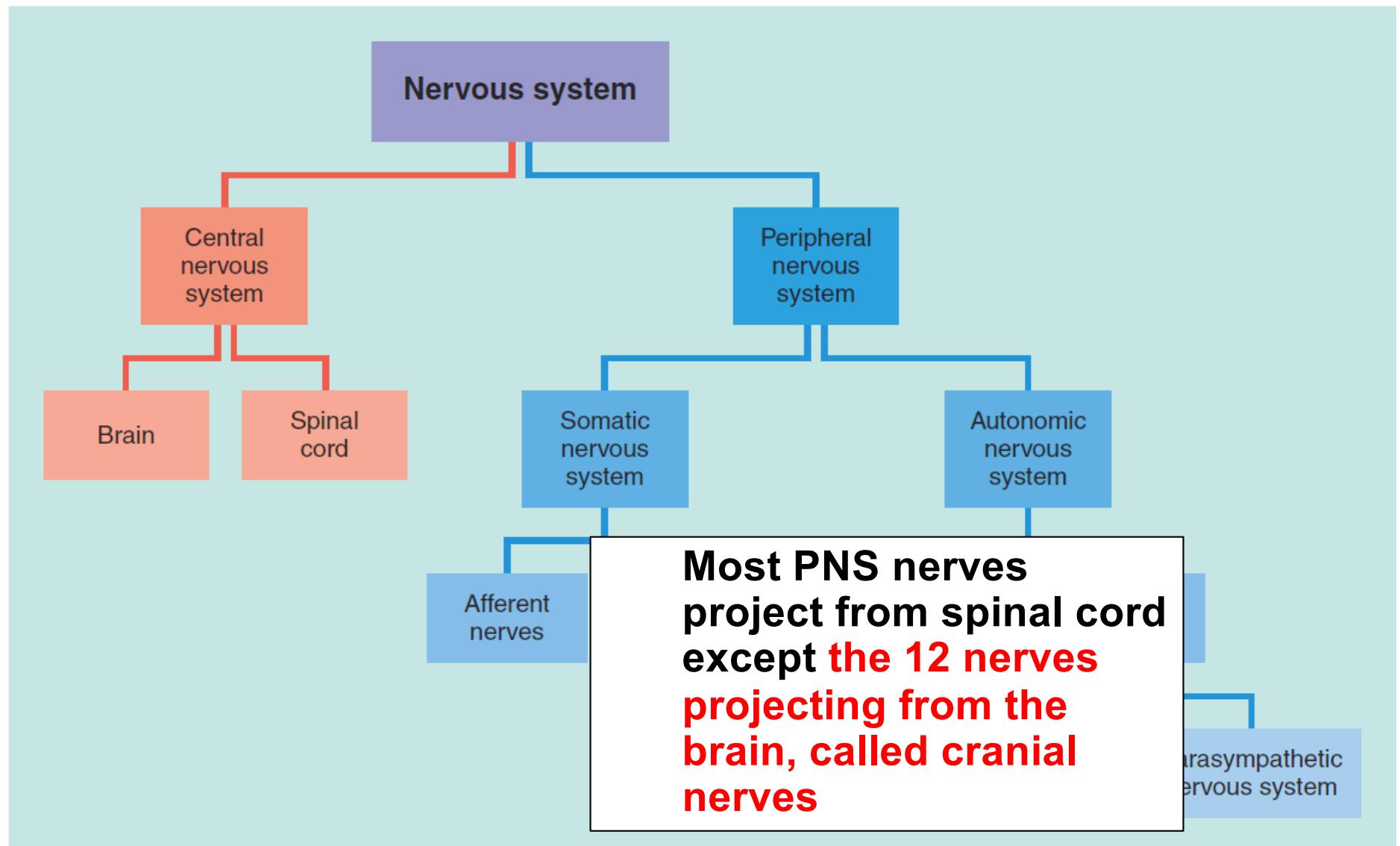
- target organs of autonomic motor nerves receive inputs from both sympathetic and parasympathetic nerves.
- Sympathetic and parasympathetic nerves generally produce opposite effects
- Balance between the two systems, depending on situation, determine the activity of target organs.

General Layout of the Nervous System

Let's go through what we have learned so far.....



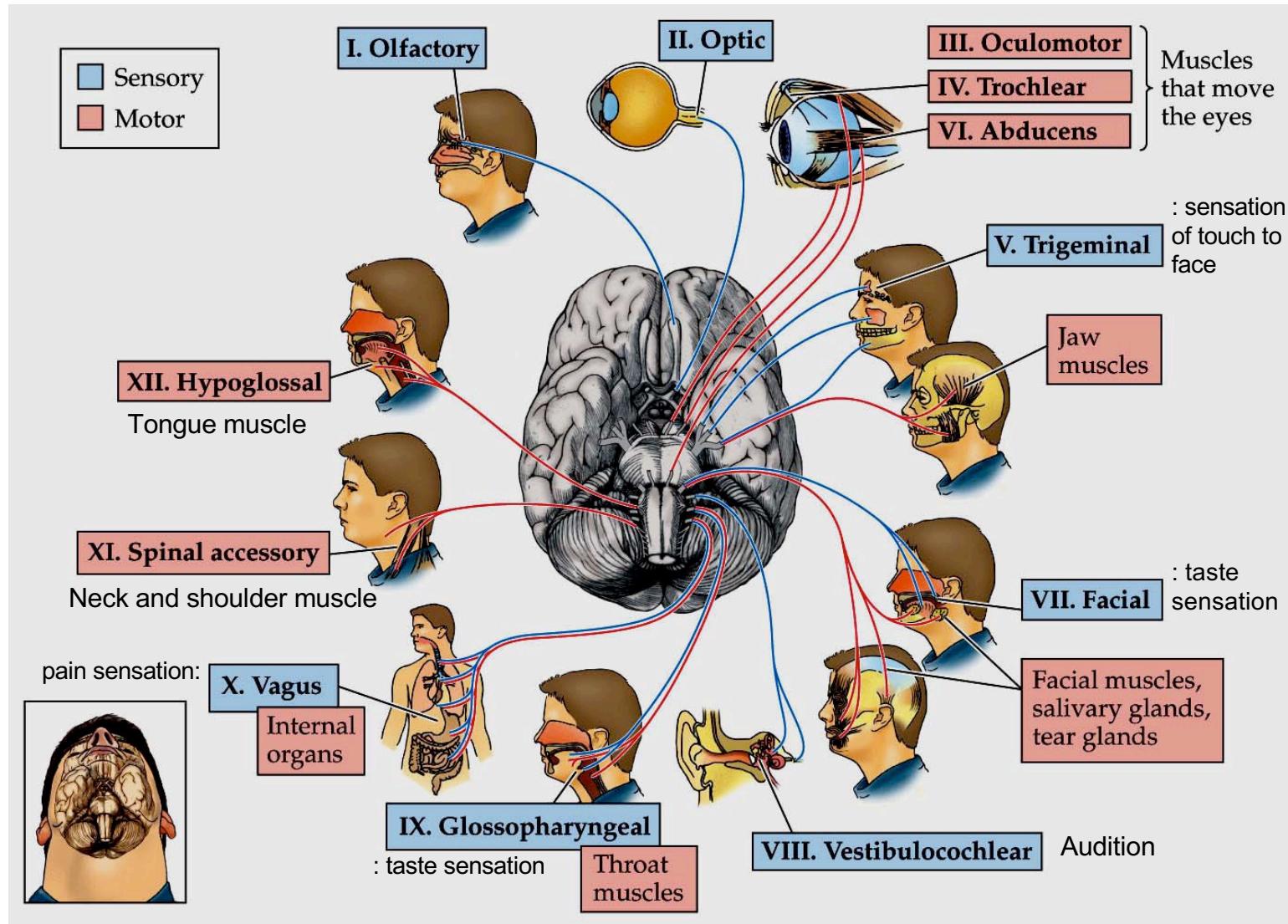
General Layout of the Nervous System



The Cranial Nerves

There are 12 pairs of cranial nerves (I to XII), mostly serving the head and neck

- Enter/exit at the brain stem
- In some cases, exclusively sensory or motor fiber
- In other cases, contains both sensory and motor fibers



Bottom view of the brain

The Cranial Nerves

NERVE NUMBER AND NAME	TYPES OF AXONS	IMPORTANT FUNCTIONS
I. Olfactory	Special sensory	Sensation of smell
II. Optic	Special sensory	Sensation of vision
III. Oculomotor	Somatic motor Visceral motor	Movements of the eye and eyelid Parasympathetic control of pupil size
IV. Trochlear	Somatic motor	Movements of the eye
V. Trigeminal	Somatic sensory Somatic motor	Sensation of touch to the face Movement of muscles of mastication (chewing)
VI. Abducens	Somatic motor	Movements of the eye
VII. Facial	Somatic sensory Special sensory	Movement of muscles of facial expression Sensation of taste in anterior two-thirds of the tongue
VIII. Auditory-vestibular	Special sensory	Sensation of hearing and balance
IX. Glossopharyngeal	Somatic motor Visceral motor Special sensory Visceral sensory	Movement of muscles in the throat (oropharynx) Parasympathetic control of the salivary glands Sensation of taste in posterior one-third of the tongue Detection of blood pressure changes in the aorta
X. Vagus	Visceral motor Visceral sensory Somatic motor	Parasympathetic control of the heart, lungs, and abdominal organs Sensation of pain associated with viscera Movement of muscles in the throat (oropharynx)
XI. Spinal accessory	Somatic motor	Movement of muscles in the throat and neck
XII. Hypoglossal	Somatic motor	Movement of the tongue

Today we will learn.....

- General layout of the nervous system
- **Structures protecting the nervous system**
- Cellular components of the nervous system
- Anatomy of major structures of the nervous system

Structures that protect the central nervous system

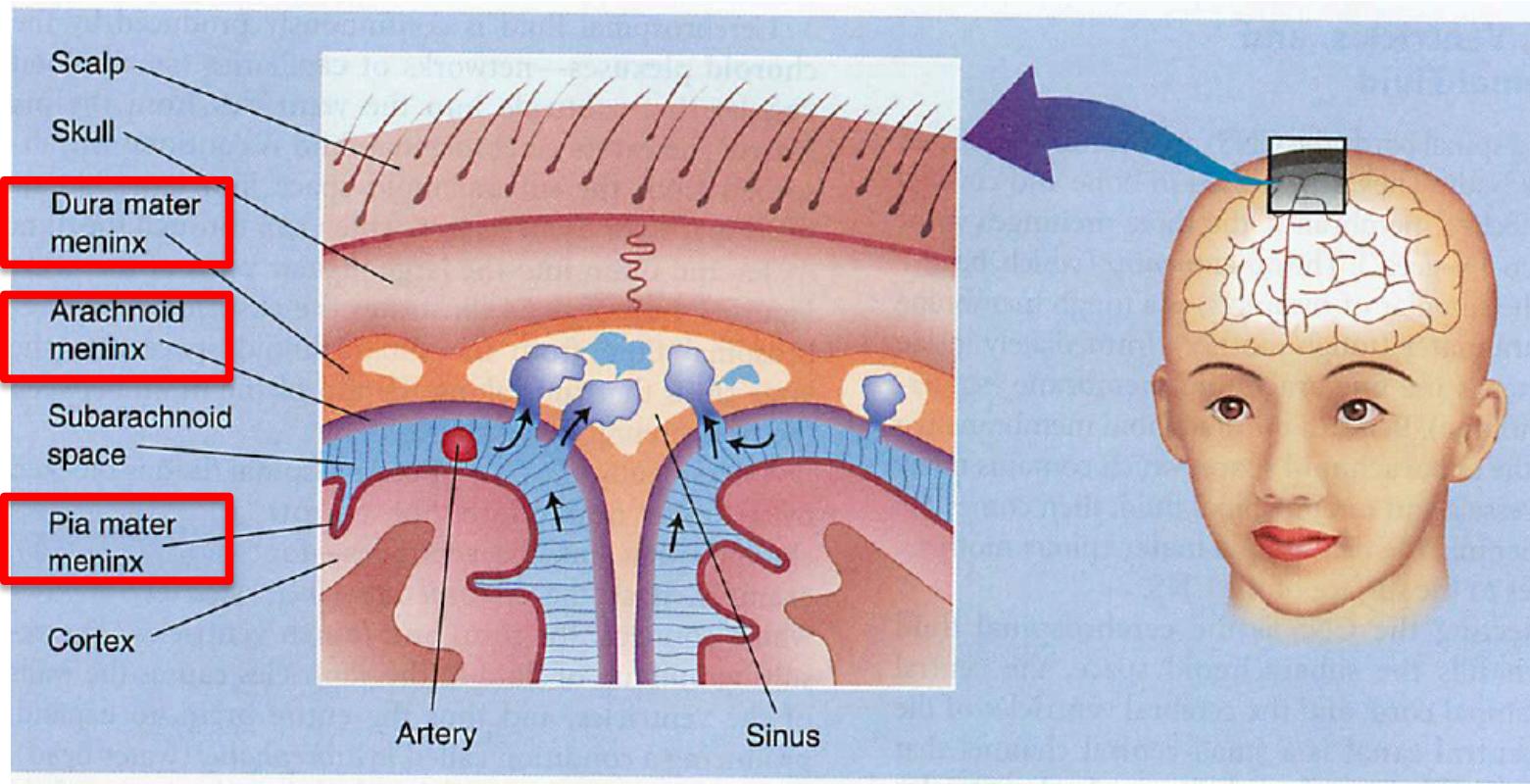
The brain and spinal cord is the most protected system in the body

Protected by three structures

- **Bones (skull and vertebrae)**
- **Membranes (meninges)**
- **Cerebrospinal fluid (CSF)**

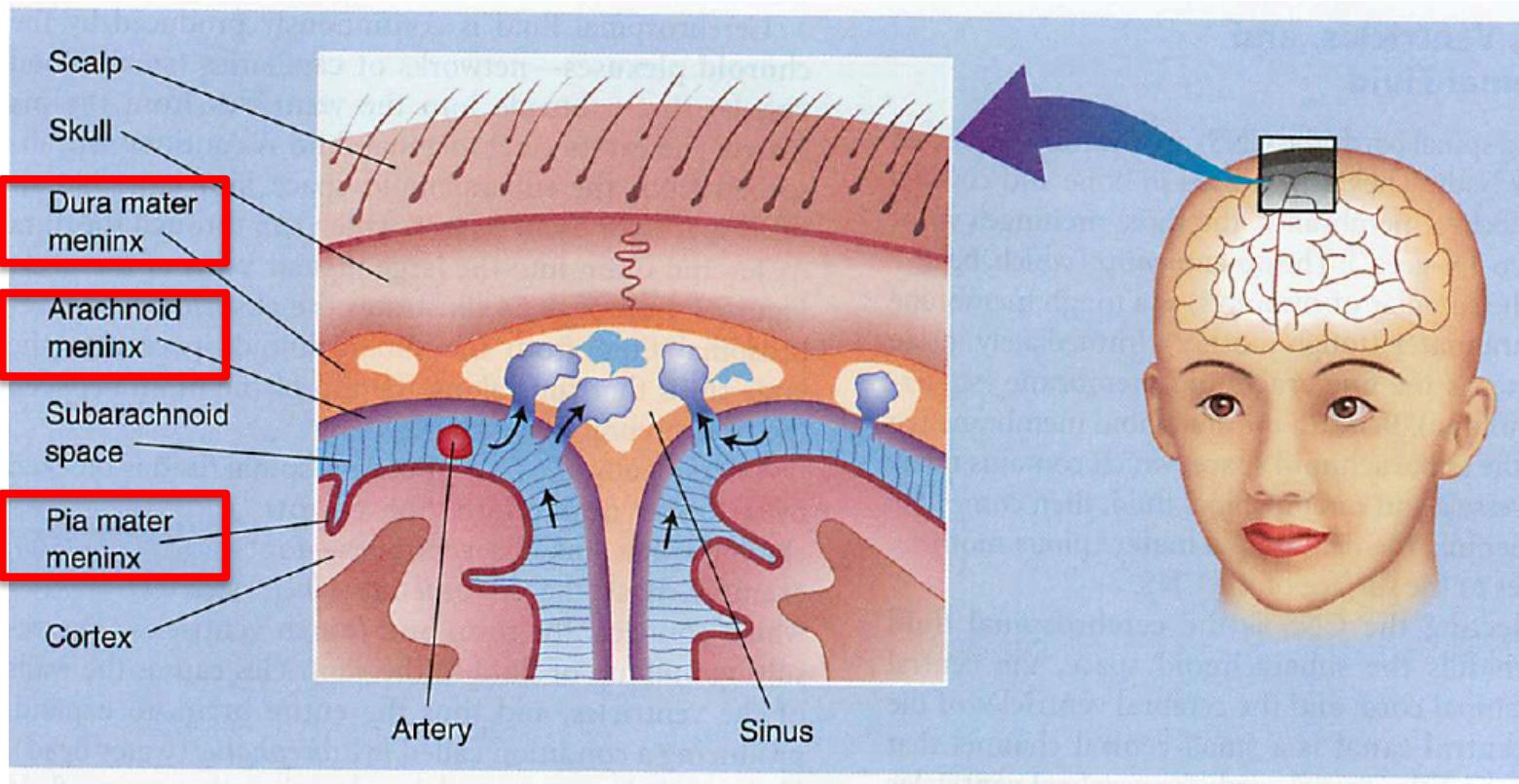
You can see all three protective components in a cross section of the brain

Three meninges (membranes)



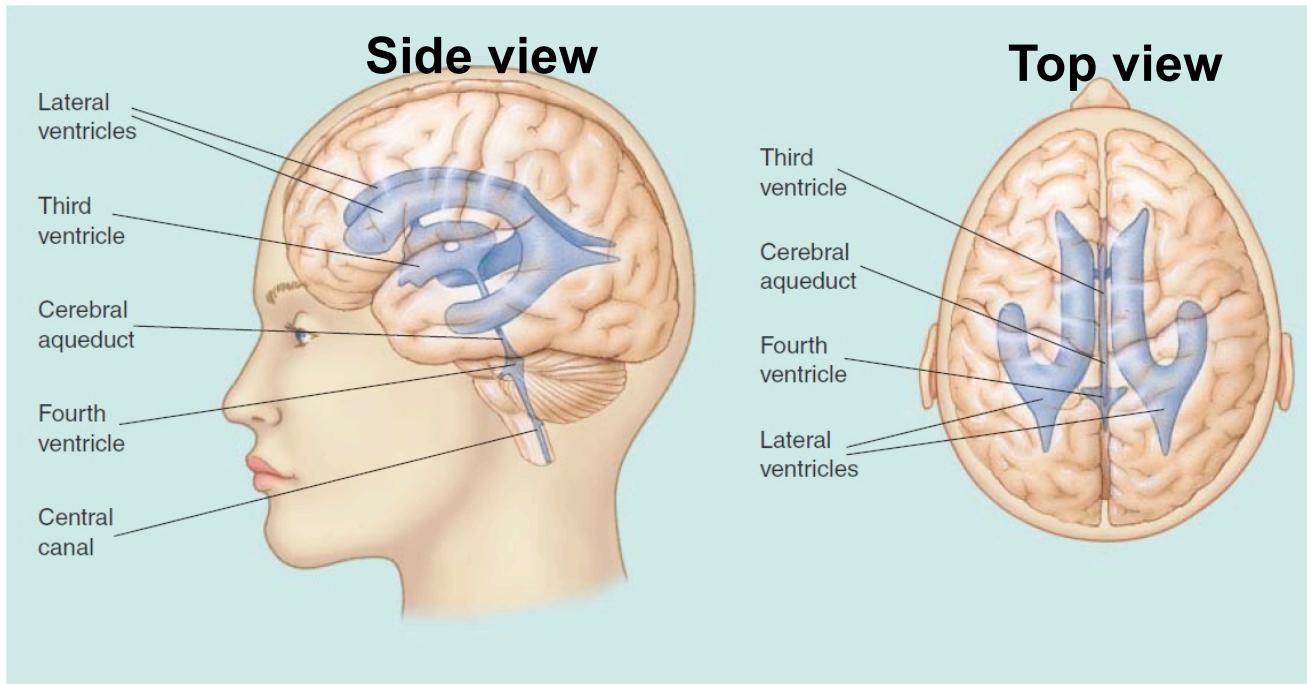
- Brain is covered by three membranes collectively called meninges (singular: menix – greek word for ‘covering’)
 1. **Dura mater** – outermost membrane (tough, leatherlike consistency)
 2. **Arachnoid membrane** – appearance resembling spider web
 3. **Pia mater** – adheres to the surface of the brain

Three meninges (membranes)



- Blood vessels pass through a space between pia and arachoid membranes
- This space is called subarachnoid space
- Subarachnoid space is filled with fluid called cerebrospinal fluid (CSF)

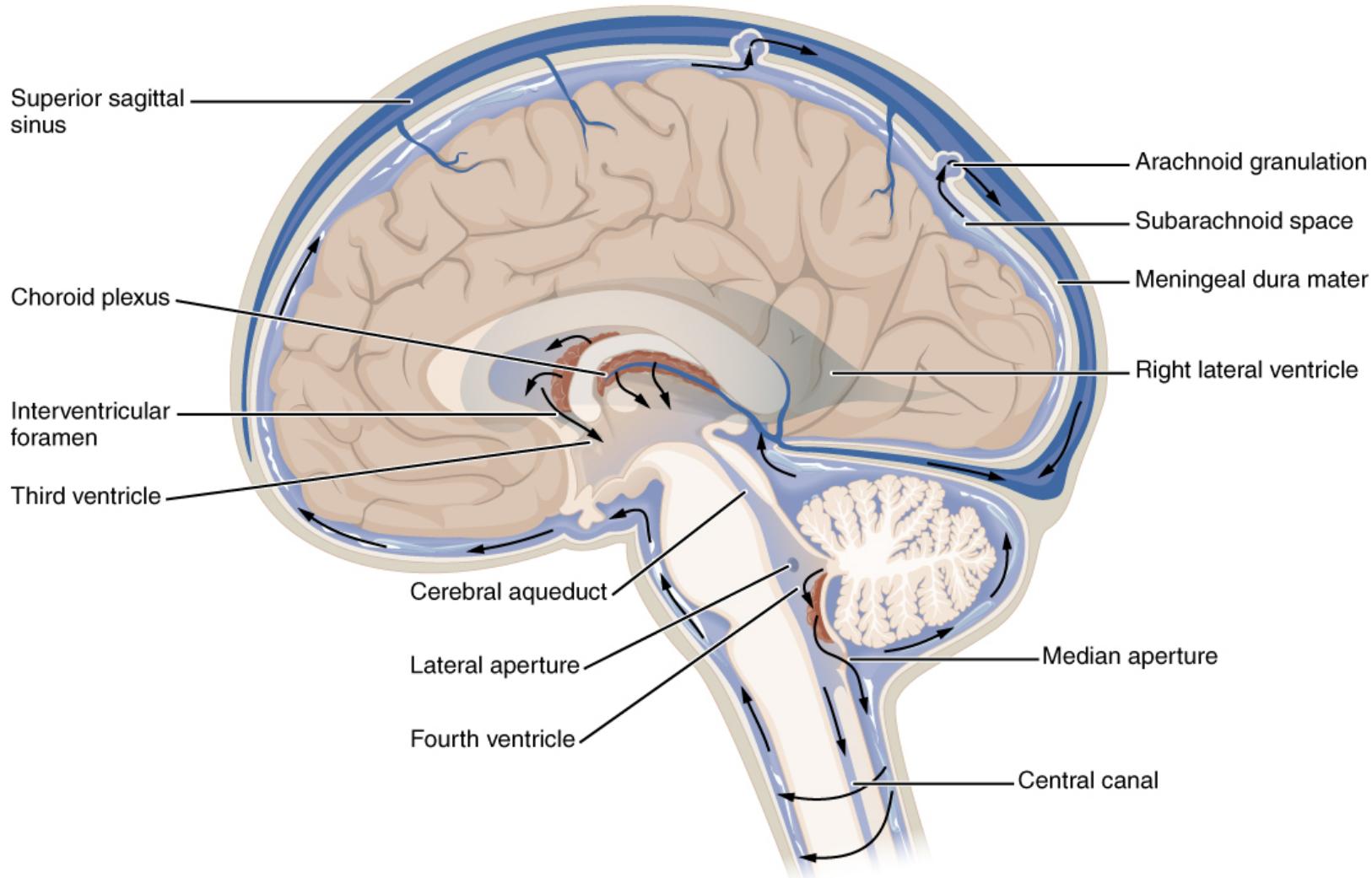
Cerebrospinal Fluid (CSF) and Ventricles



CSF: what is it for? And how is it maintained?

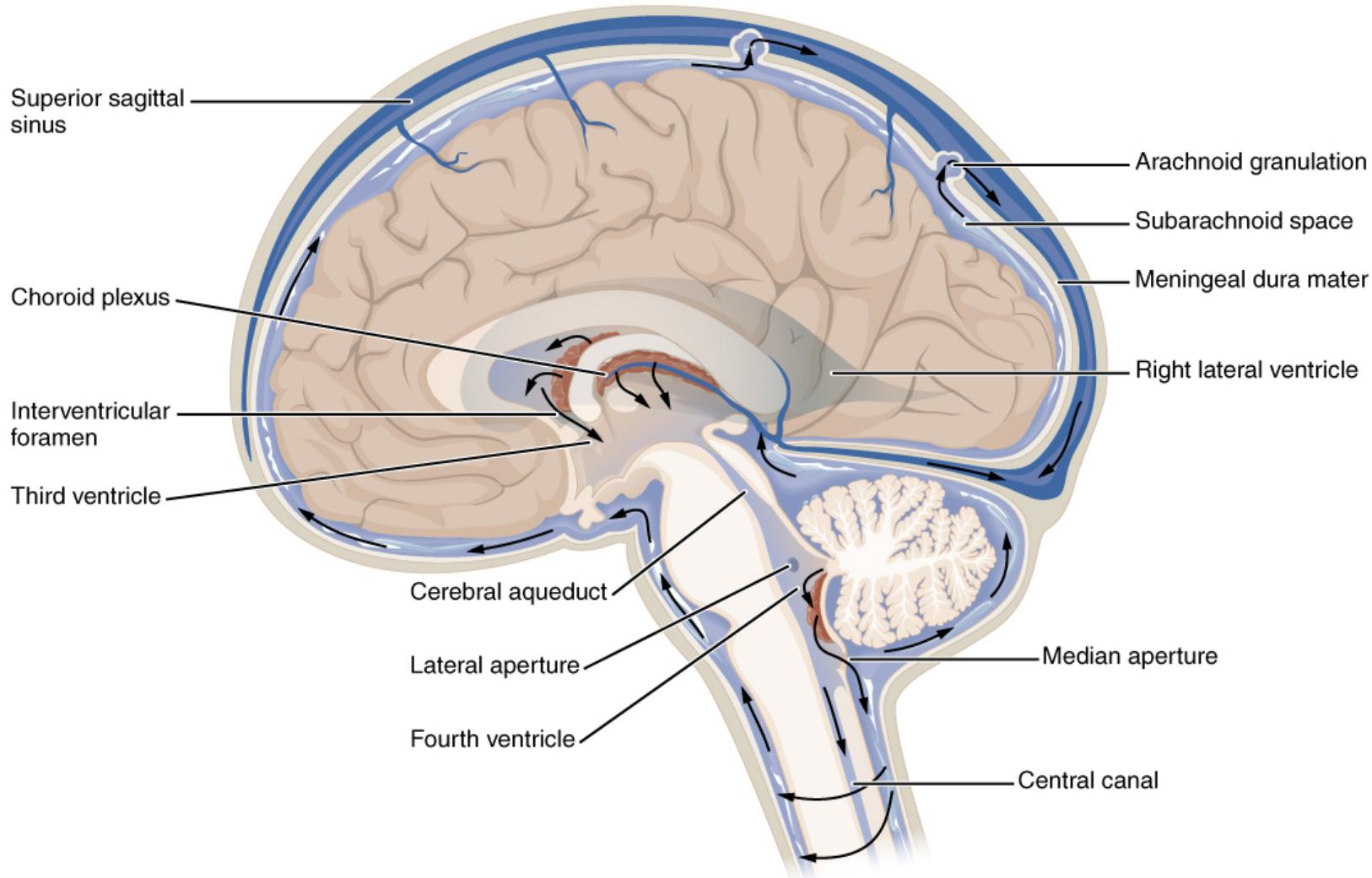
- **CSF has two main functions:**
 - Acts as a shock absorber (**mechanical cushion**)
 - Provides an exchange medium between blood and brain (**nutritional support**)
- **Brain contains CSF in a series of chambers.**
 - These chambers are called the ventricles
 - **Four ventricles in the brain: two lateral, one third, one fourth ventricle.**

Cerebrospinal Fluid (CSF) and Ventricles



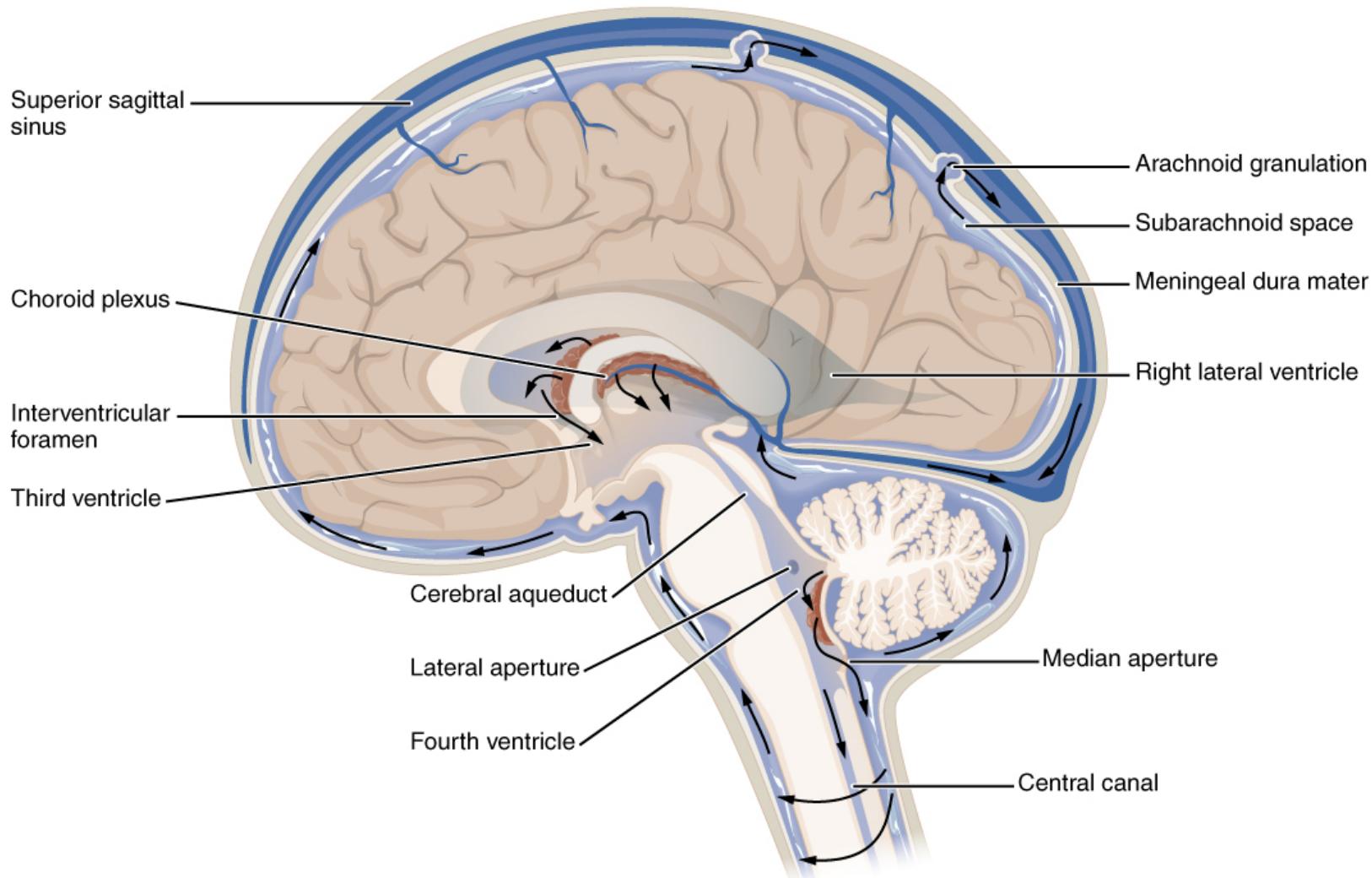
1. CSF is produced by a network of blood vessels that protrude into the ventricles – this organ is called the **choroid plexus**

Cerebrospinal Fluid (CSF) and Ventricles



2. CSF leaves the ventricles through holes in the fourth ventricle and travel along the surface of brain through the subarachnoid space

Cerebrospinal Fluid (CSF) and Ventricles

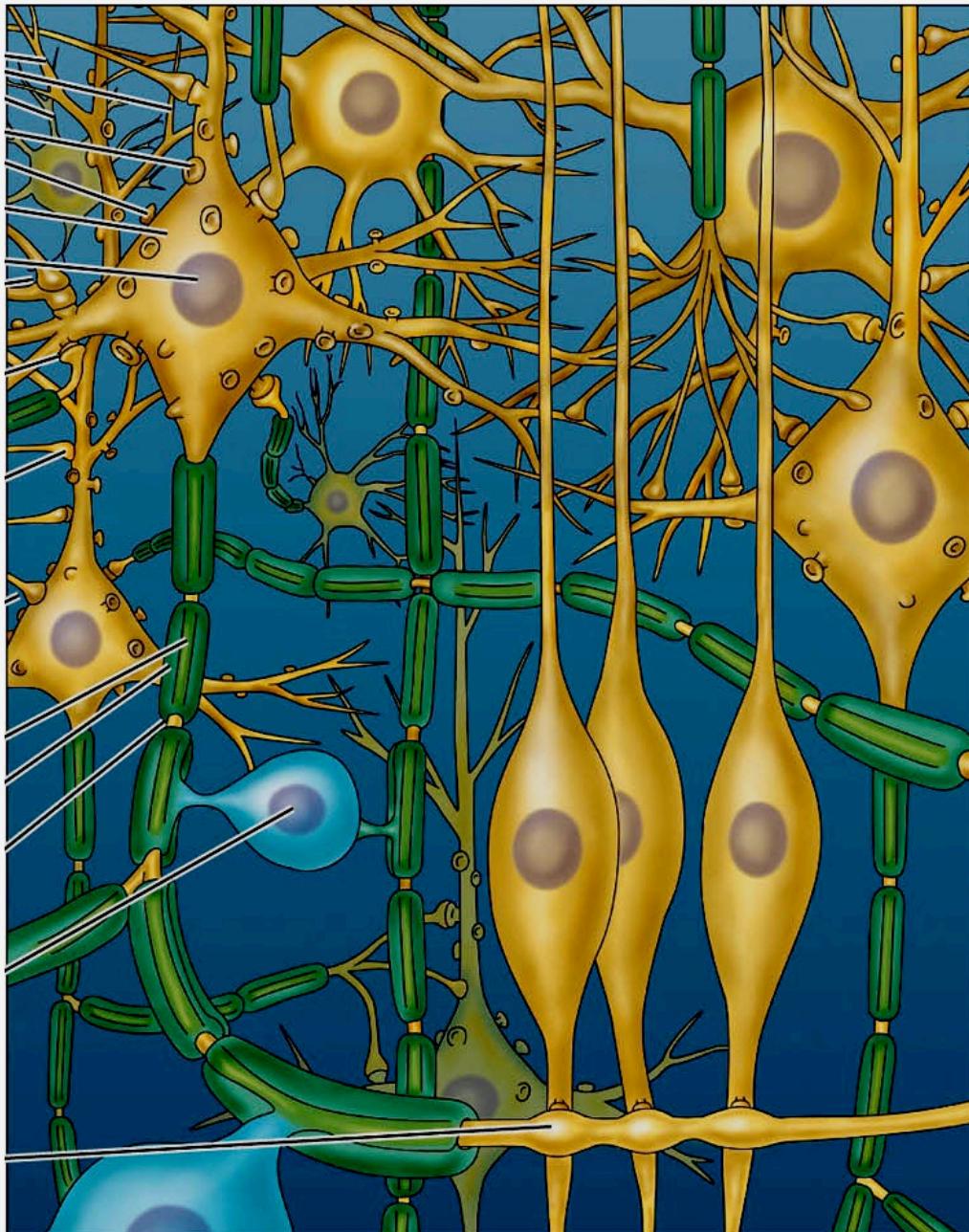


3. CSF is absorbed back into a blood vessel called 'dural sinus'

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- **Cellular components of the nervous system**
- Anatomy of major structures of the nervous system

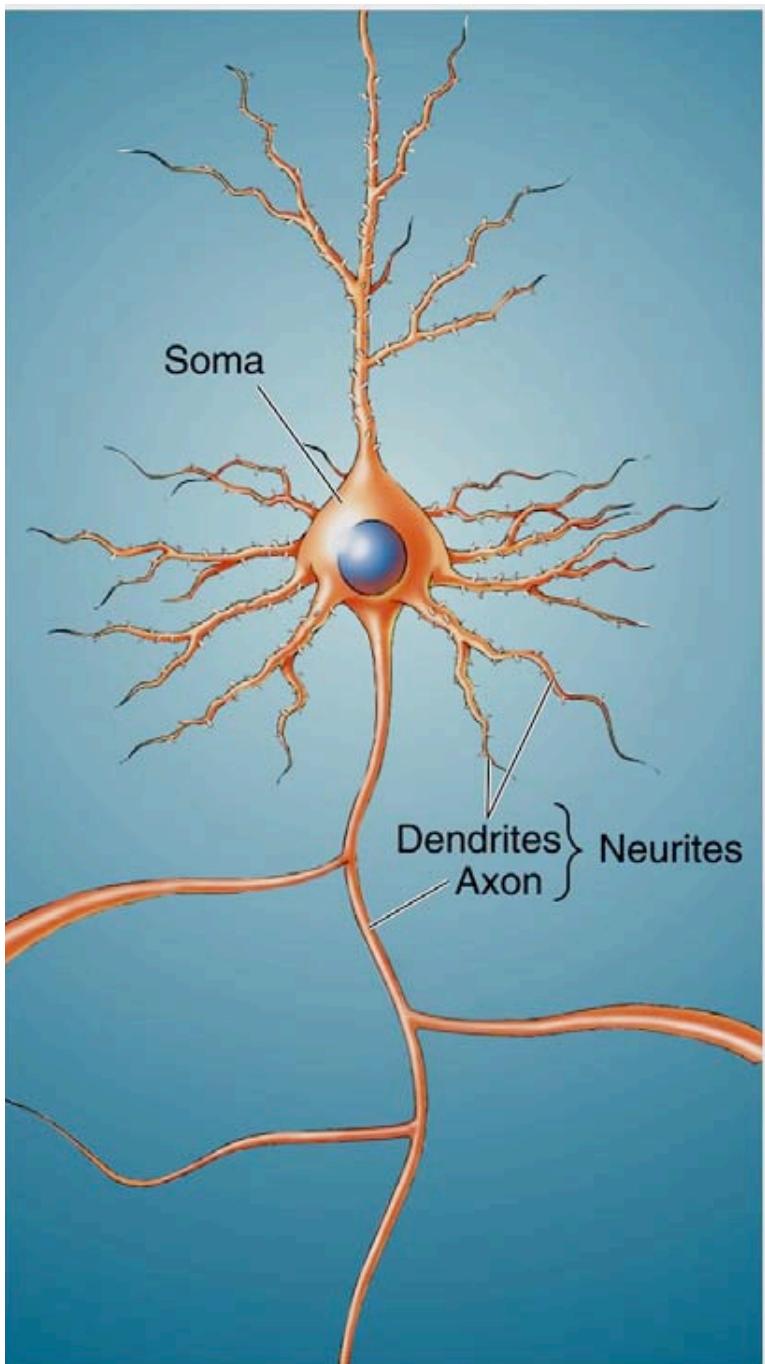
Cells of the Nervous System



the nervous system consists of two types of cells:

- neurons (or nerve cells)
- glia (or glial cells)

Cells of the Nervous System



Neurons

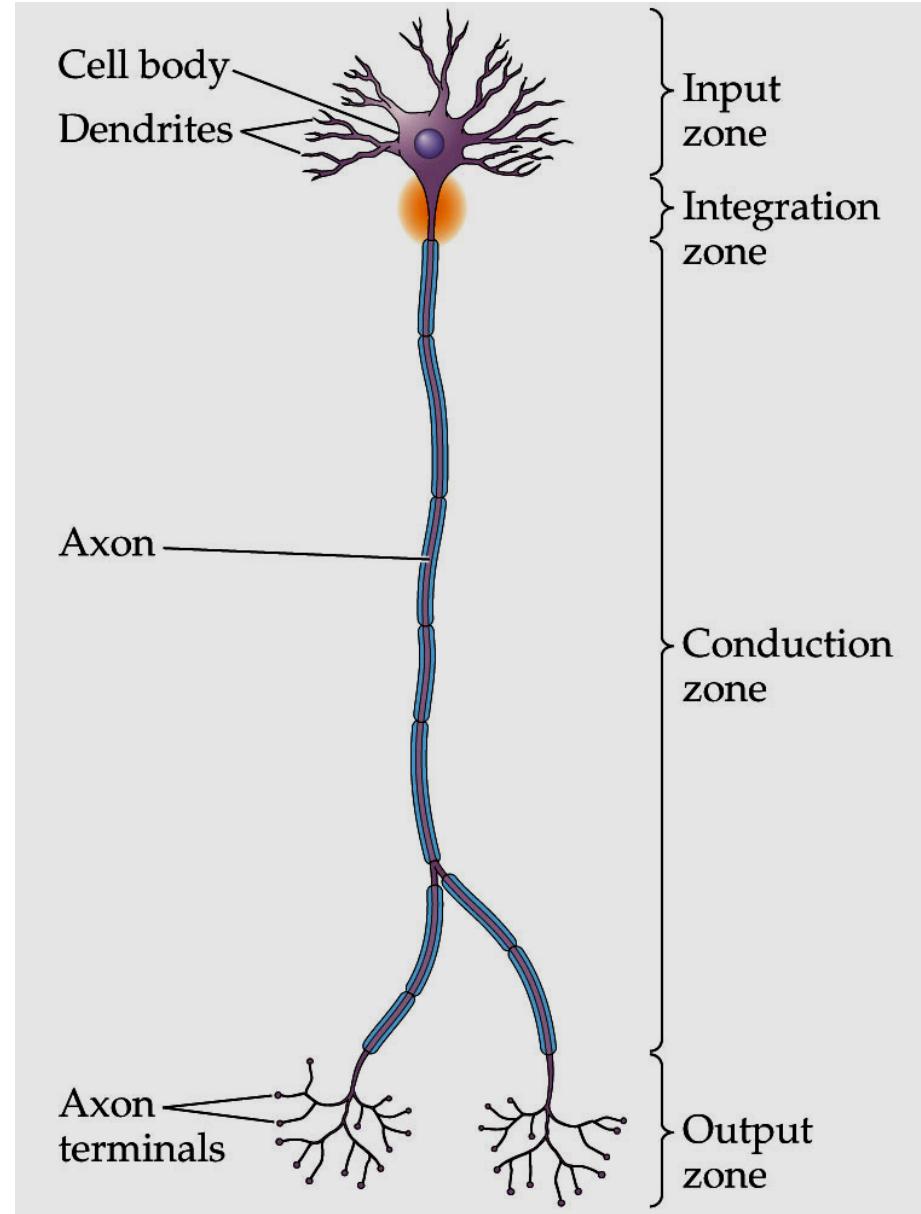
- Specialized cells for the reception, conduction, and transmission of electrochemical signals
- Many sizes and shapes



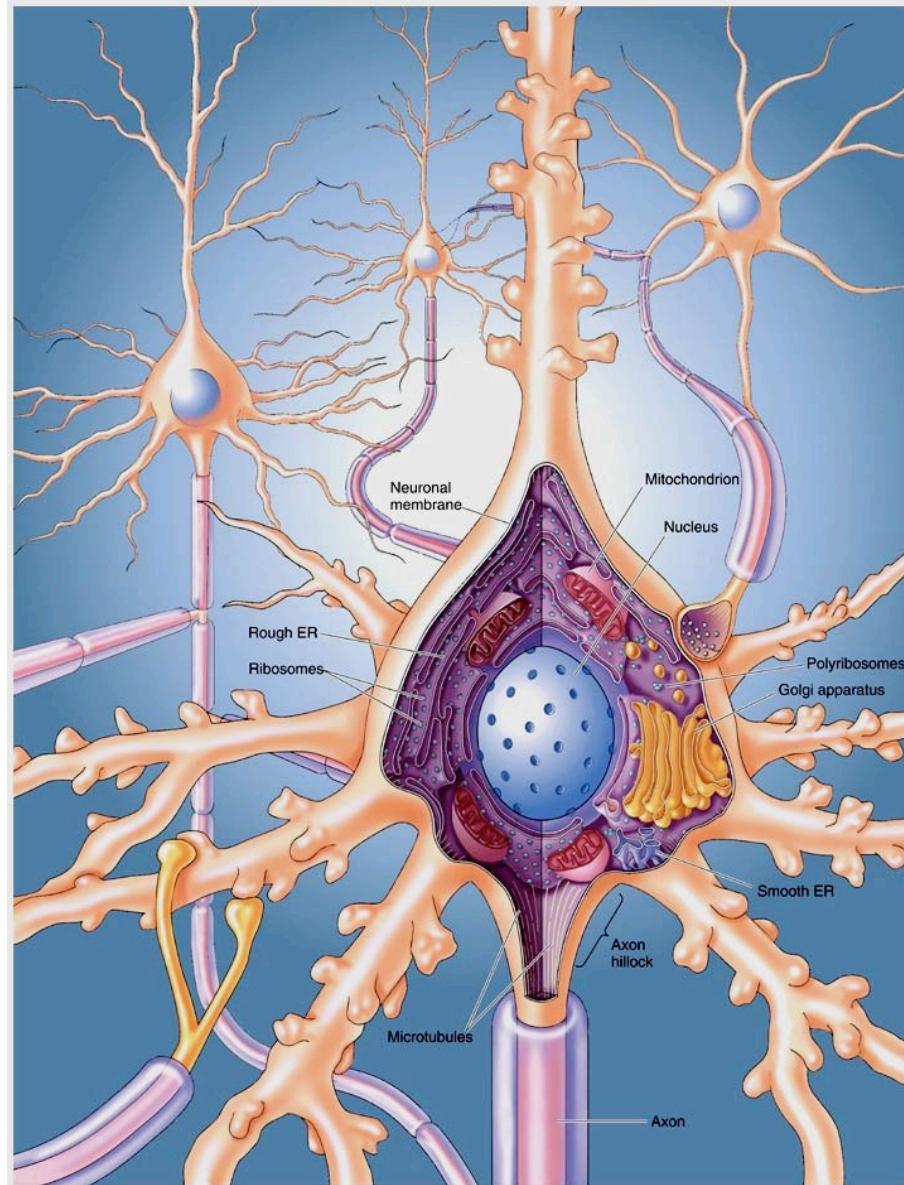
The Neuron: Structure and Function

the neuron consists of:

- a **soma** (or **cell body**)
- an **axon**
- **Axon terminals**
- **Dendrites**



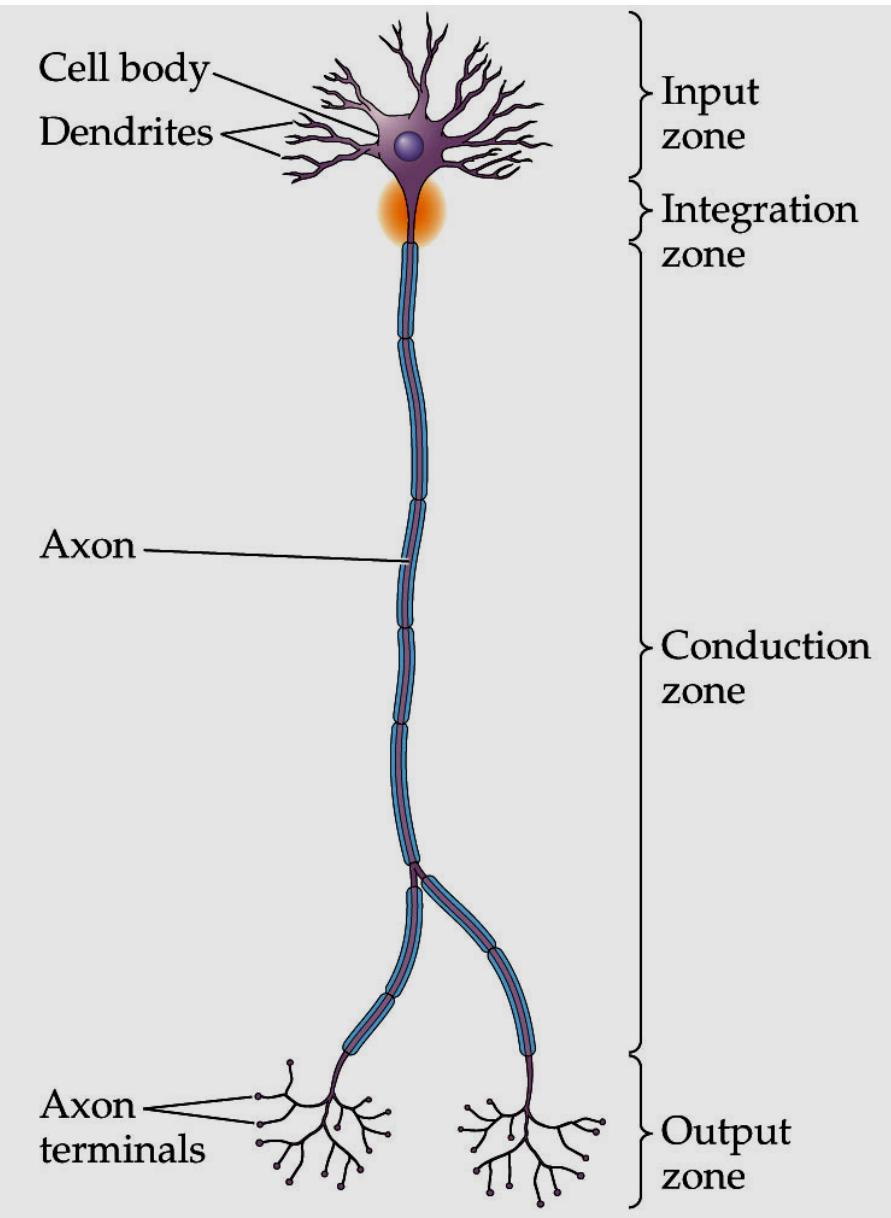
The Neuron: Structure and Function



Soma (cell body)

- consists of a number of organelles including the **nucleus, rough and smooth endoplasmic reticulum, Golgi apparatus, mitochondria**
- these perform various functions including protein synthesis and production of energy for cellular activity.

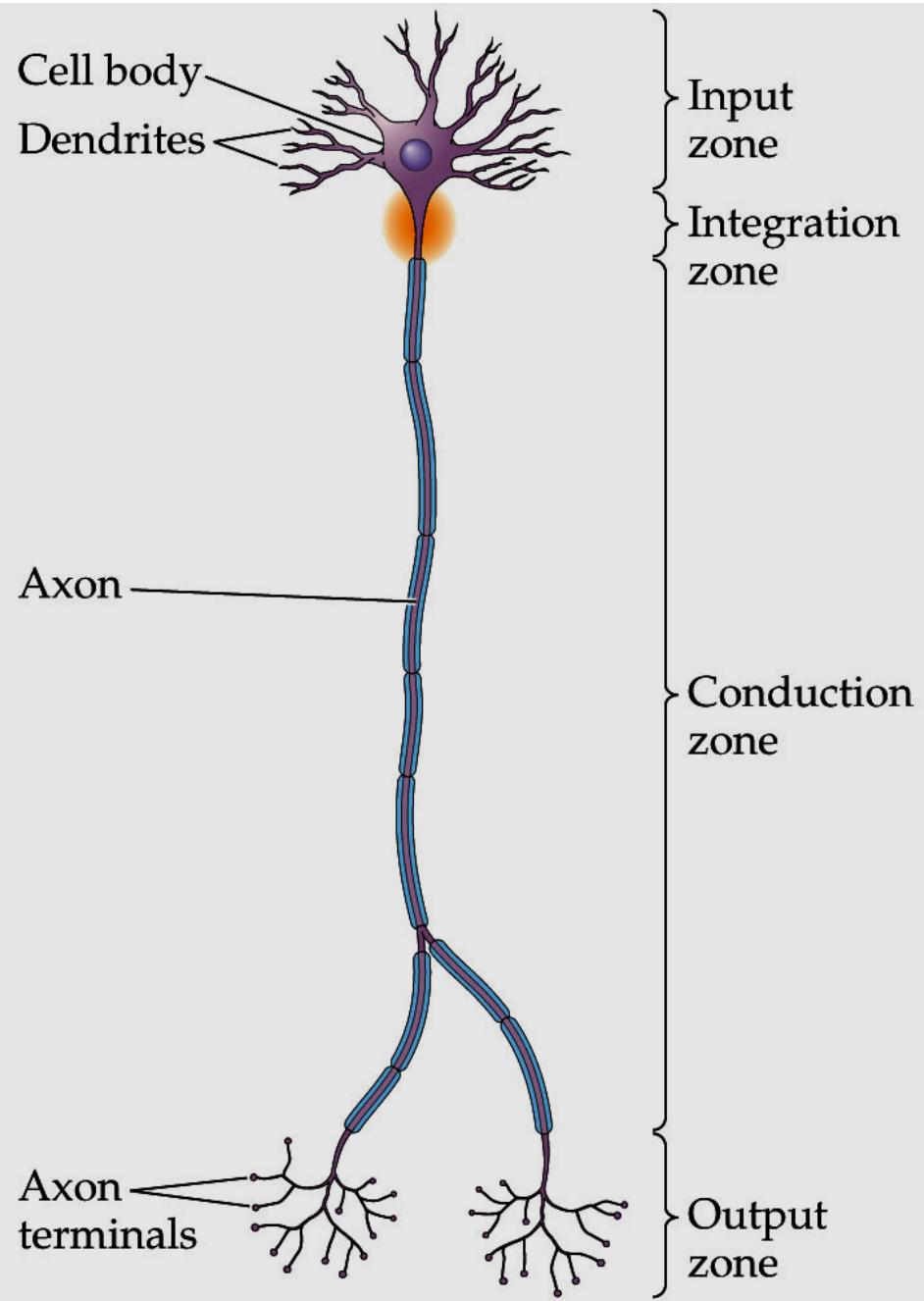
The Neuron: Structure and Function



The Dendrites

- extend from soma like branches
- function → receive information from other neurons (i.e., the “antennae” of the system)
- covered with receptors (protein molecules that detect neurotransmitters)

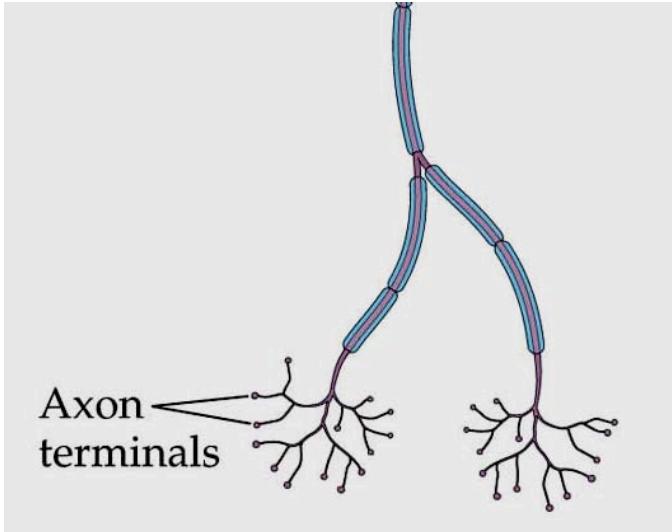
The Neuron: Structure and Function



The Axon

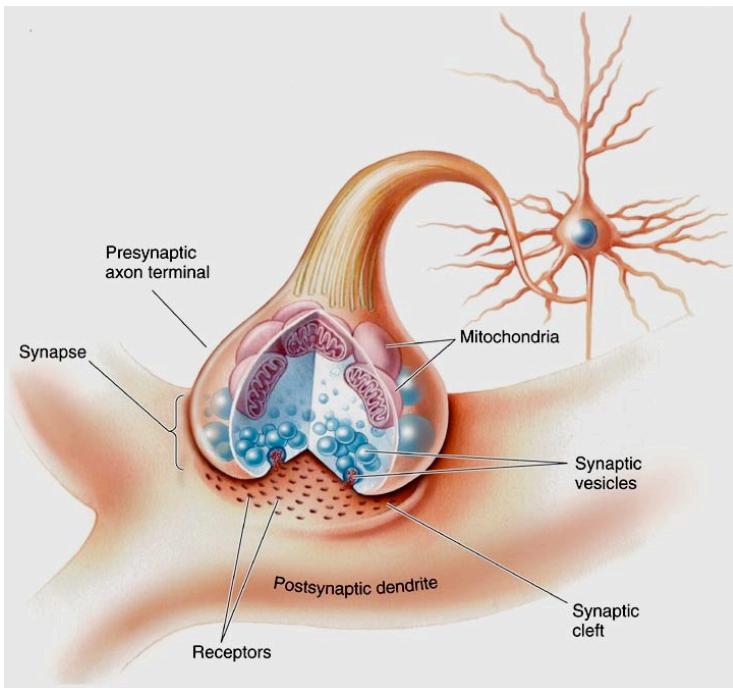
- highly specialized structure found only in neurons
- function → to carry signals (information) over distances within the nervous system (i. e., the “wires” of the system)

The Neuron: Structure and Function

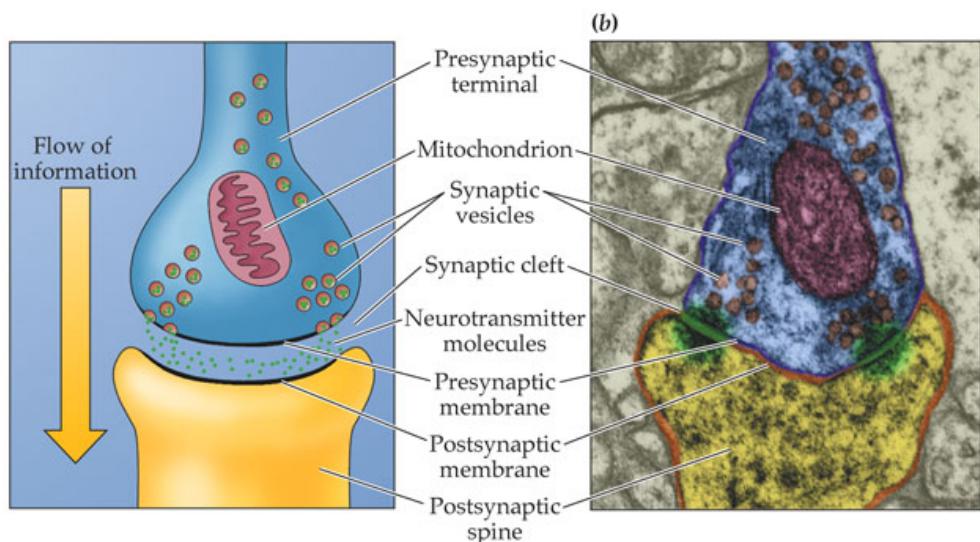
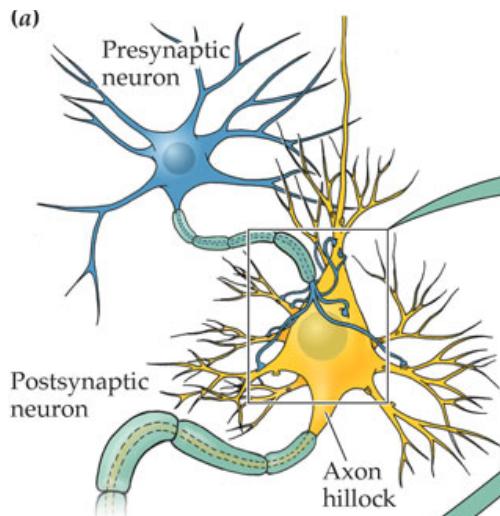


Axon Terminals

- region that makes contact with other neurons or cells
- Where the transfer of information occurs



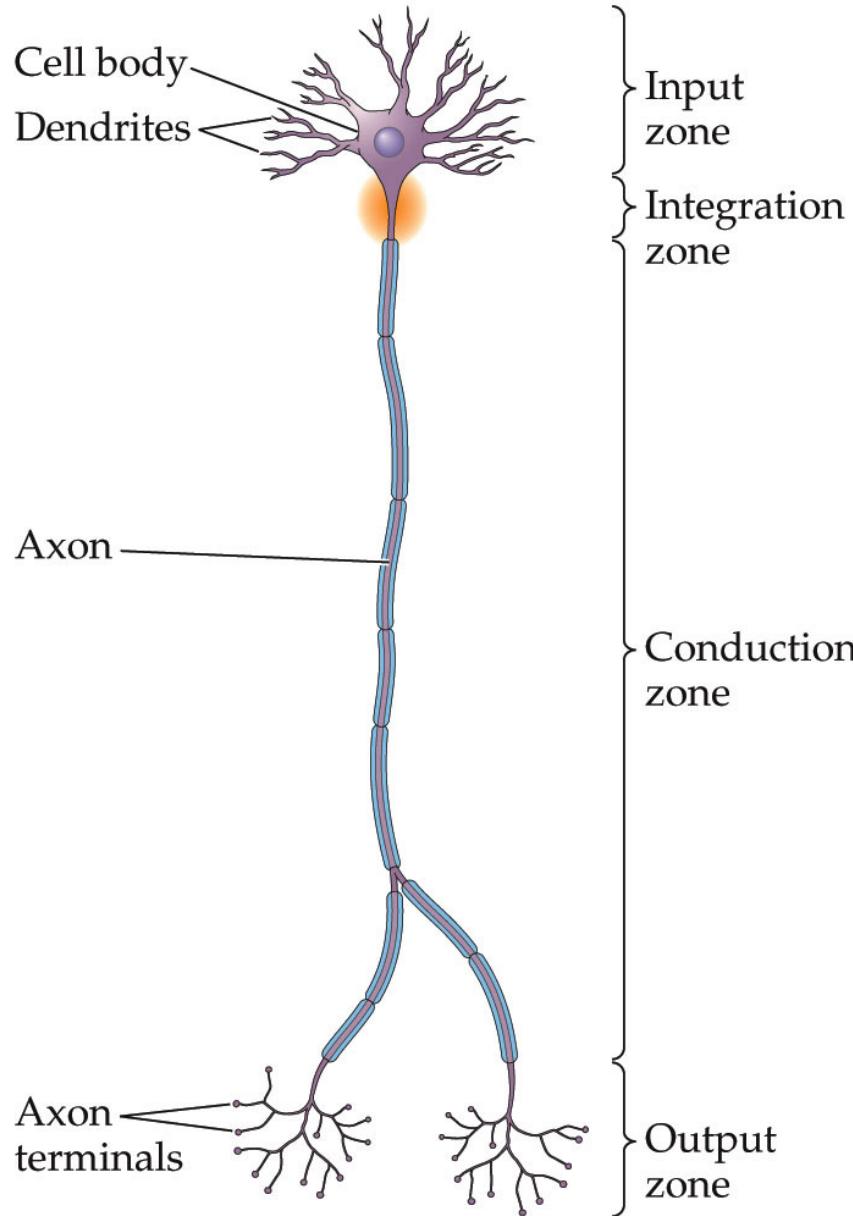
The Neuron: Structure and Function



Synapse

- the point of contact between one neuron's axon terminal and another neuron (or other cell type)
- a specialized junction where communication between cells occurs

The Neuron: Structure and Function (recap)

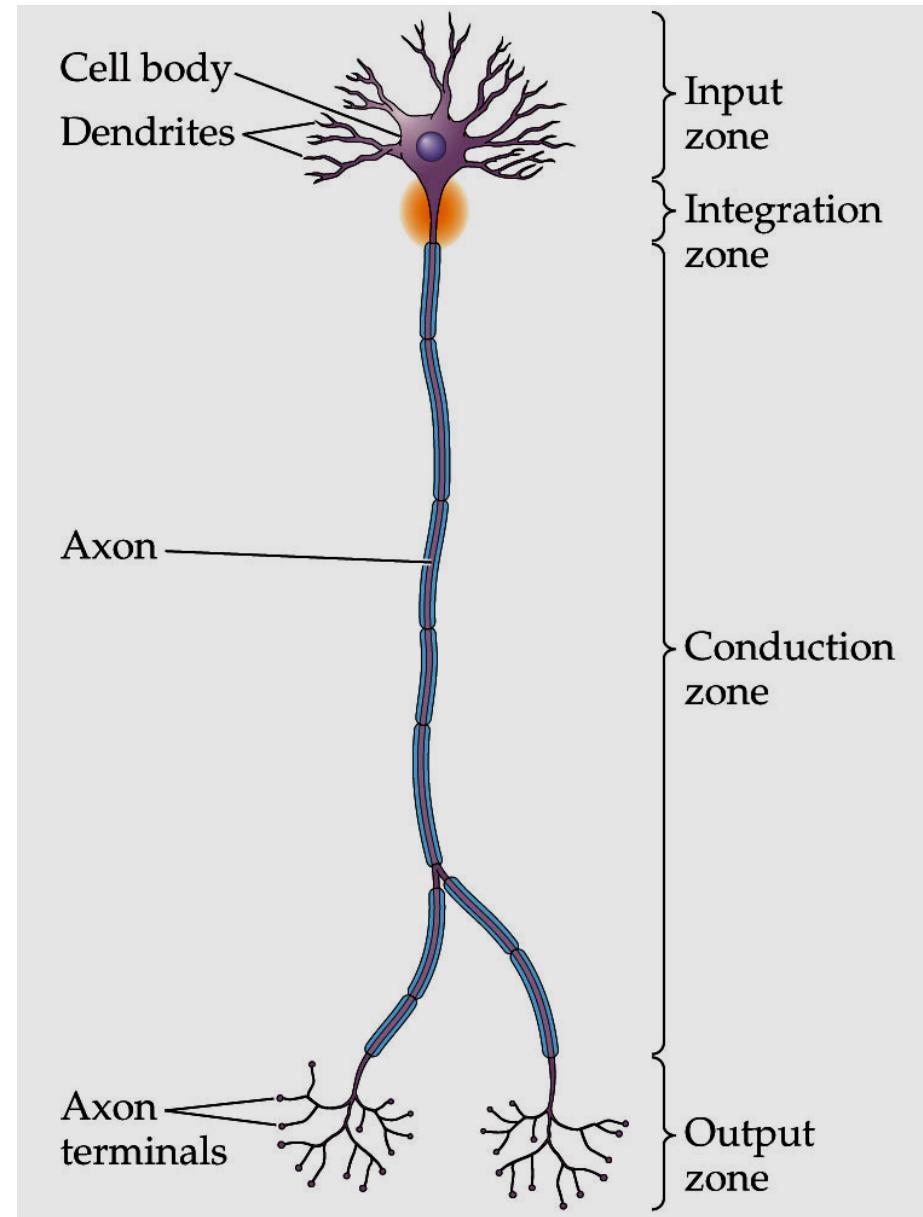


- Input zone—receives information from other cells through dendrites
- Integration zone—a region where inputs are combined and transformed
- Conduction zone—single axon leads away from the cell body and transmits the electrical impulse
- Output zone—axon terminals at the end of the axon communicate activity to other cells

The Neuron: Structure and Function

Do every neurons look like this?

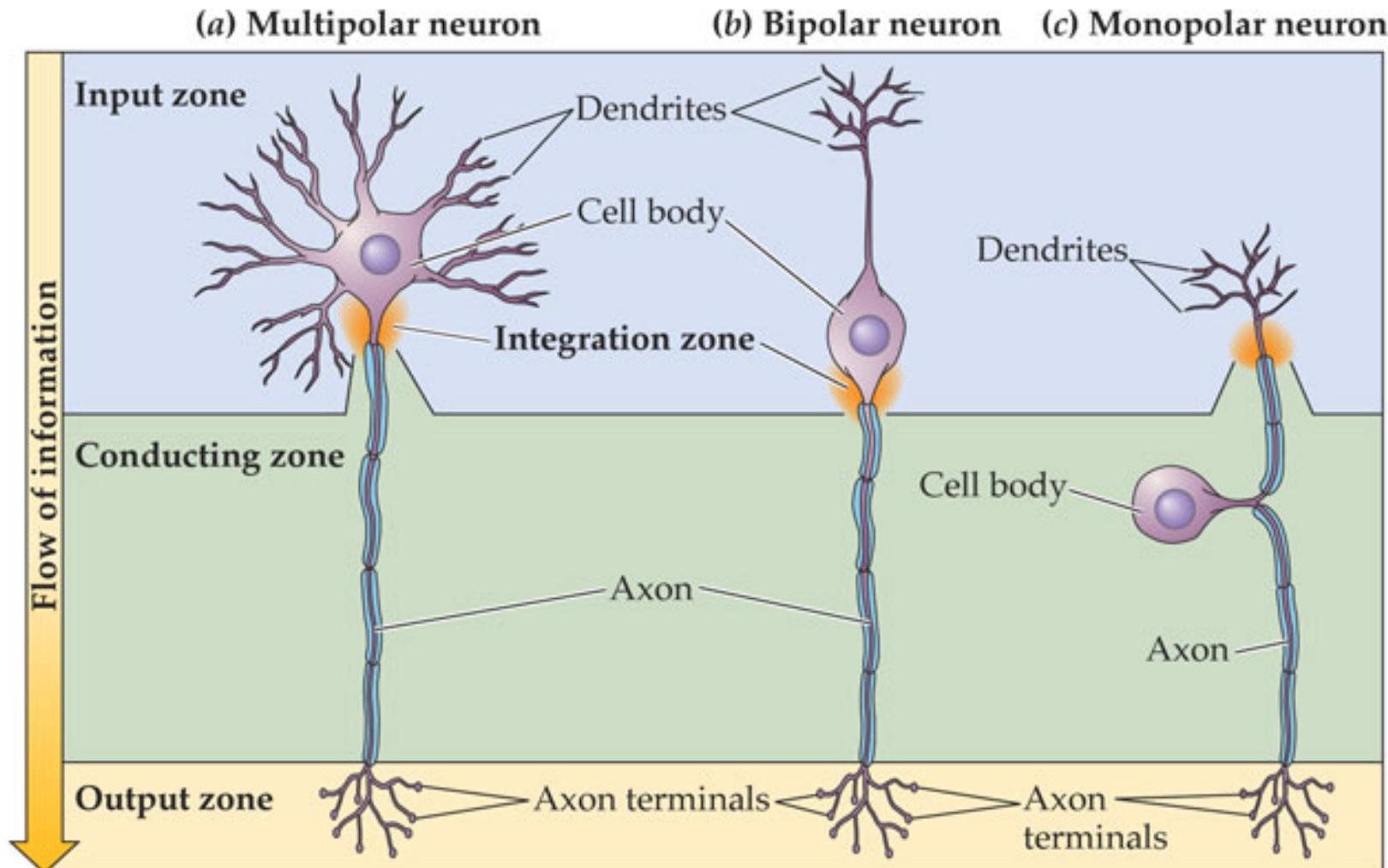
.....NO!



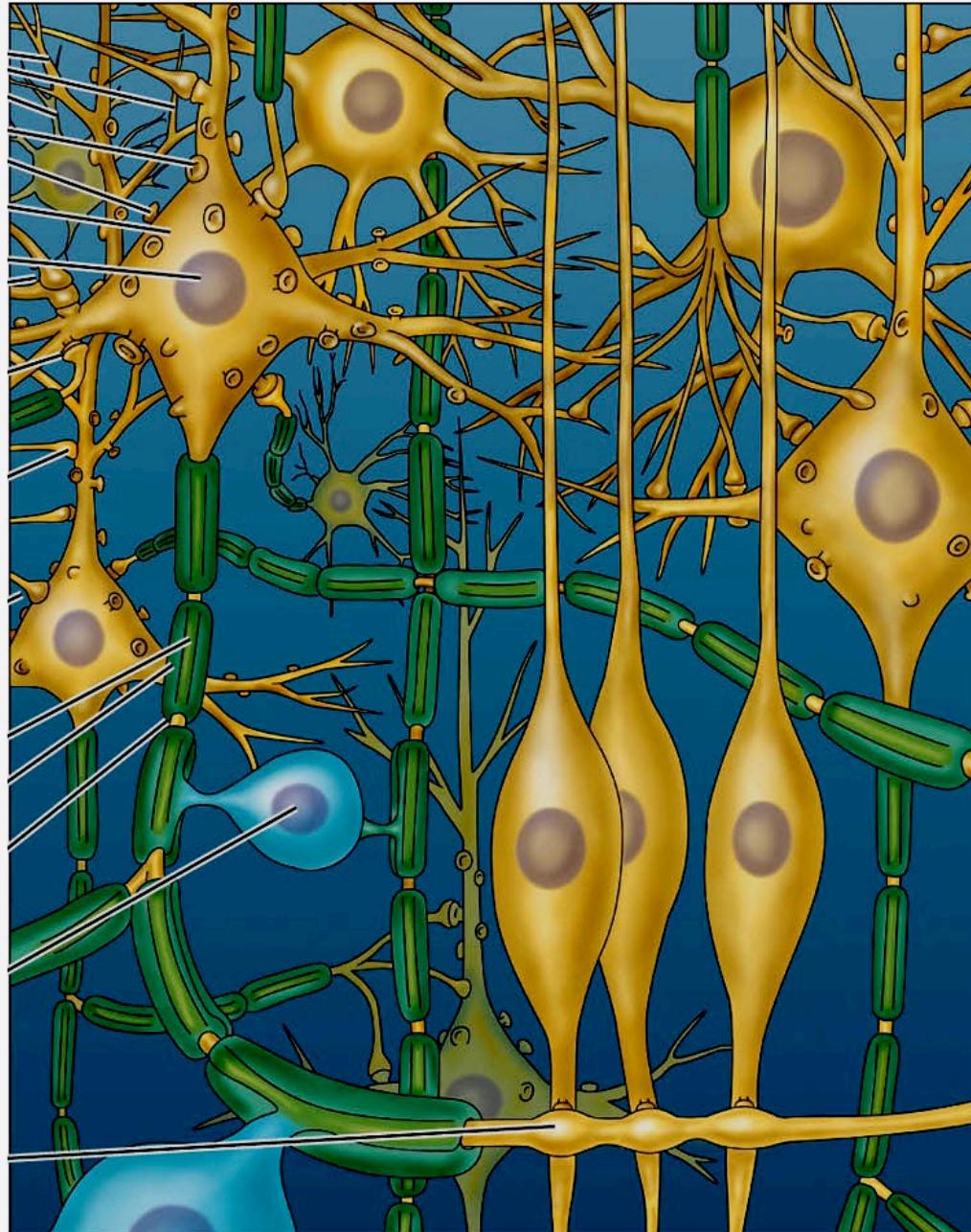
The Neuron: Structure and Function

Types of Neurons

- neurons differ in their shape, size, and function



Cells of the Nervous System



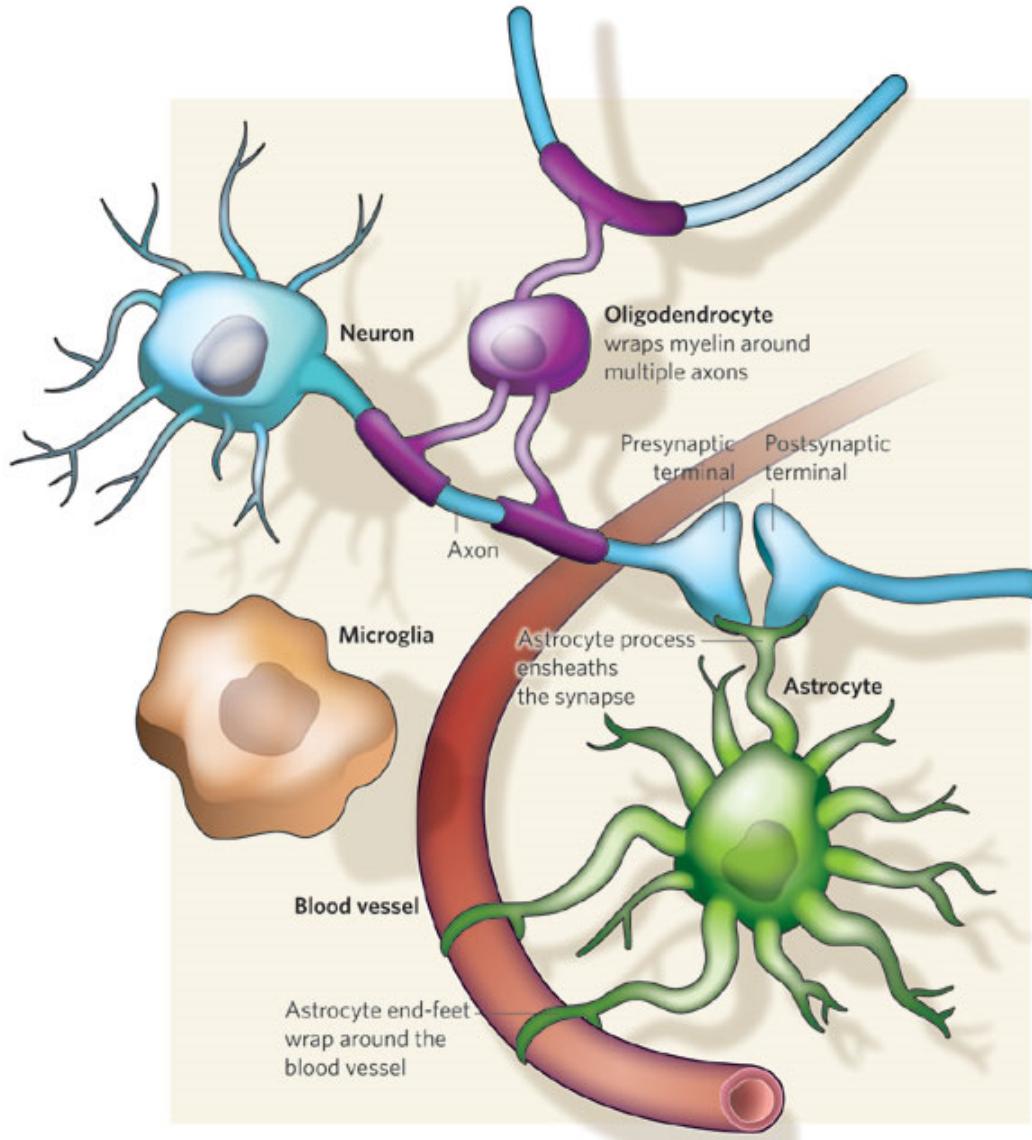
the nervous system consists of two types of cells:

- neurons (or nerve cells)
- glia (or glial cells)

Glia

- serve to **support** the functions of neurons (i.e., supporting cells)
- have many functions in the nervous system
 - e. g., structural support, insulation, nutrition
- Recent evidence for glial communication and modulatory effects of glia on **neuronal communication**

Glia



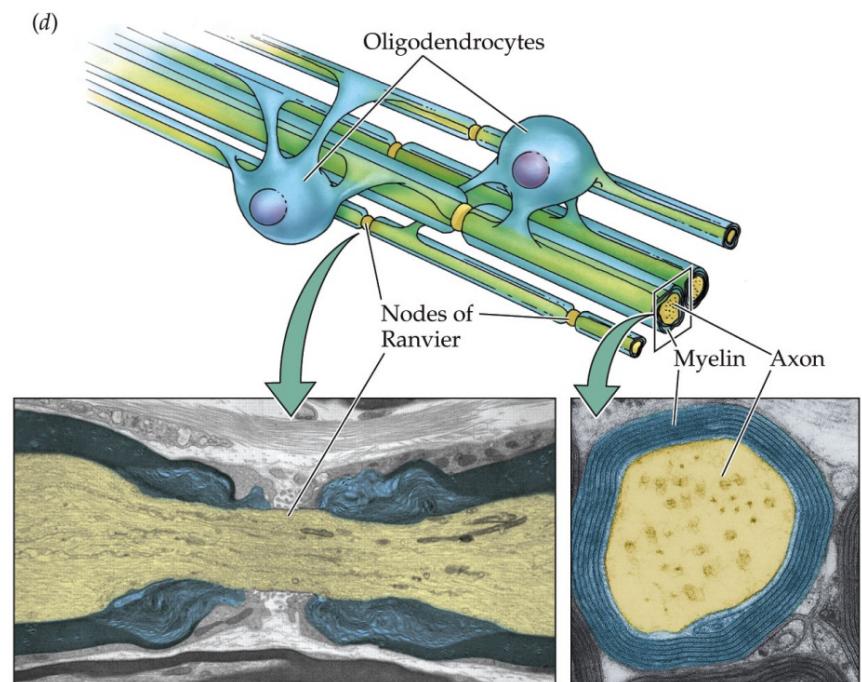
Four classes of Glial cells:

- Oligodendrocytes
- Schwann cells
- Astrocytes
- Microglia

Glia: Structure and Function

Oligodendrocytes

- glial cells that provide membrane extensions called **myelin**.
- myelin extensions wrap around axons of CNS neurons multiple times forming **myelin sheath**.
- Myelin sheath insulates axons, preventing current (ion) leaks → speeds up conduction of electrical signals
- found in central nervous system



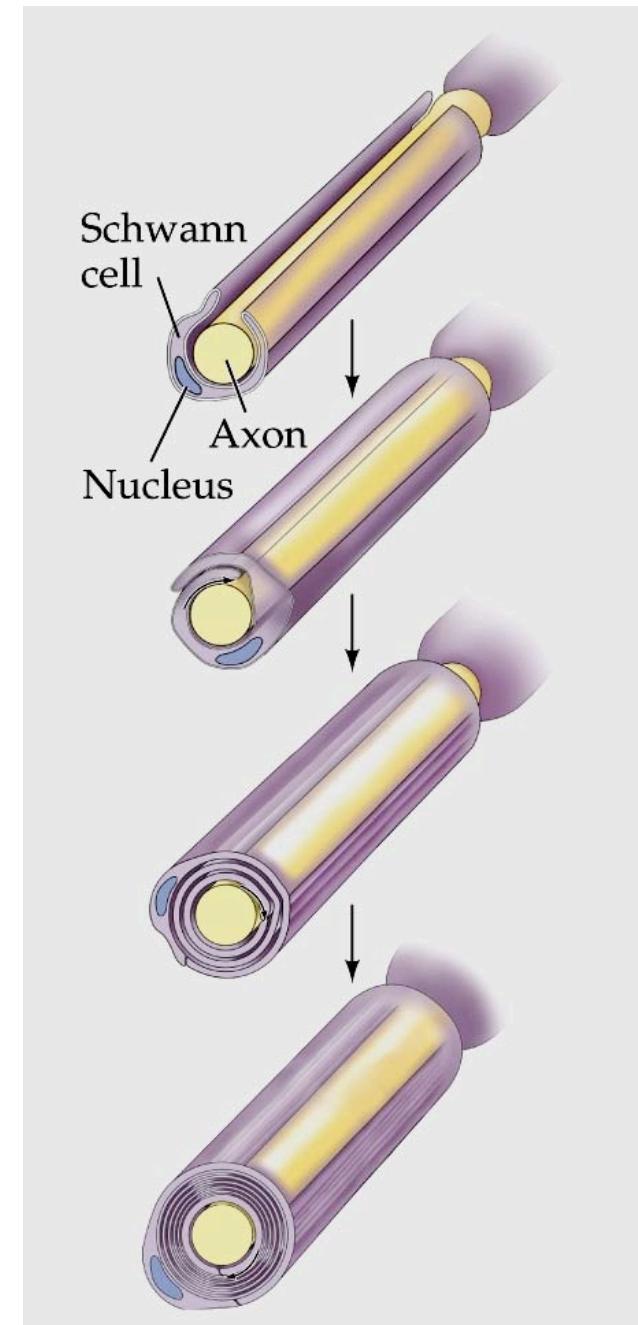
Biological Psychology 6e, Figure 2.6 (Part 3)

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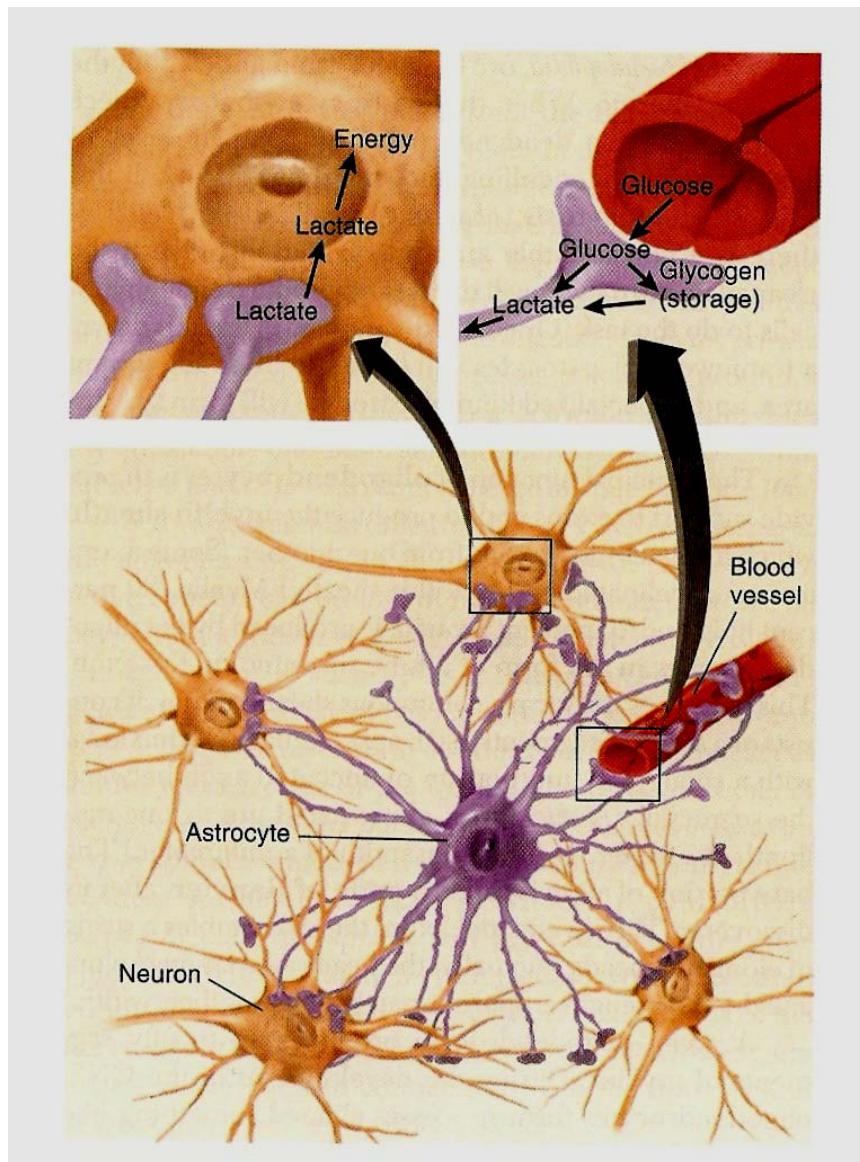
Glia: Structure and Function

Schwann Cells

- similar to oligodendrocytes, but **found in peripheral nervous system**
- insulates axons in peripheral nervous system and speeds conduction of electrical signals
- Notice more differences?



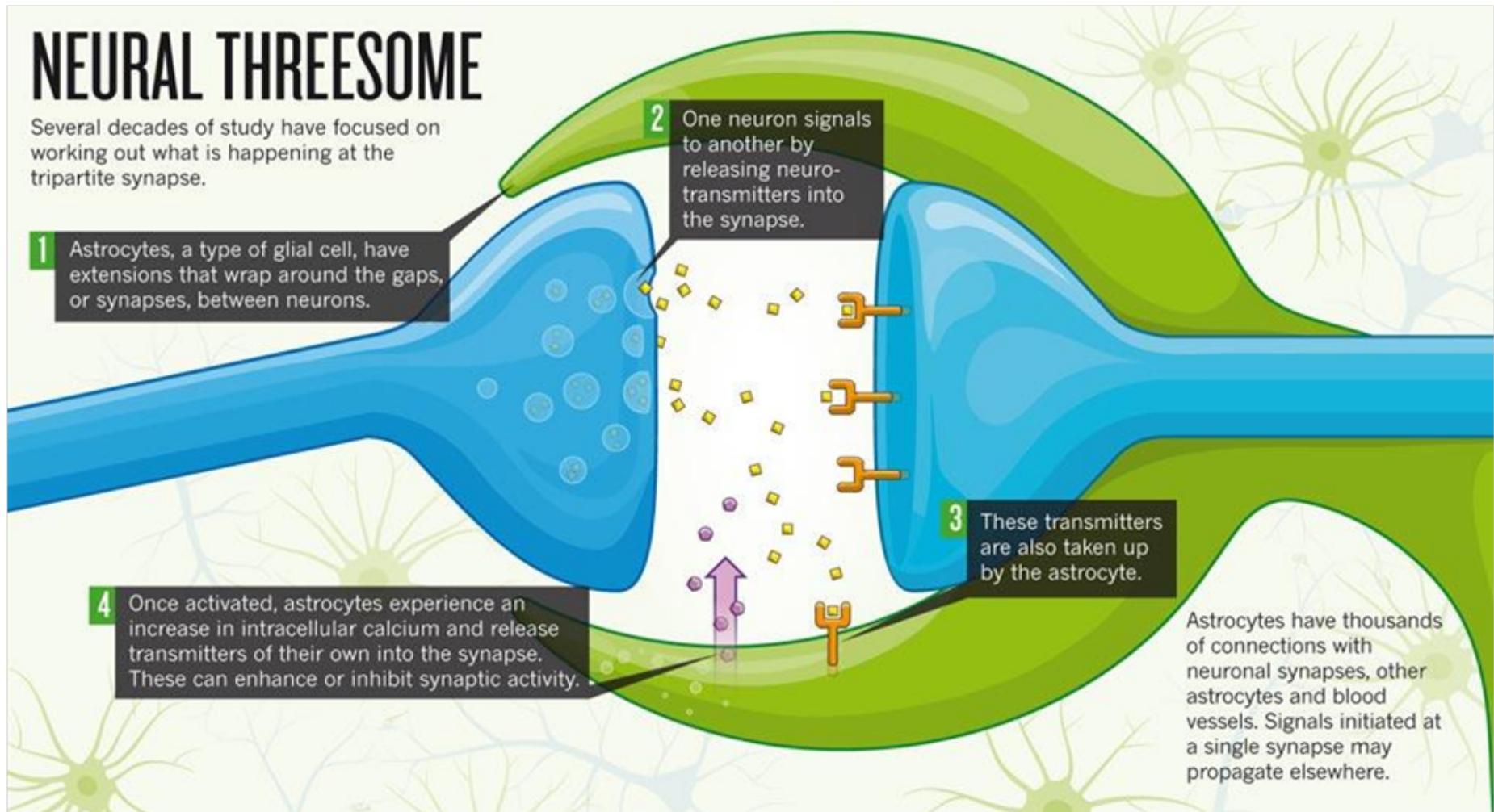
Glia: Structure and Function



Astrocytes

- star-shaped
- Hold neurons and blood vessels together - provide structural support to neurons
- transfer nutrients from blood vessels to neurons (e.g., glucose, amino acids, ions, etc.)
- actively involved in neural communication by forming tripartite synapses

The extension of astrocytes wraps around a synapse, forming a tripartite synapse



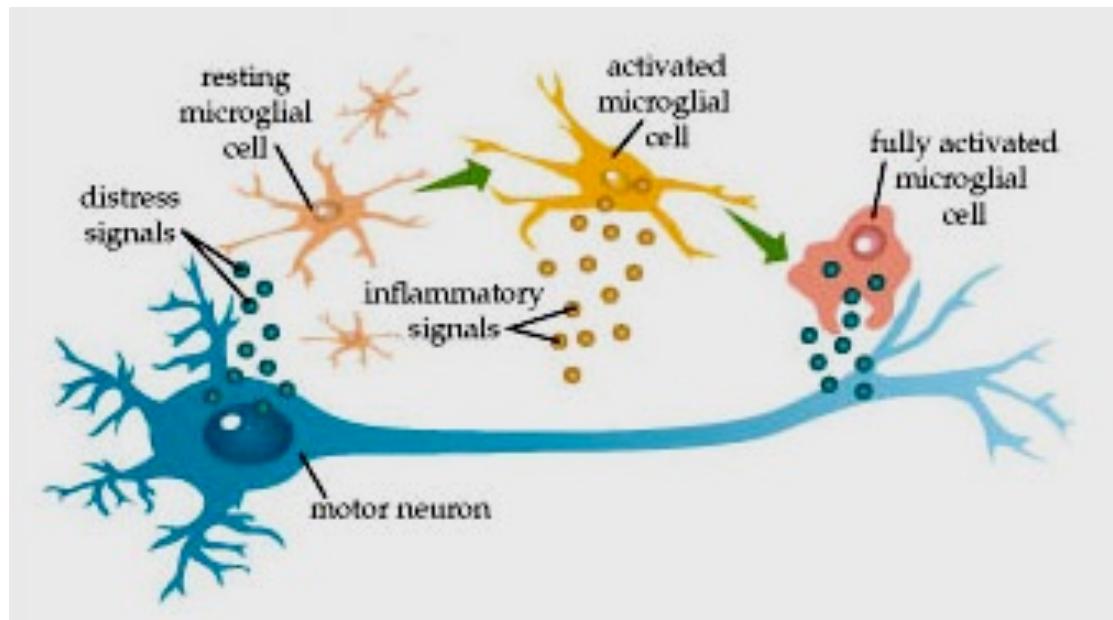
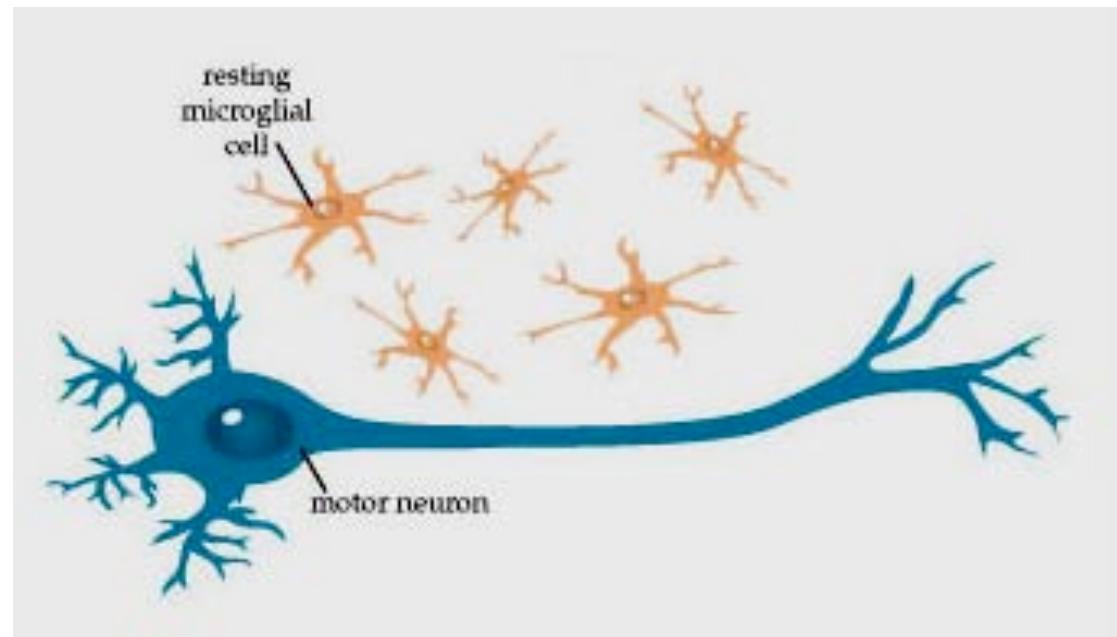
K. Smith 2010

Nature

Glia: Structure and Function

Microglia

- smallest of the glial cells found in CNS
- move around CNS looking for foreign bodies, viruses, bacteria, etc.
- destroy infectious material or infected neurons by phagocytosis



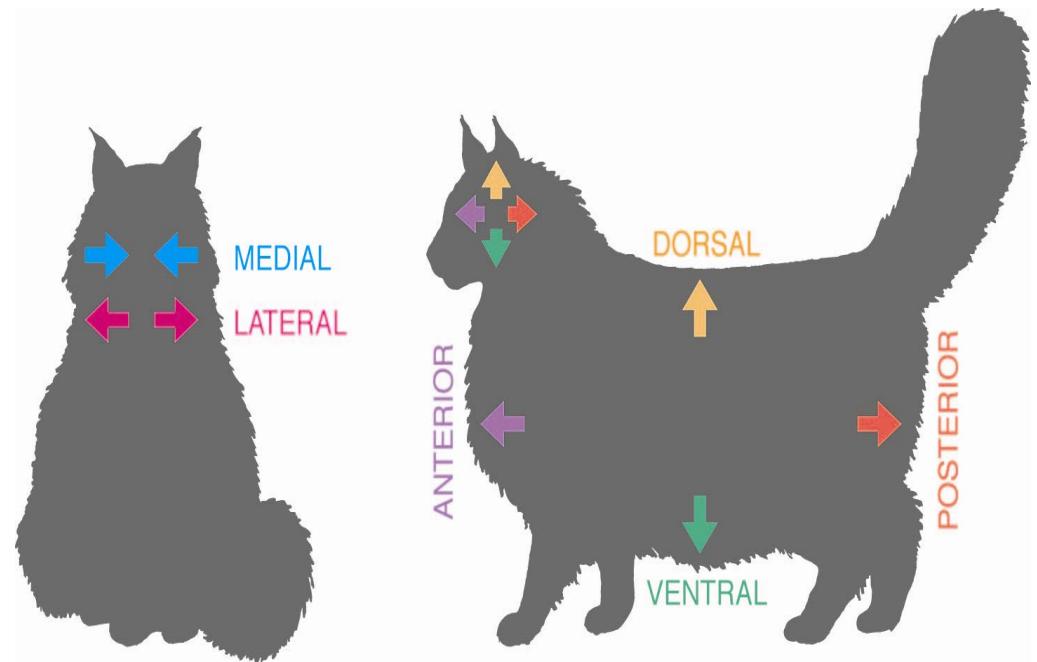
Cleaners of the streets

Today we will learn.....

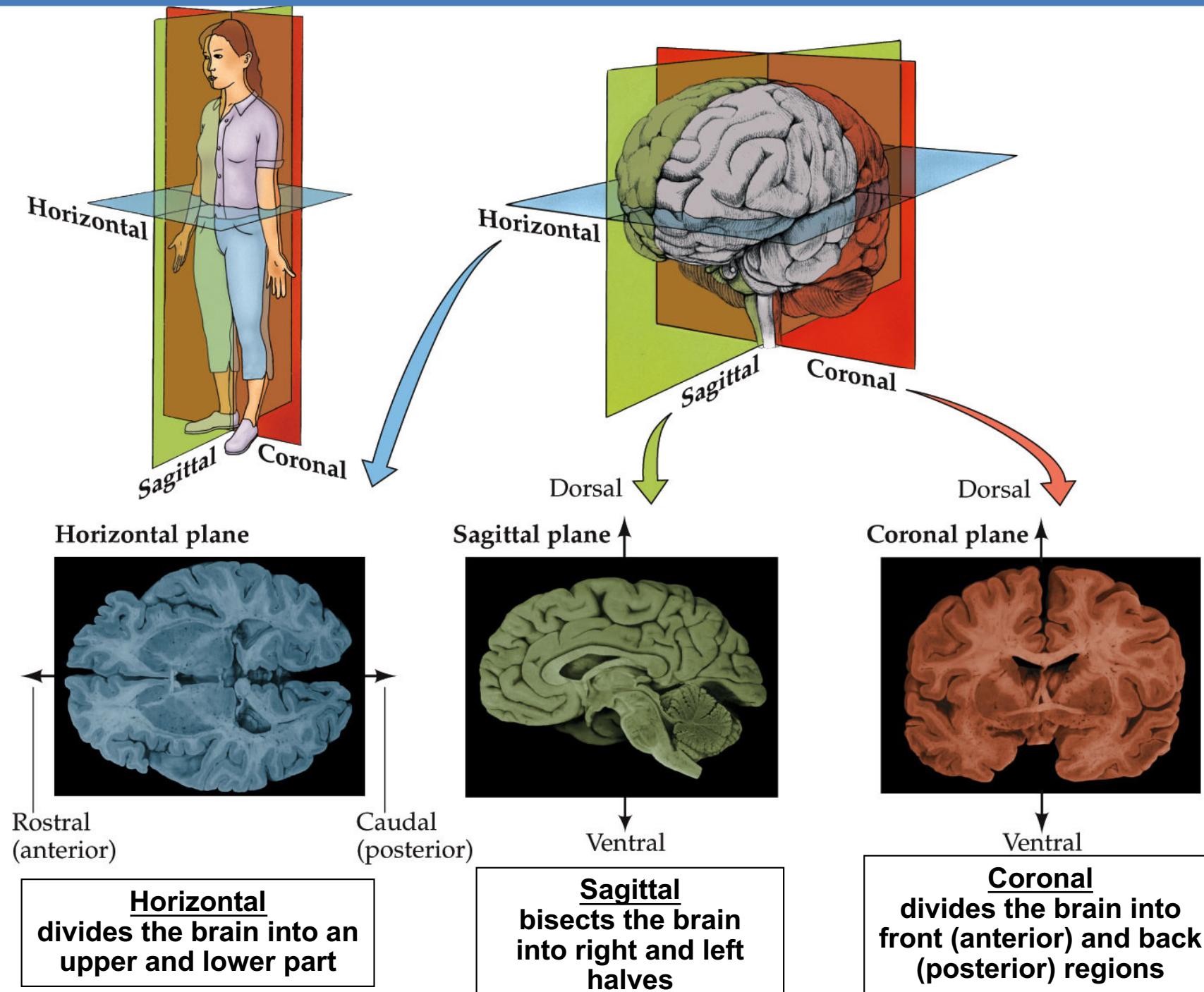
- General layout of the nervous system
- Structures protecting the nervous system
- Cellular components of the nervous system
- 5 min break
- **Anatomy of major structures of the nervous system**

Keywords for Navigating with Anatomy

- **Medial**—towards the middle
- **Lateral**—towards the side
- **Ipsilateral**—same side
- **Contralateral**—opposite side
- **Anterior** or **rostral**—head end
- **Posterior** or **caudal**—tail end
- **Dorsal**—toward the back
- **Ventral**—toward the belly



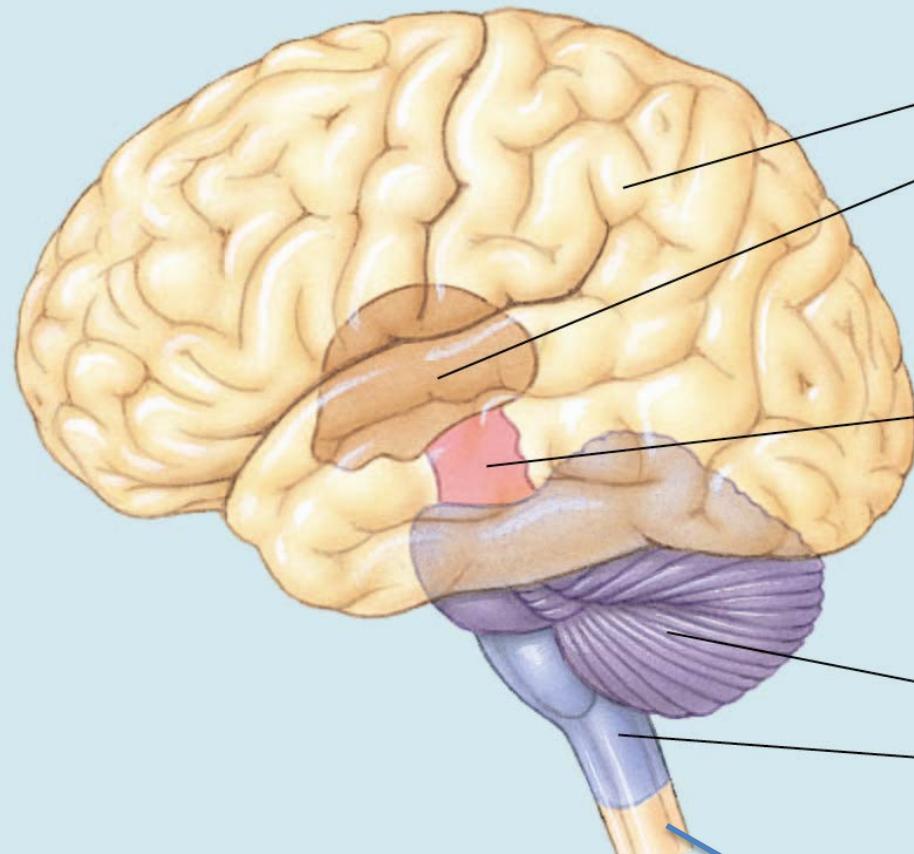
Three Customary Orientations for Viewing the Brain



Anatomy of the Brain

- Orientations
- Major structures of the central nerve system
 - Most names are Latin or Greek
 - Do you have to memorize all the names ?????

Anatomy of the Brain



4. Forebrain

Telencephalon

Diencephalon

3. Midbrain

Mesencephalon

2. Hindbrain

Metencephalon

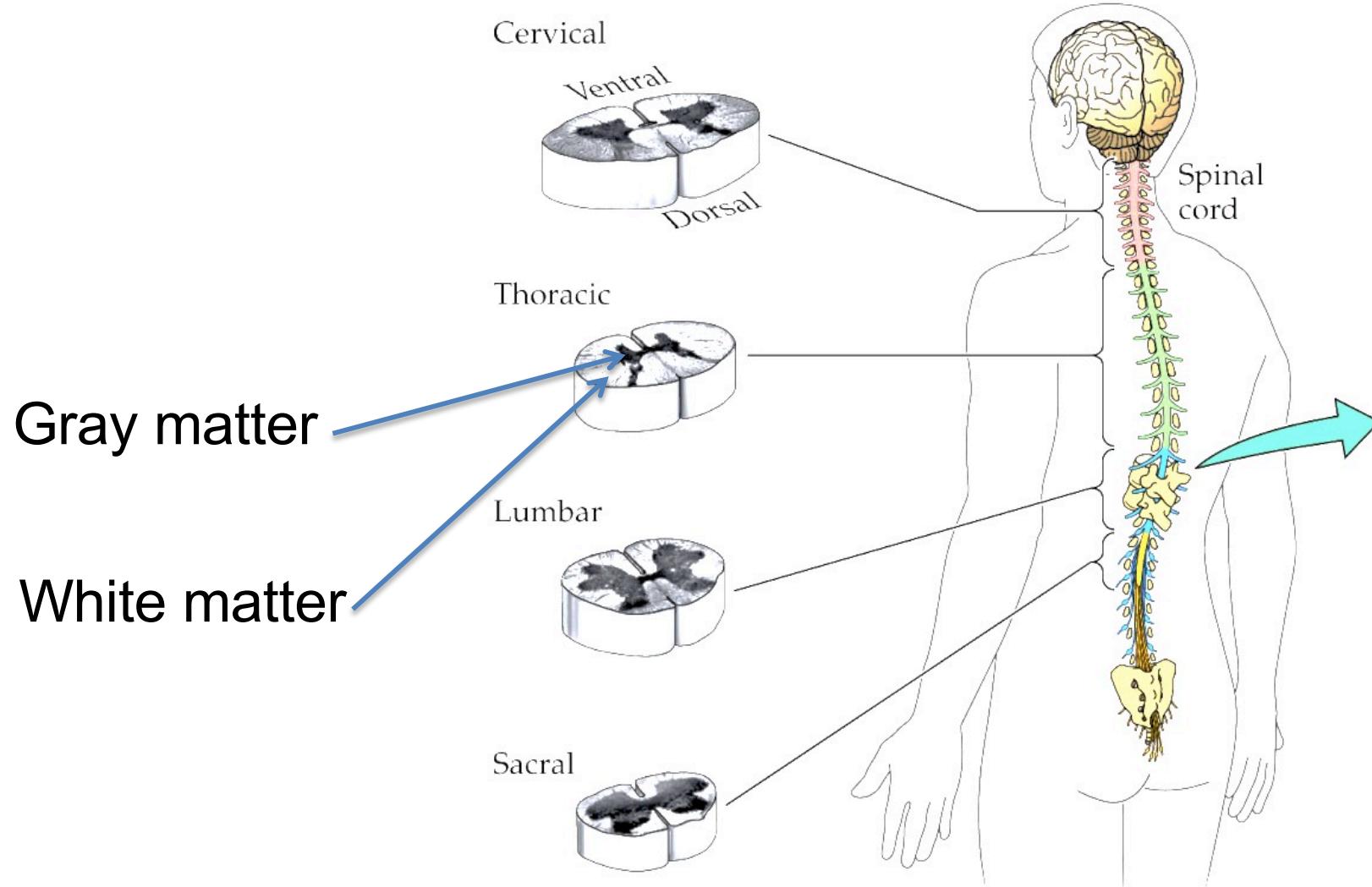
Myelencephalon

1. Spinal cord

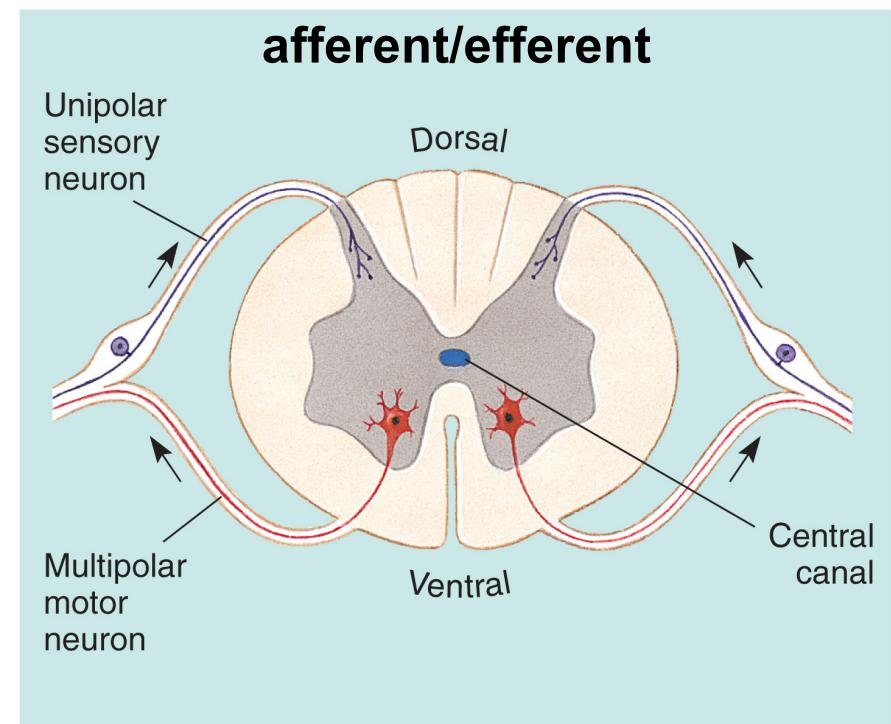
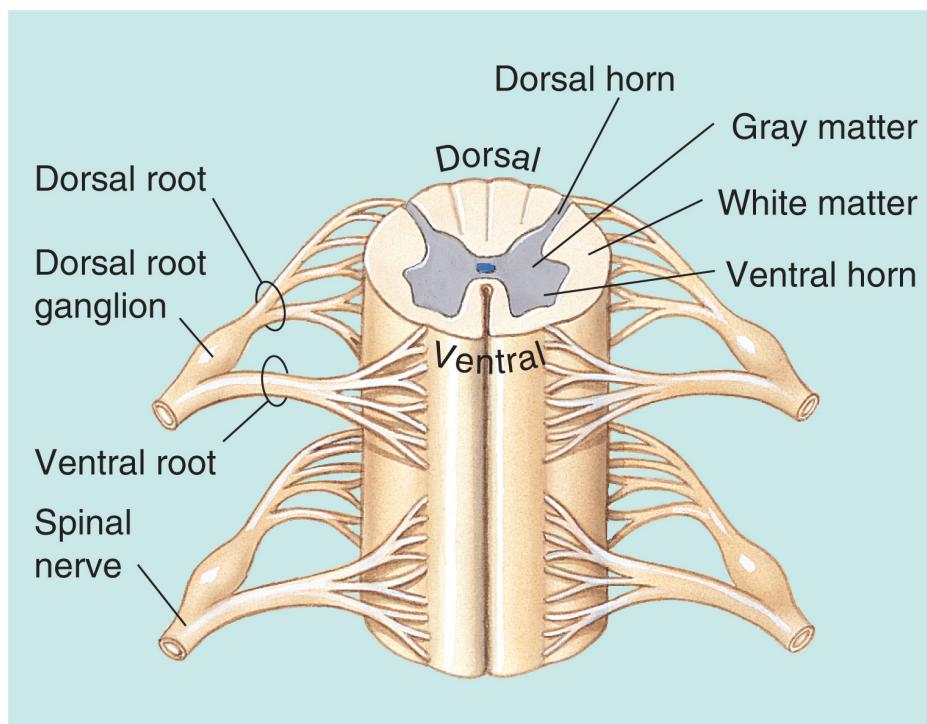
We will learn anatomy of CNS, starting from the spinal cord, moving upward to hindbrain, midbrain, forebrain

Anatomy of the Spinal Cord

Horizontal sections of the spinal cord reveal two distinct features...

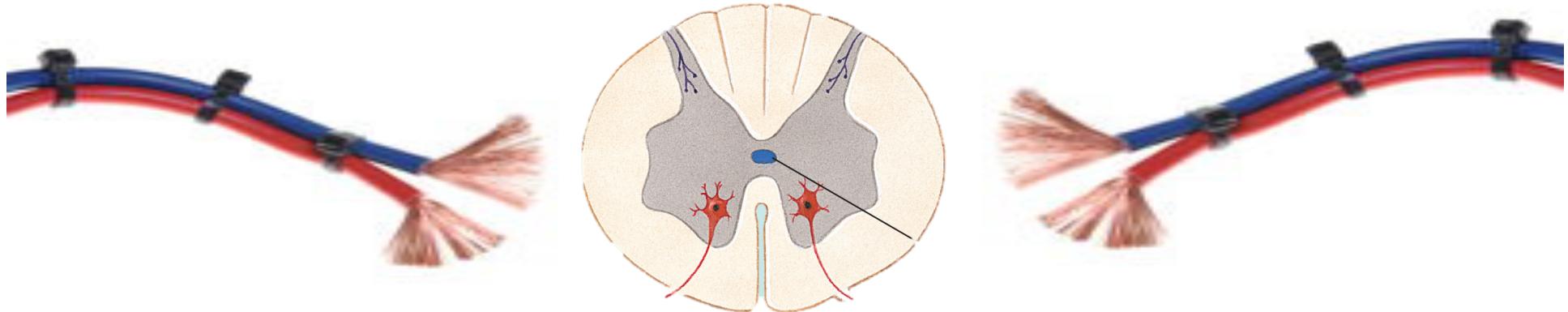
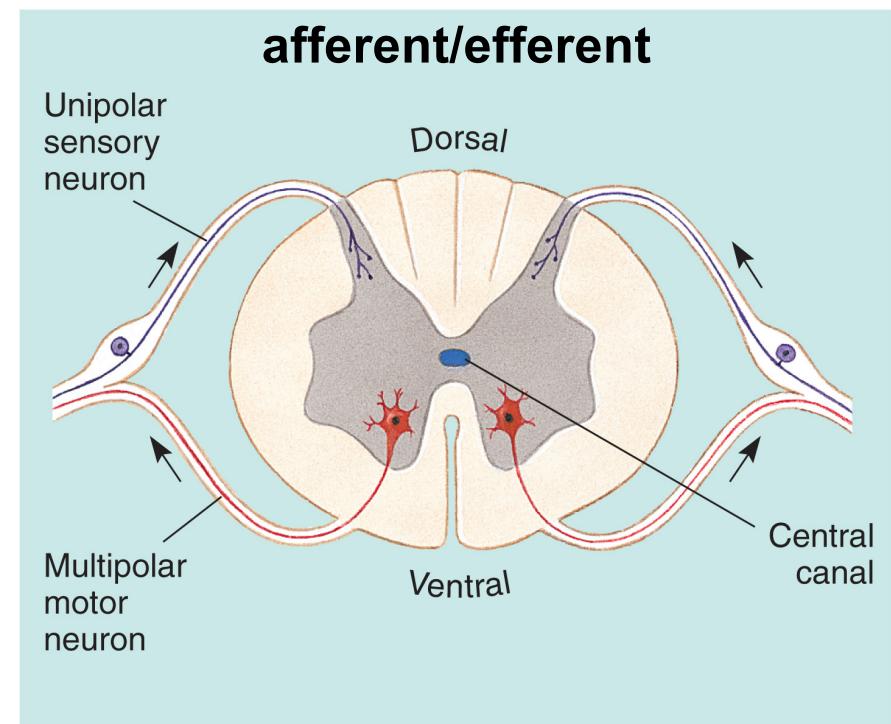
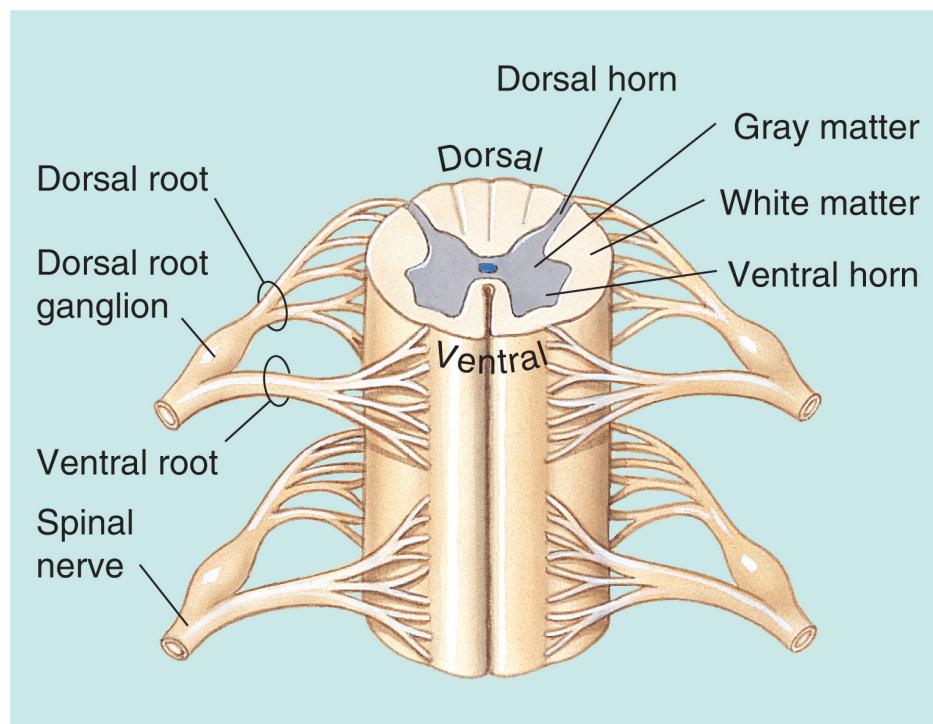


Anatomy of the Spinal Cord



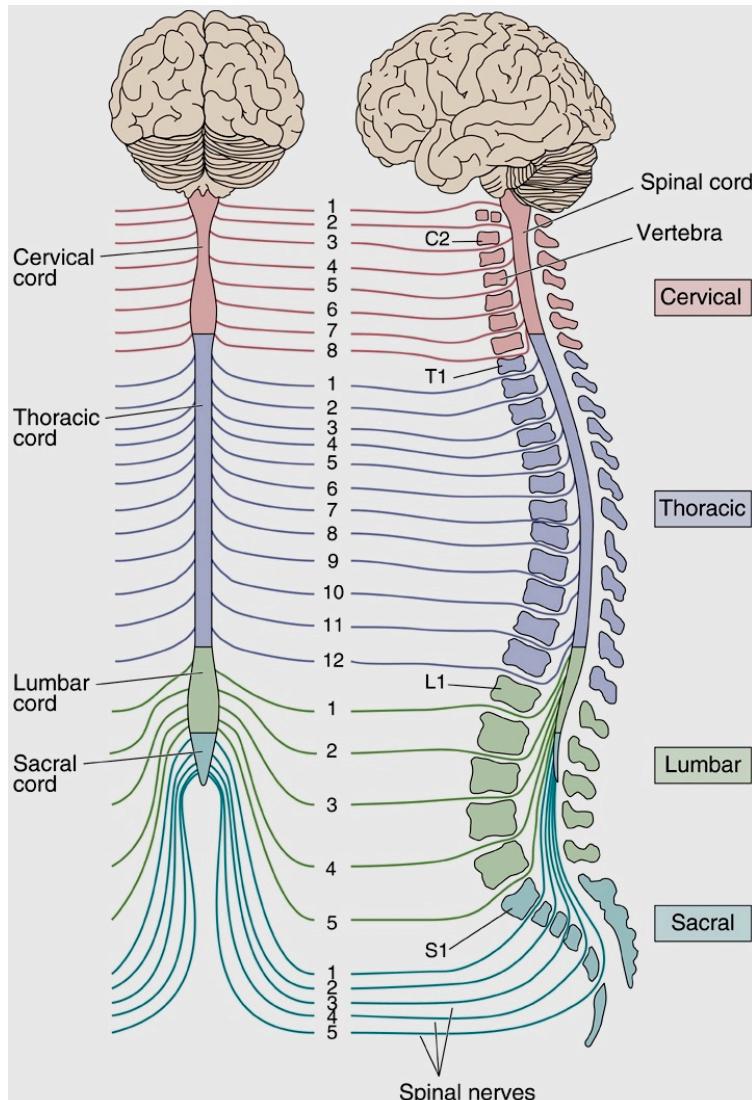
- Gray matter (H-shaped) – primarily cell bodies
- White matter – mainly myelinated axons
 - myelin gives white matter glossy white color
- At each level of spine, a pair of spinal nerves are attached to spinal cord
Each nerve is attached to the cord via dorsal roots and ventral roots.
 - **dorsal roots** -bring **sensory information** into spinal cord
 - **ventral roots** -send **motor information** to body

Anatomy of the Spinal Cord



Anatomy of the Spinal Cord

Spinal cord is attached to spinal nerves

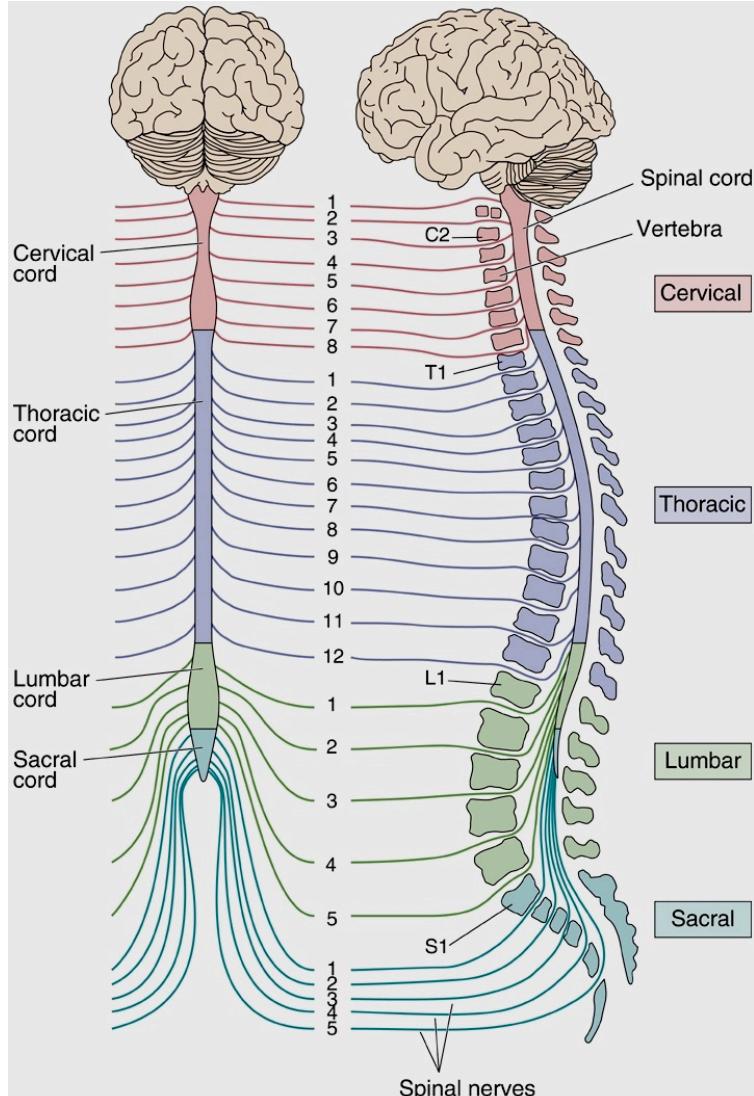


There are 31 pairs of spinal nerves

- named according to segment of spinal cord to which they are connected
 - 8 cervical nerves (C1-C8)
 - 12 thoracic nerves (T1-T12)
 - 5 lumbar nerves (L1-L5)
 - 5 sacral nerves (S1-S5)
 - 1 coccygeal nerve

Anatomy of the Spinal Cord

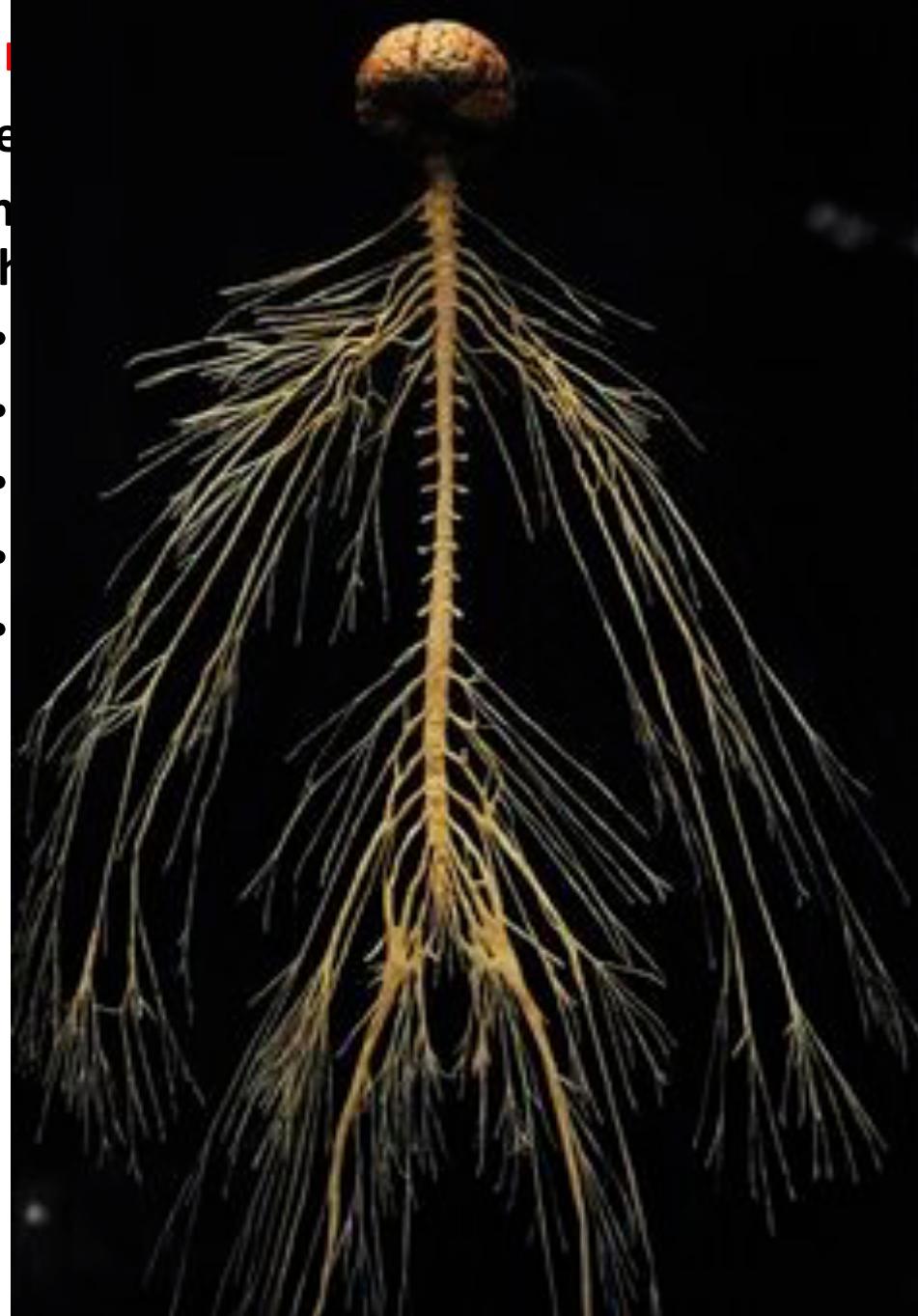
Spinal cord is attached to spinal meninges.



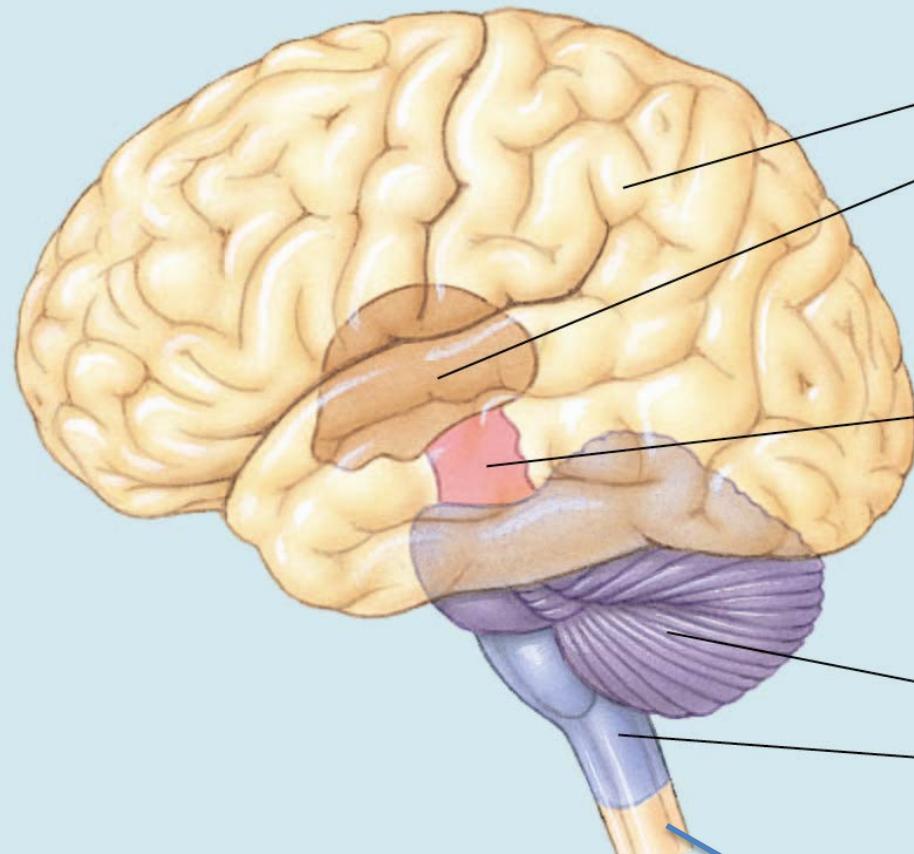
There are three types of spinal nerves:

- sensory which carry information to the brain

-
-
-
-
-



Anatomy of the Brain



4. Forebrain

Telencephalon

Diencephalon

3. Midbrain

Mesencephalon

2. Hindbrain

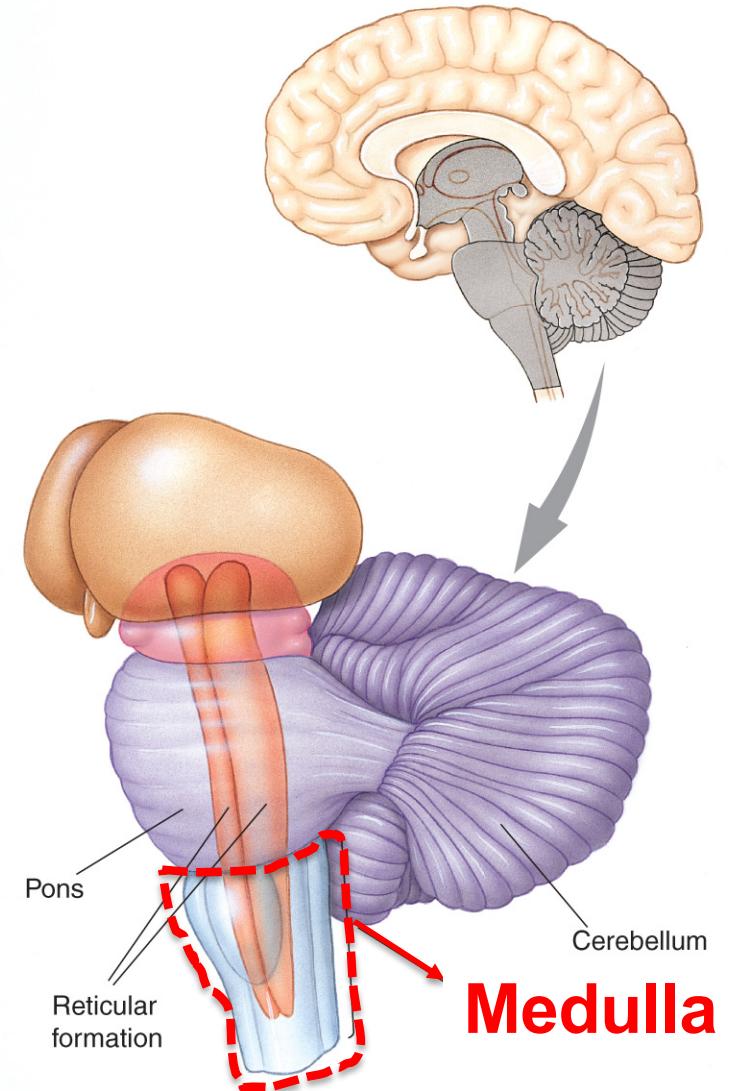
Metencephalon

Myelencephalon

1. Spinal cord

Anatomy of the hindbrain

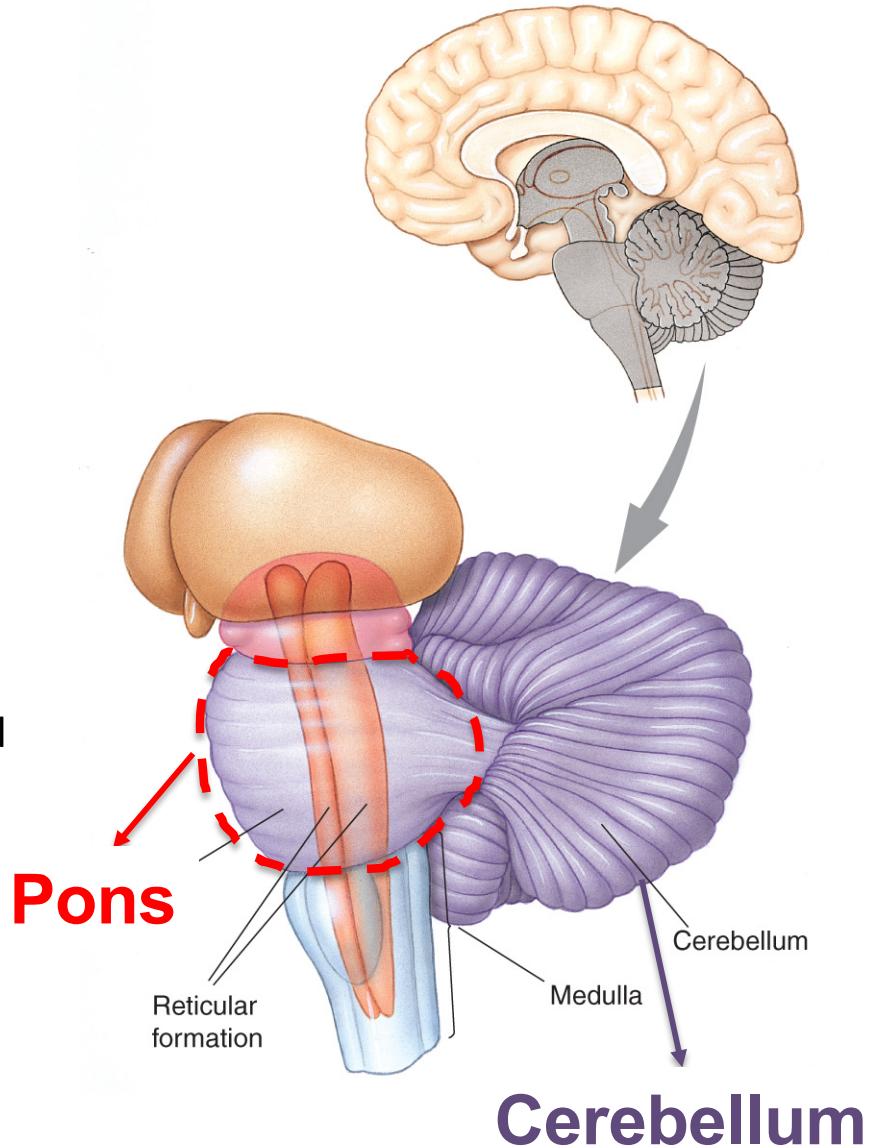
- Hindbrain: myelencephalon + metencephalon
- Myelen-cephalon (also known as medulla)
 - Composed largely of axon tracts
 - the reticular formation (neuron clusters)
 - Cross section looks like small nets
 - Extend from the medulla to the midbrain
 - Consists of about 100 nuclei, each involved in a variety of vital functions including **sleep, breathing, heart rate, blood pressure, etc.**



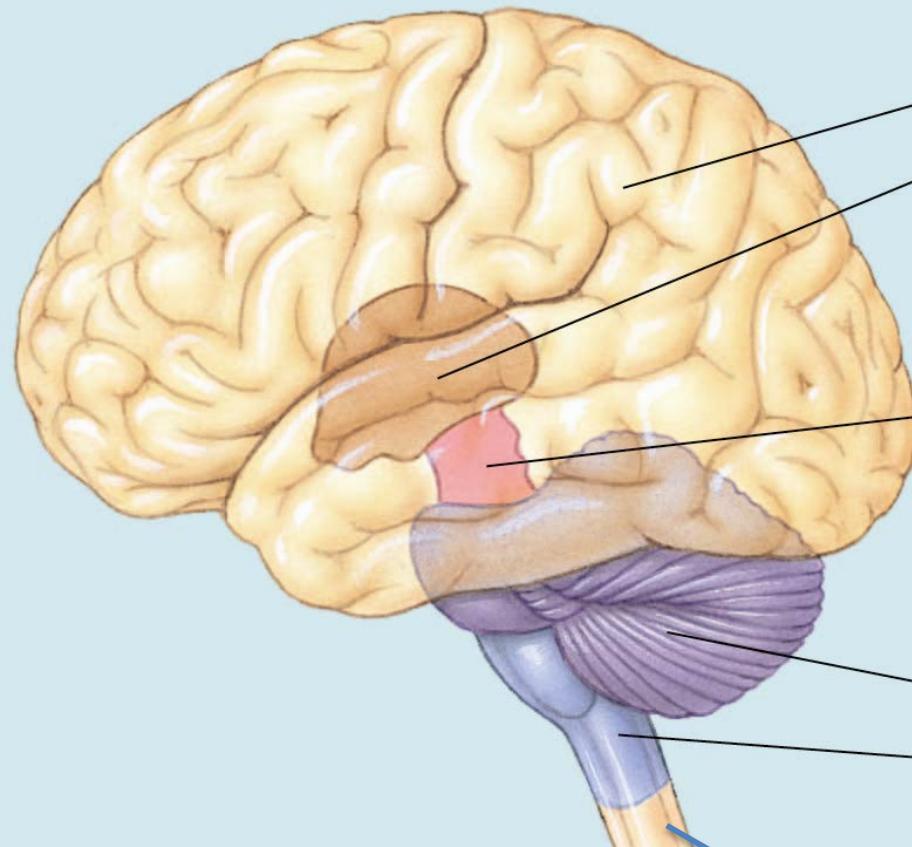
Anatomy of the hindbrain

- Metencephalon

- Pons
 - Very similar arrangement to the medulla
 - Rich in axon tracts
 - Reticular formation
 - several some nuclei involved in sleep and arousal, others involved in movement and muscle tone
- Cerebellum
 - consists of cerebellar cortex and subcortical cerebellar nuclei
 - involved in motor control → necessary for production of accurate and coordinated movement



Anatomy of the Brain



4. Forebrain

Telencephalon

Diencephalon

3. Midbrain

Mesencephalon

2. Hindbrain

Metencephalon

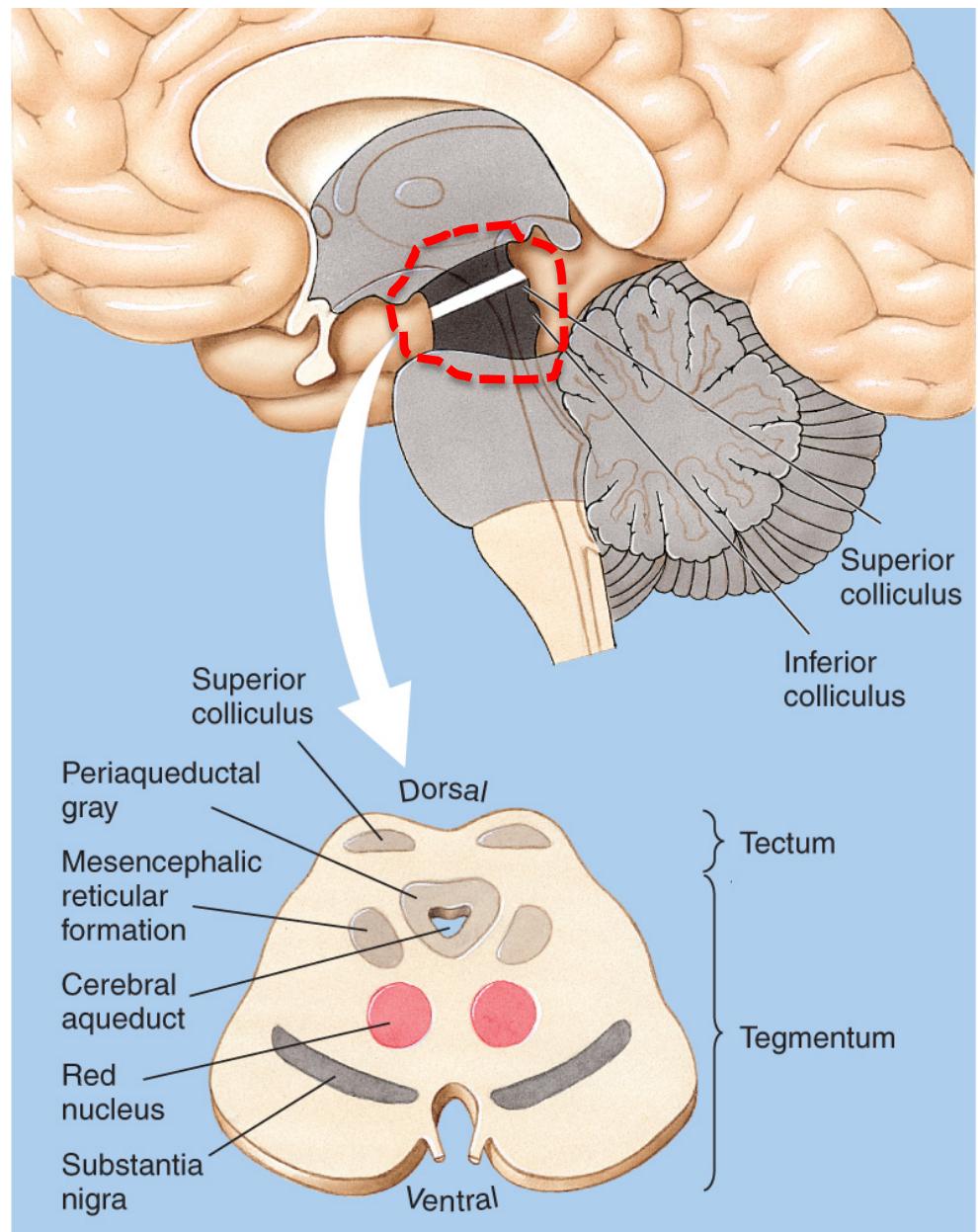
Myelencephalon

1. Spinal cord

Anatomy of the midbrain

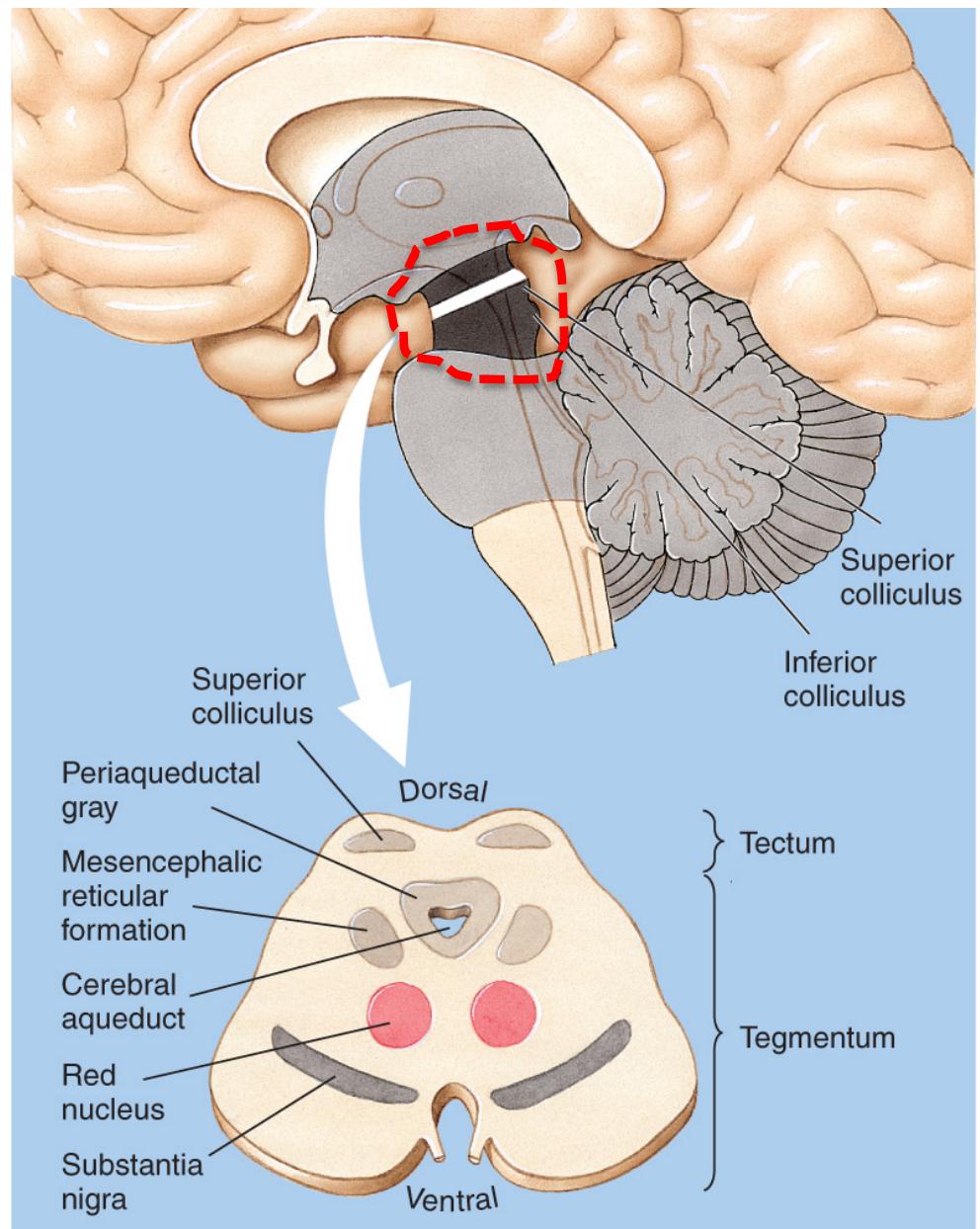
Mesencephalon = midbrain

- Divided into
 - tectum (dorsal part)
 - tegmentum (ventral part)

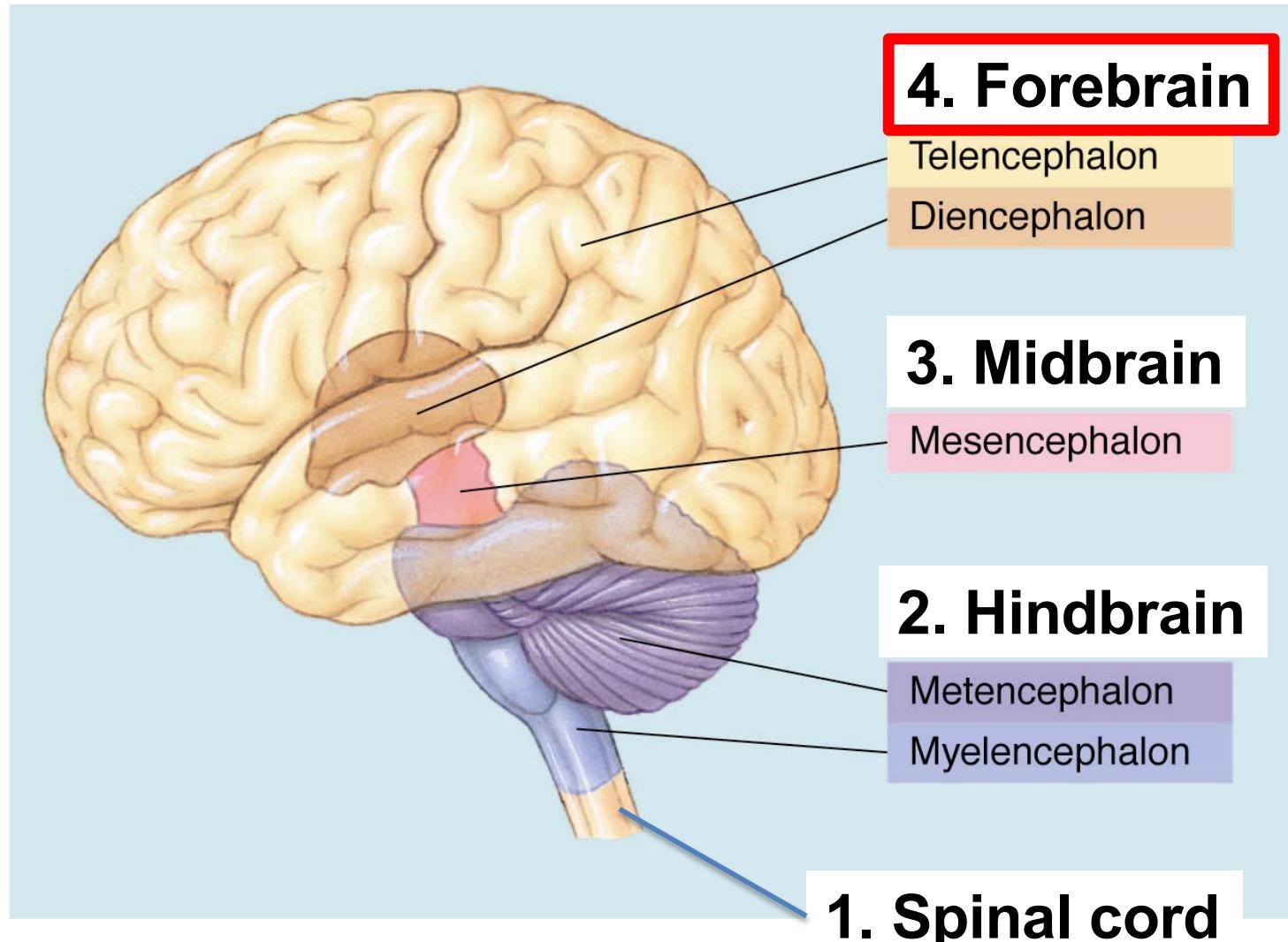


Anatomy of the midbrain

- **Tectum** consists of two pairs of bumps (colliculi)
 - superior colliculus - receive visual information from retina
 - inferior colliculus - receive auditory information from ear
- **Tegmentum** consists of reticular formation, periaqueductal gray, substantia nigra, red nucleus
 - Periaqueductal gray – gray matter around the aqueduct, mediating pain sensation.
 - Substantia nigra and red nucleus – involved in motor function.



Anatomy of the Brain

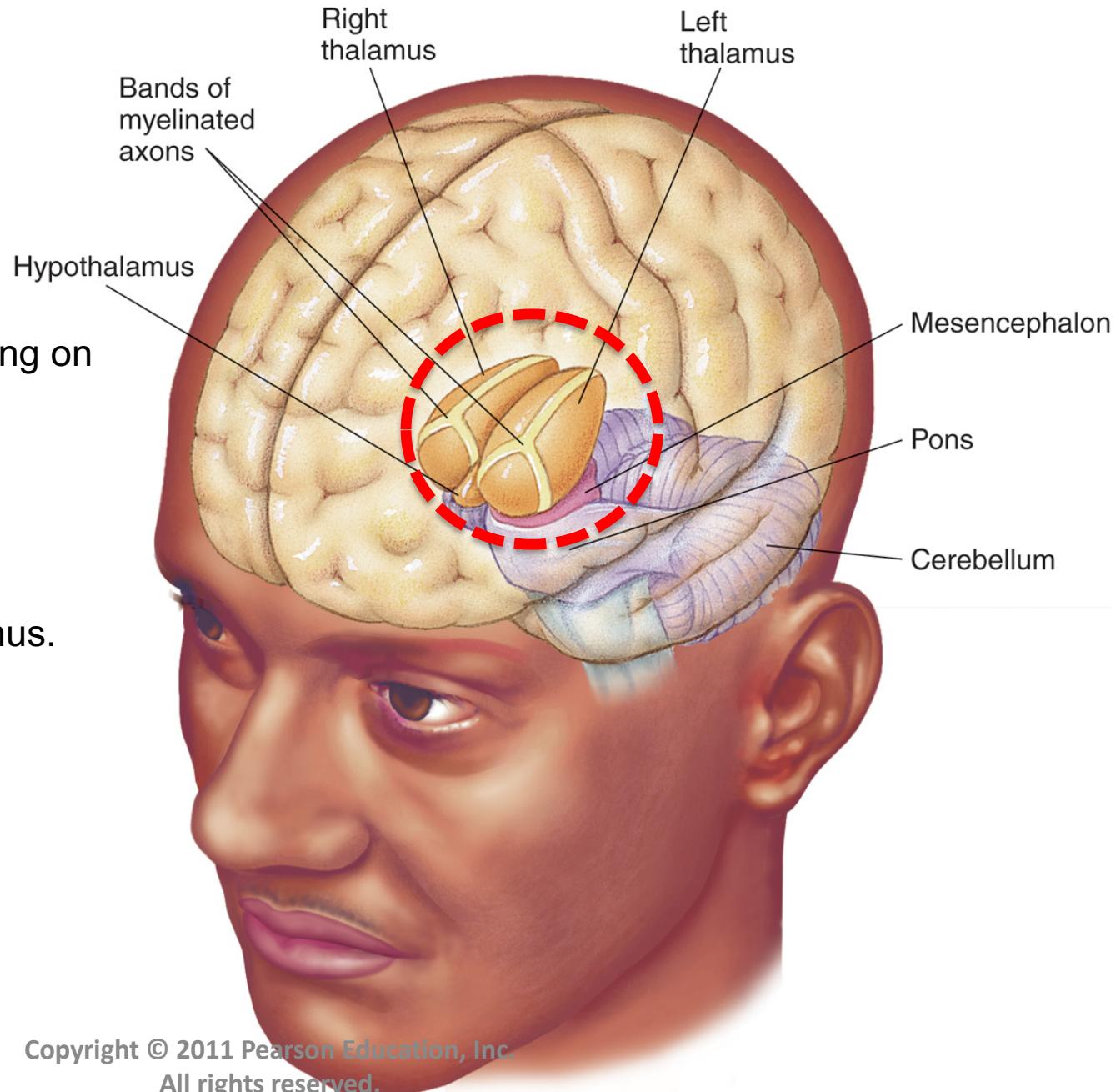


Forebrain = telencephalon + diencephalon

Anatomy of the forebrain

Diencephalon (TWIN brain)

- **THALAMUS**
 - two-lobbed structure sitting on top of brainstem.
- **HYPOTHALAMUS**
 - located below the thalamus.

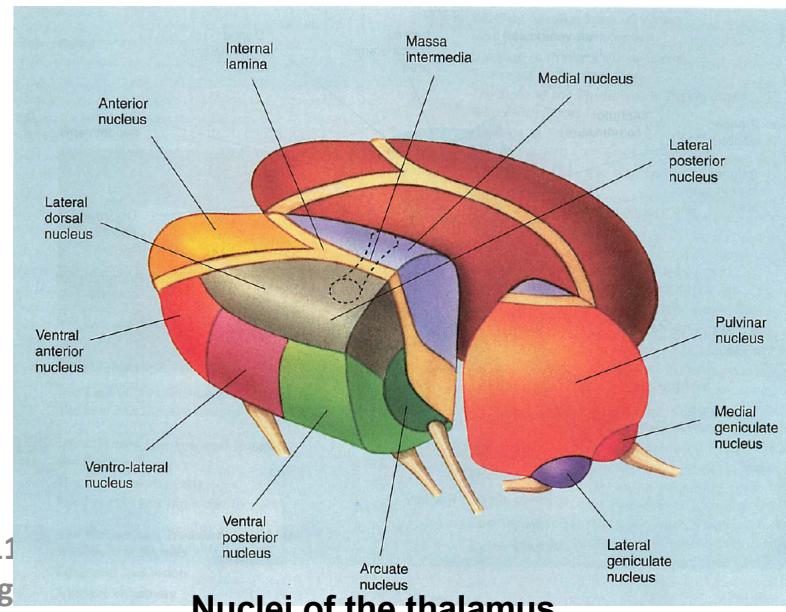
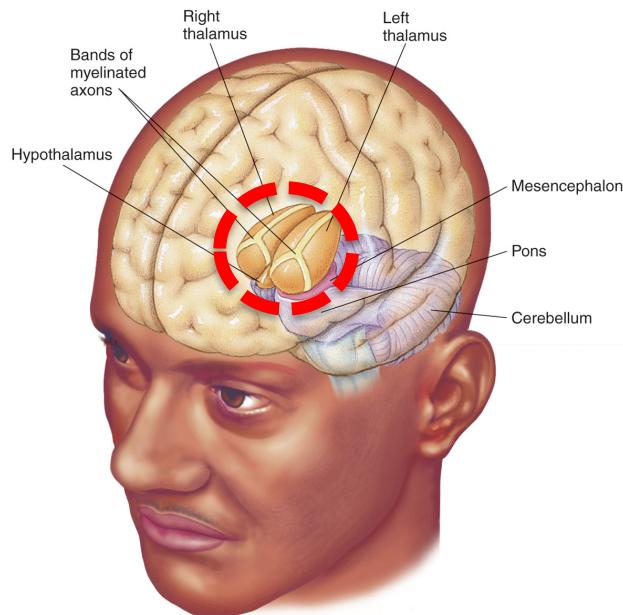


Anatomy of the forebrain

Diencephalon (TWIN brain)

THALAMUS

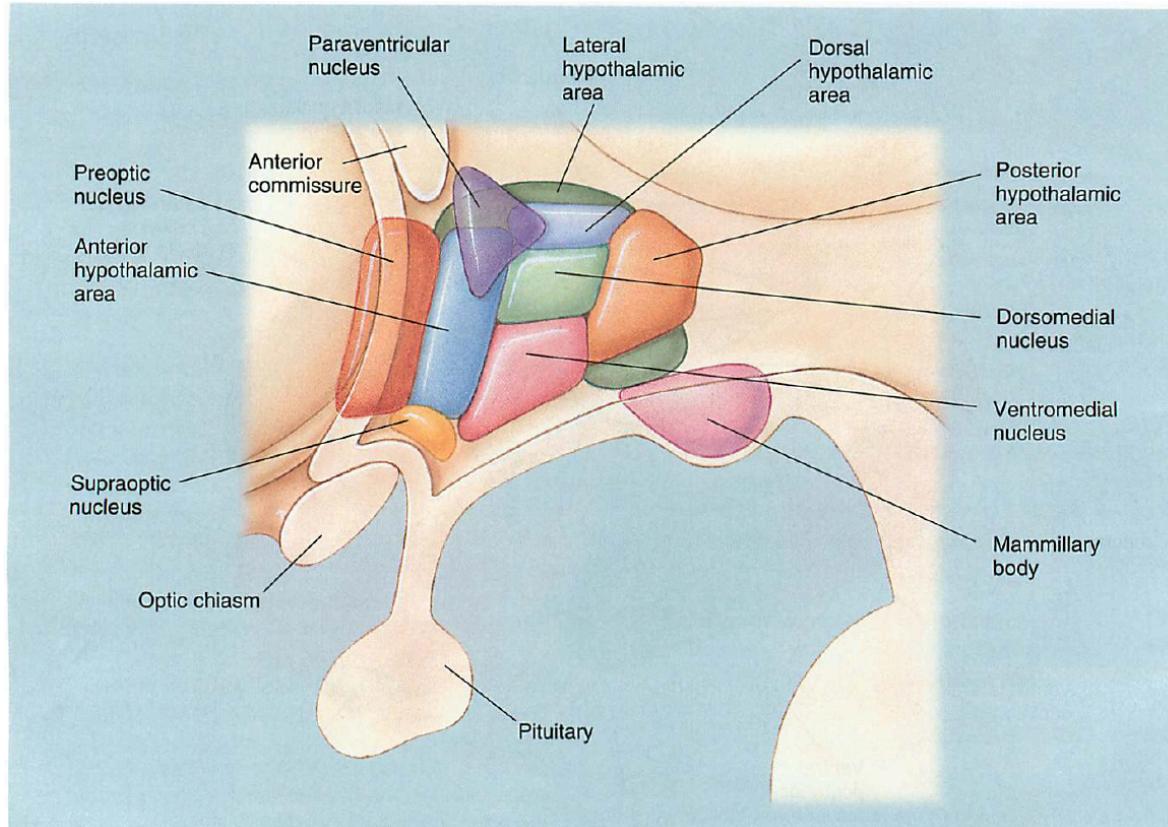
- receives sensory information and relays it to the cortex (“**relay station**”)
- made up of many subnuclei, each of which receives different sensory information
 - lateral geniculate nuclei - visual signals.
 - medial geniculate nuclei - auditory signals.
 - Ventral posterior nuclei - somatosensory signals.



Anatomy of the forebrain

HYPOTHALAMUS

- consists of many nuclei, each controlling different **motivated behaviors** such as eating, sleep, sexual behaviors, stress responses, etc.

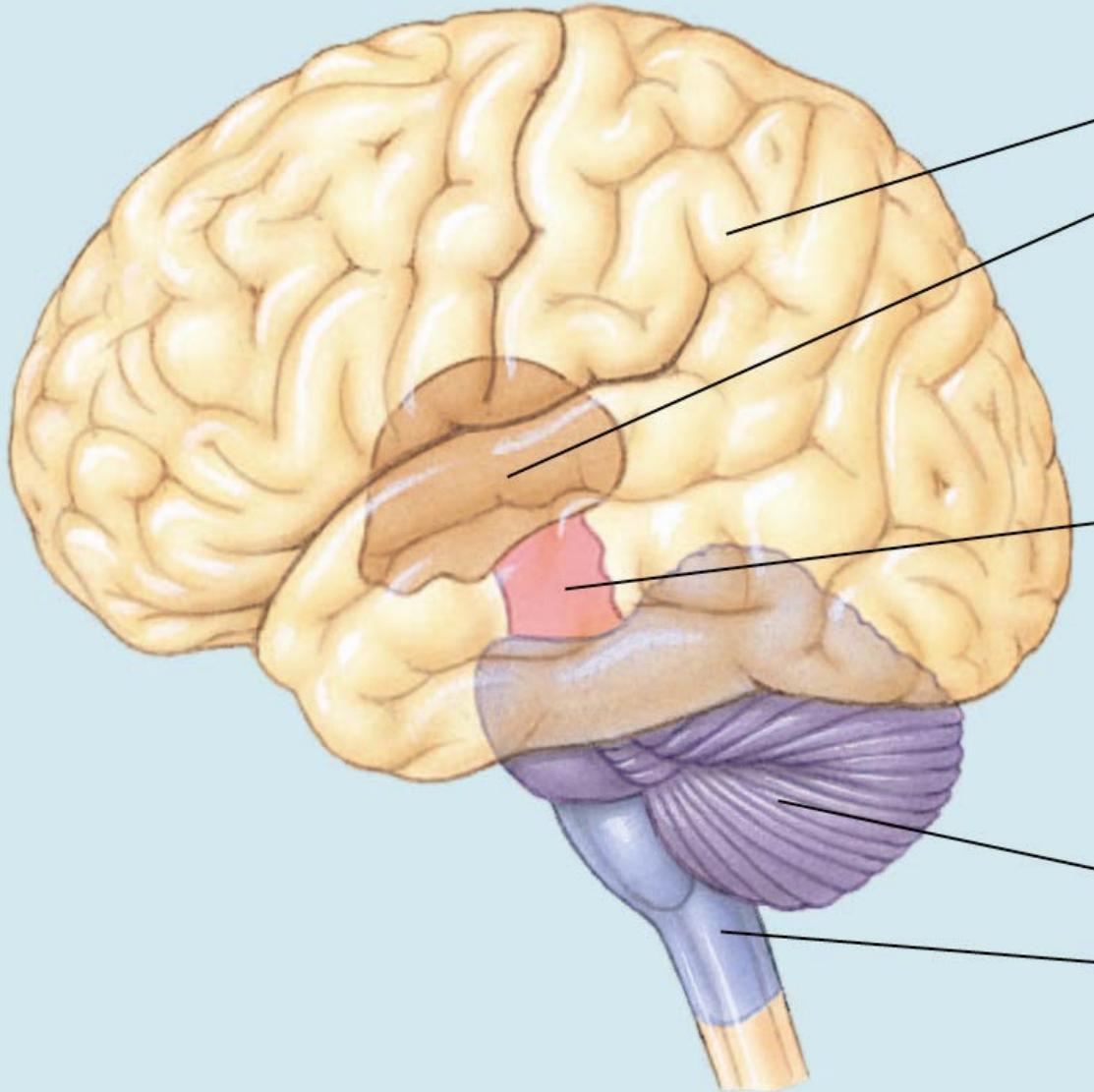


Nuclei of the hypothalamus

Anatomy of the Brain

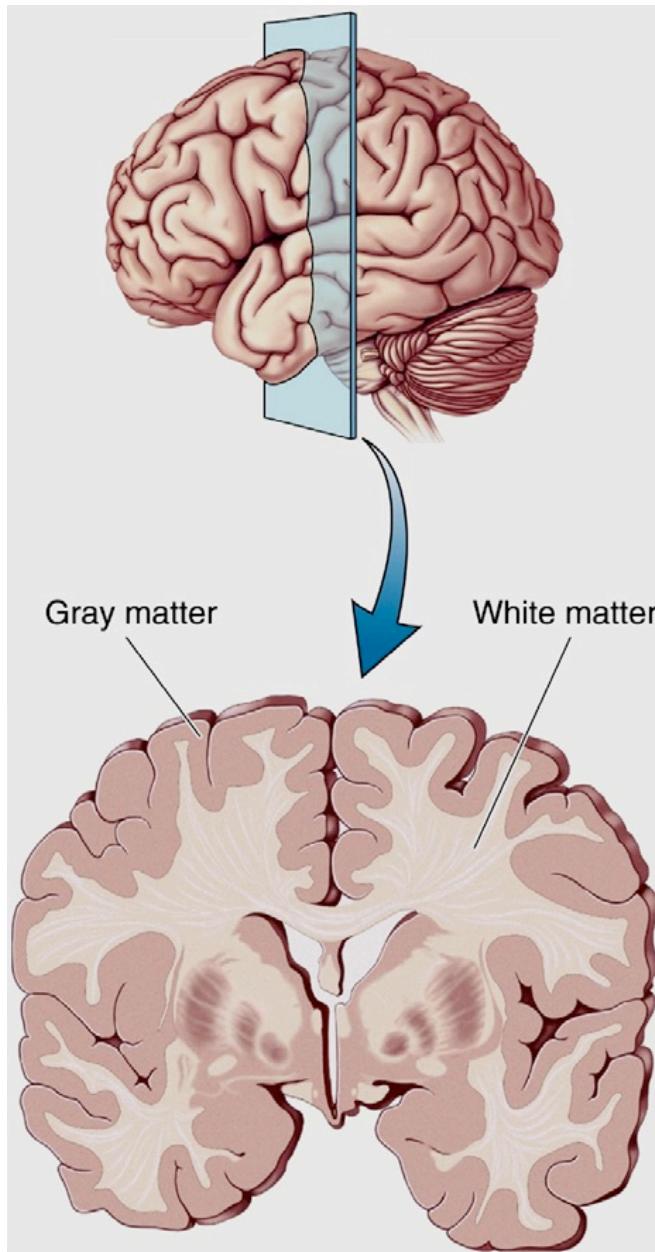
4. Forebrain

Telencephalon
Diencephalon



Anatomy of the forebrain (continued)

Telencephalon



Telencephalon consists of: three parts

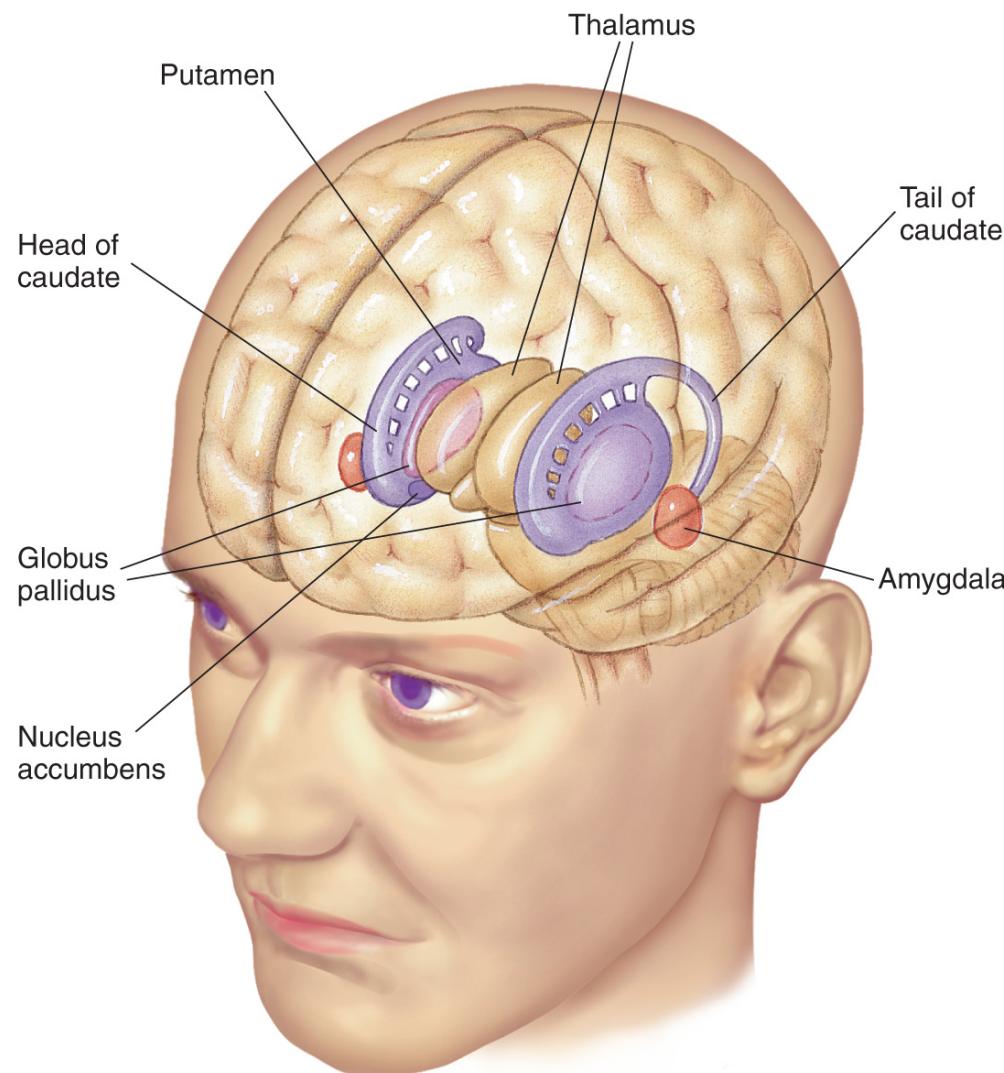
- 1. Cerebral cortex →outermost layer**
- 2. Cortical white matter →lies beneath cortex**
- 3. Subcortical regions →lie beneath cortical white matter**

: subcortical regions contain two major systems

- 1. Basal ganglia**
- 2. Limbic system**

Anatomy of the Brain

Telencephalon – Subcortical Structures

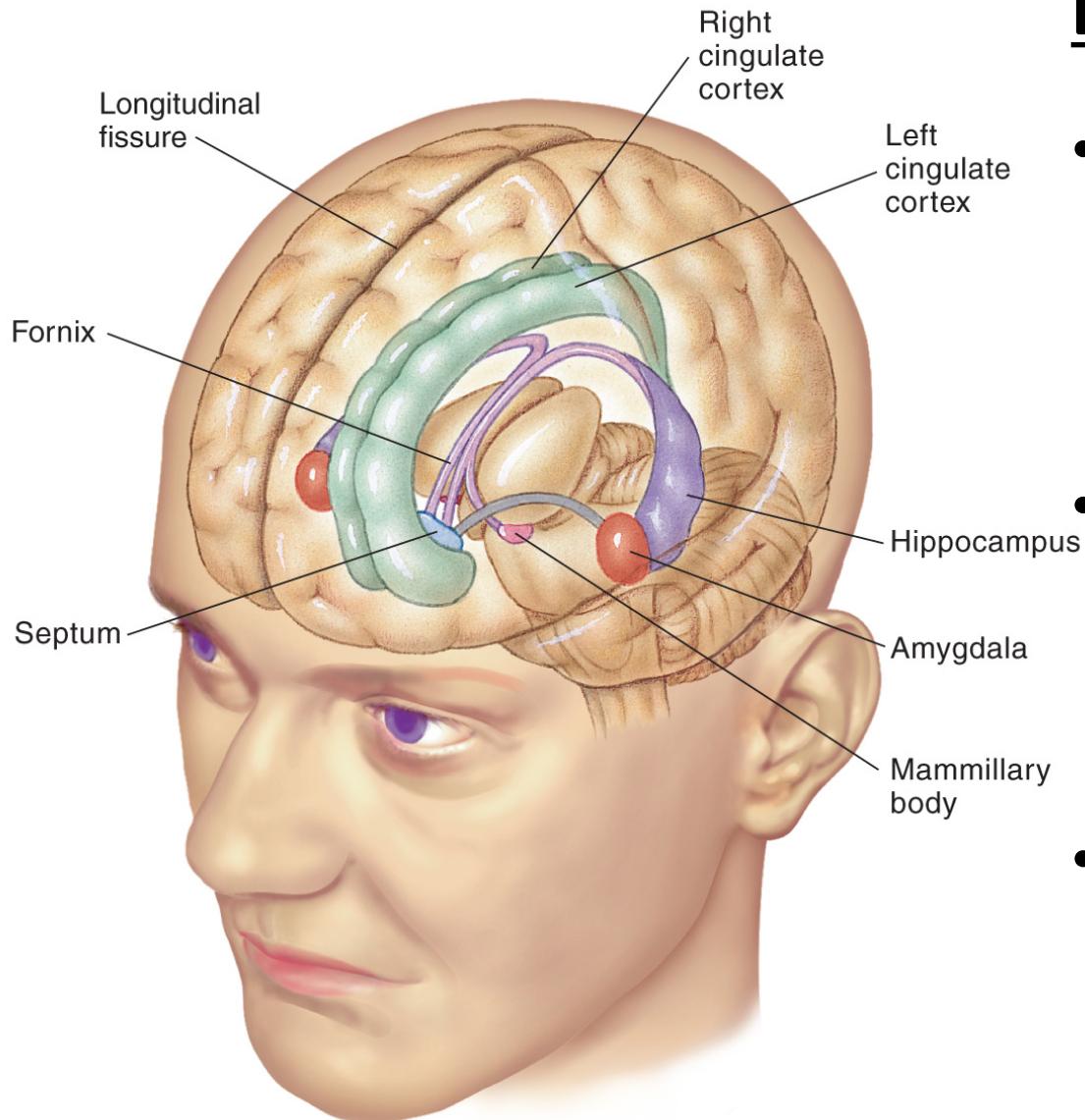


BASAL GANGLIA

- Includes 3 main structures: **striatum (caudate nucleus + putamen) and globus pallidus**
- **necessary for voluntary movement**

Anatomy of the Brain

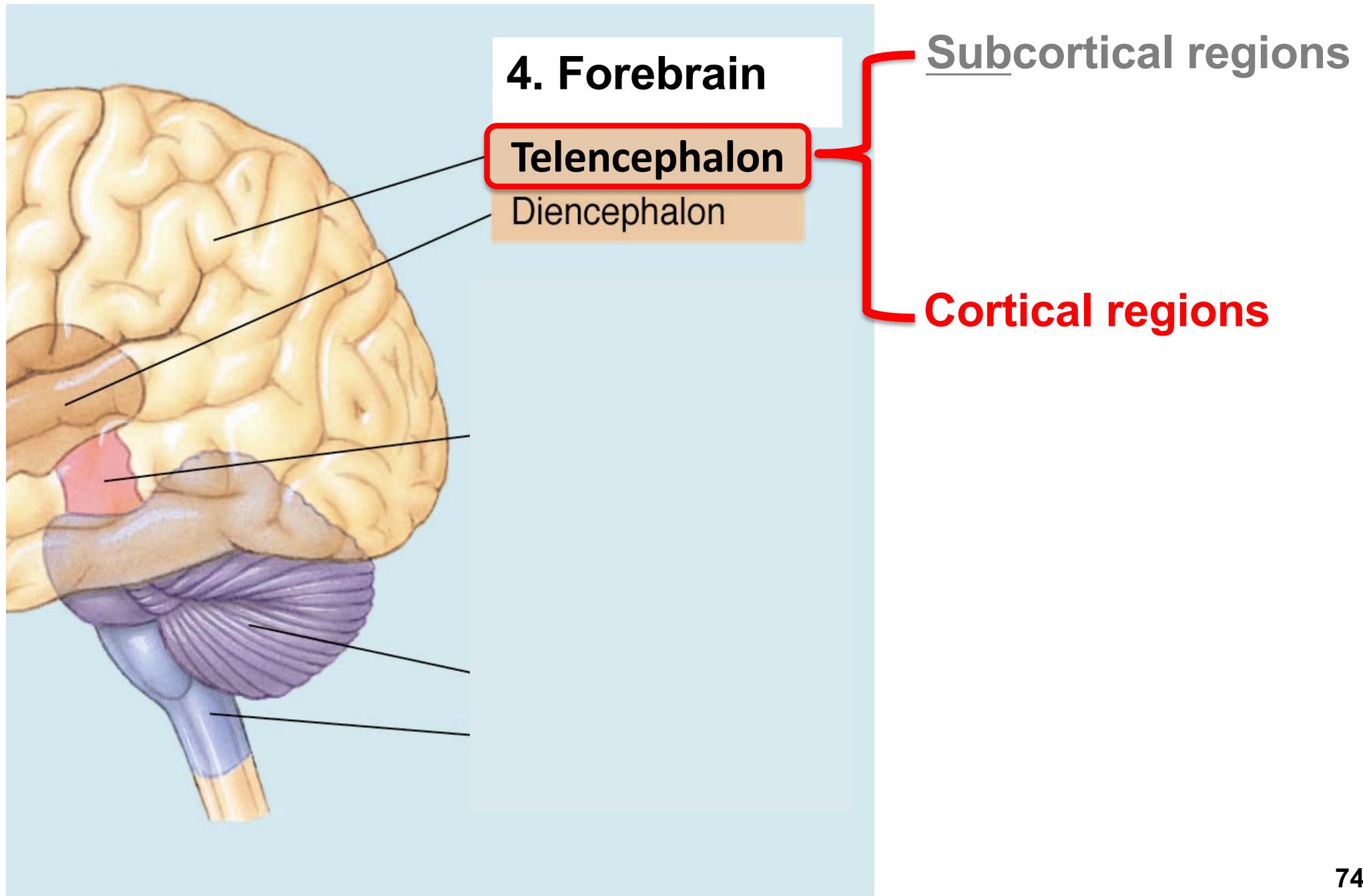
Telencephalon – Subcortical Structures



LIMBIC SYSTEM

- A group of structures that surround the thalamus like a ring shape. Limbic means ring.
- consists of the hippocampus, amygdala, fornix, cingulate cortex, septum, mammillary bodies
- involved in four Fs (feeding, fighting, fleeing, sexual behaviors) as well as learning and memory

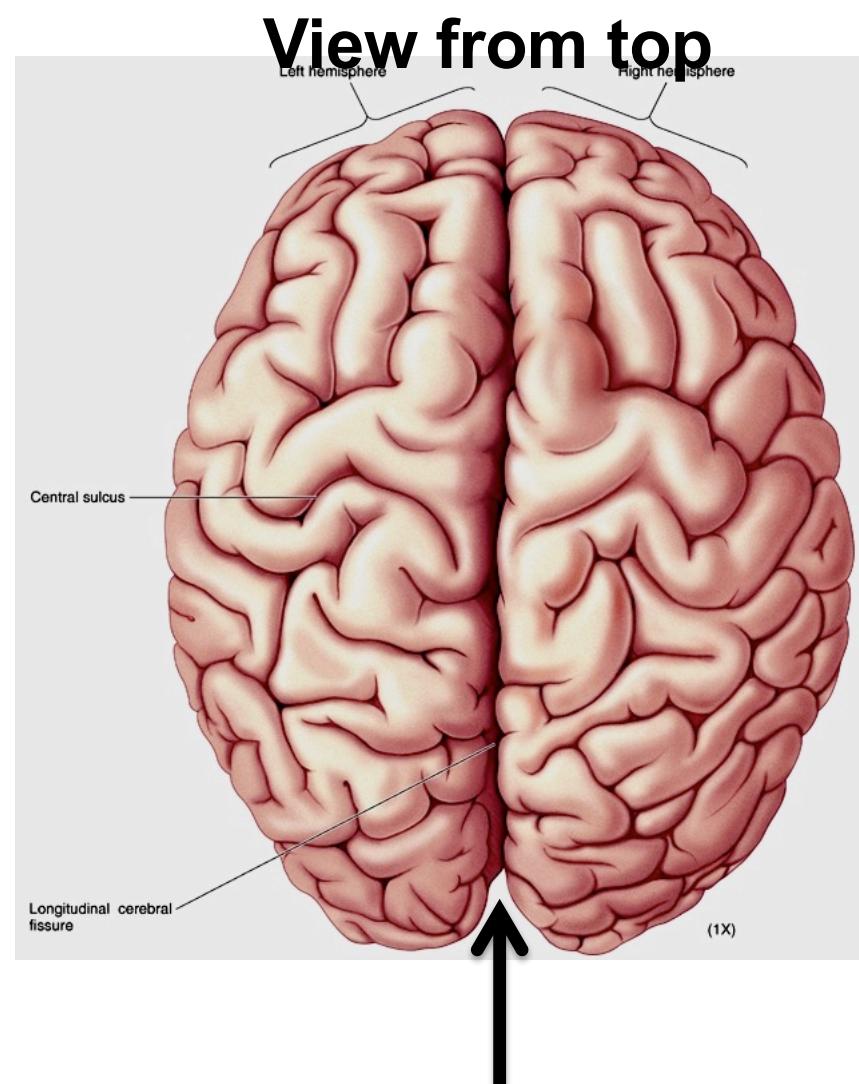
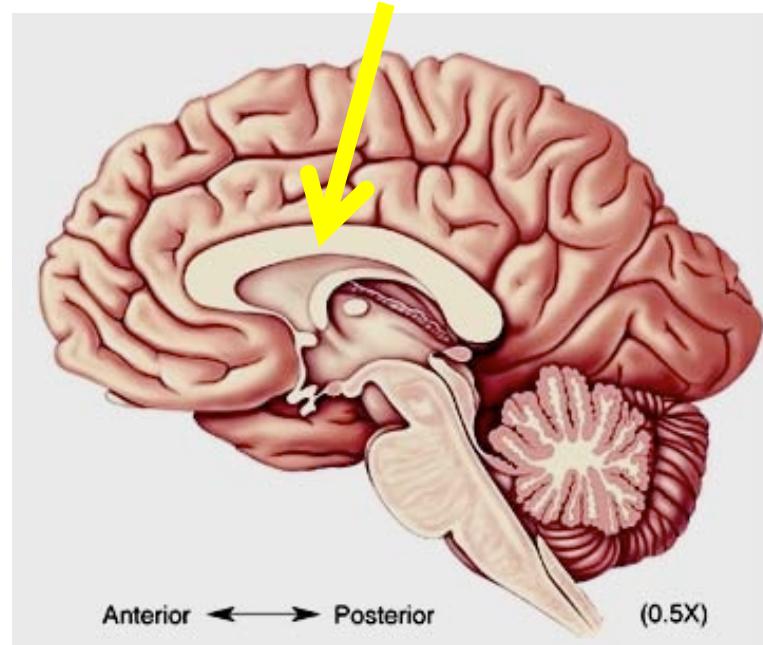
Anatomy of the Brain



Anatomy of the forebrain (continued)

Telencephalon –Cerebral cortex

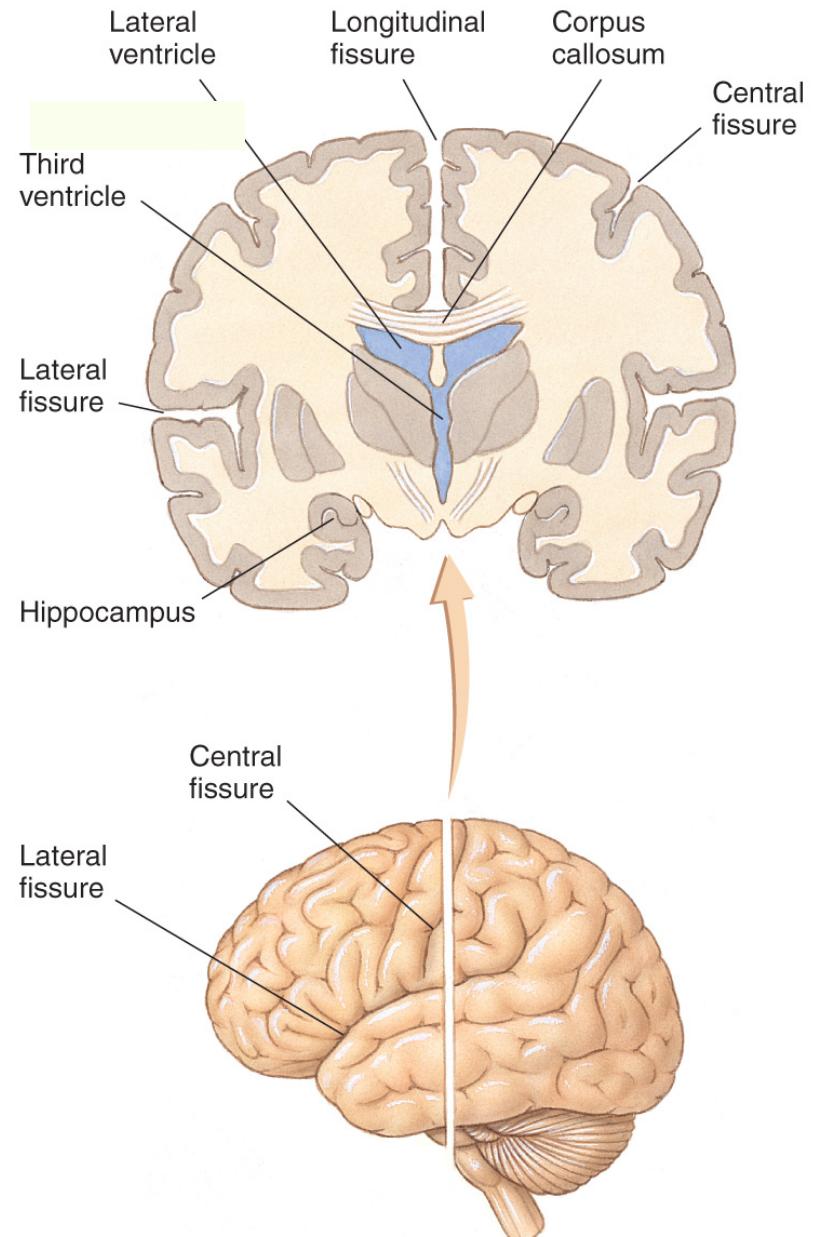
- Right and left cortical hemispheres separated by a crack called longitudinal fissure
- Two hemispheres connected by corpus callosum– largest hemisphere-connecting axon tract



Anatomy of the forebrain (continued)

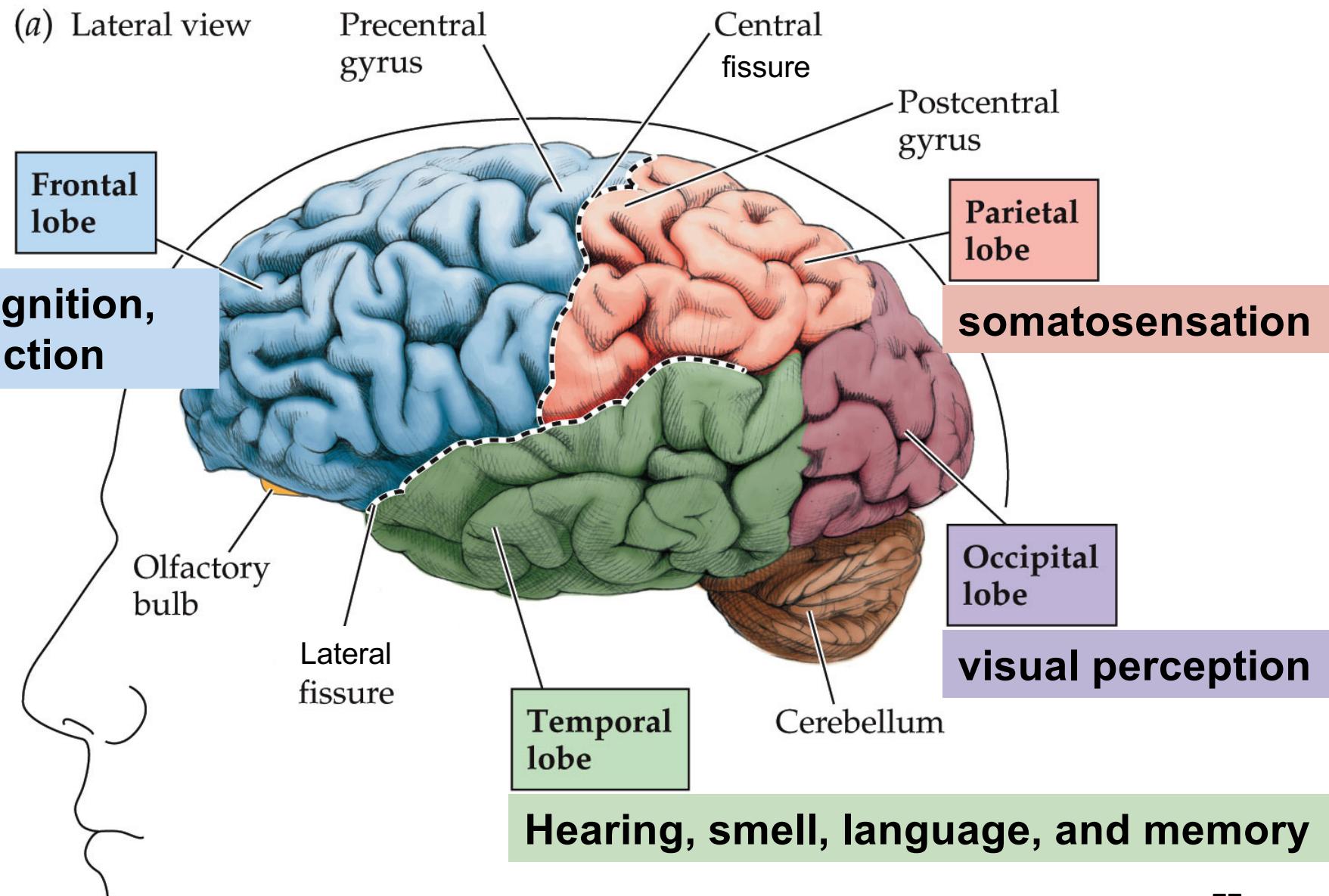
Key terminology for cortical structures

- **Fissure:** A deep crack (e.g., lateral fissure, longitudinal fissure).
- **Sulcus:** A shallow crack (e.g., central sulcus).
- **Gyrus:** A strip of cortex between two sulci (e.g., postcentral gyrus, cingulate gyrus).
- **Lobe:** A large subregion of cortex containing several gyri and sulci.
 - there are four lobes...

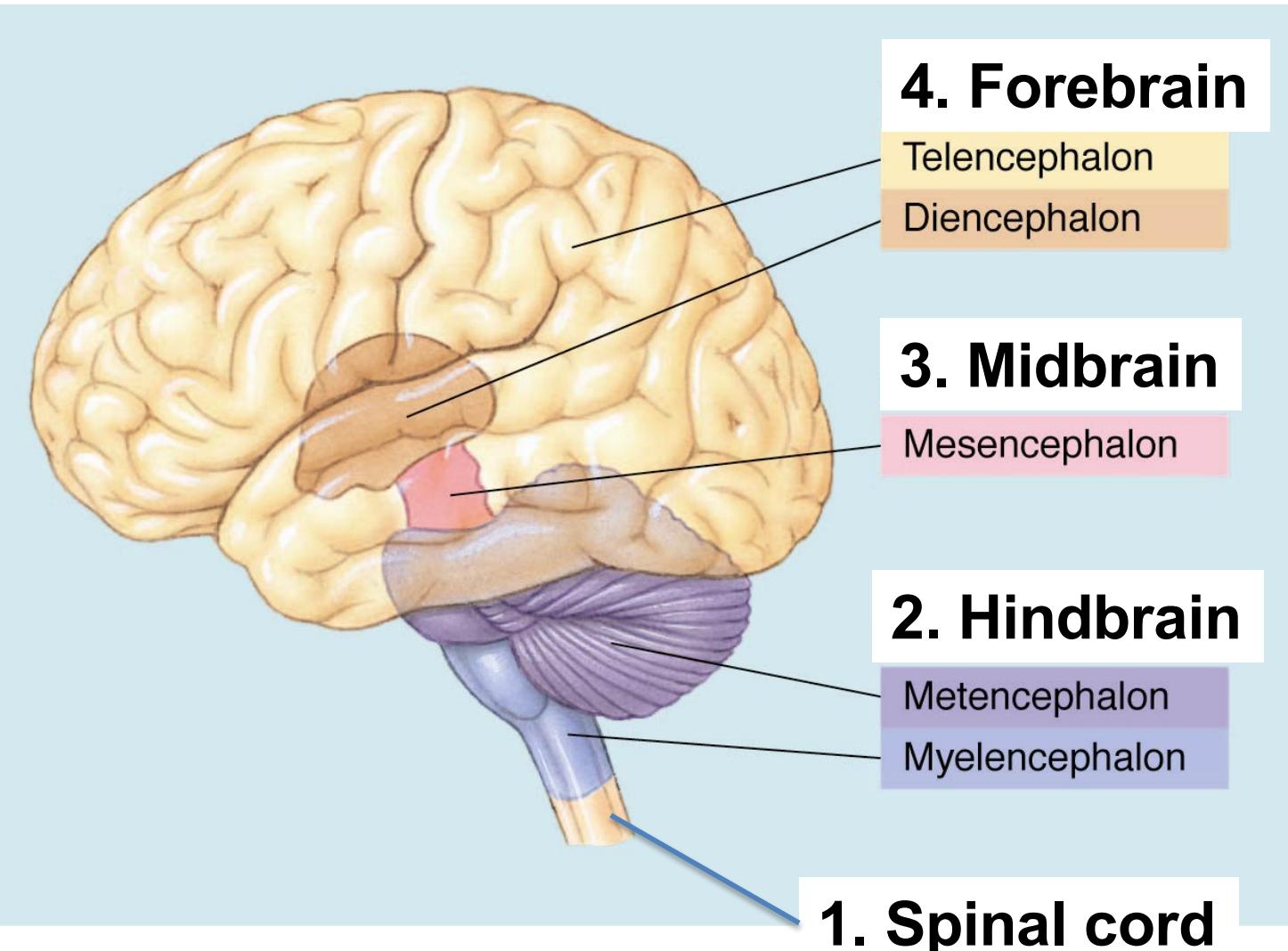


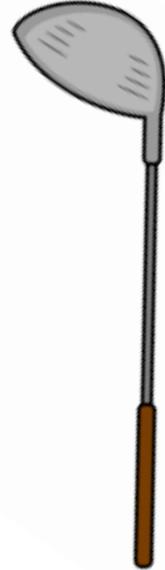
Anatomy of the forebrain (continued)

Major Divisions of the Brain: Lobes



Summary of major brain structures





+



Spinal cord
Hindbrain
Midbrain
Diencephalone

Telencephalone
(left and right hemisphere)

Today we have learned.....

- **General layout of the nervous system**
- **Structures protecting the nervous system**
- **Cellular components of the nervous system**
- **Anatomy of major structures of the nervous system**

Summary of major brain structures

(b) Organization of the adult human brain

