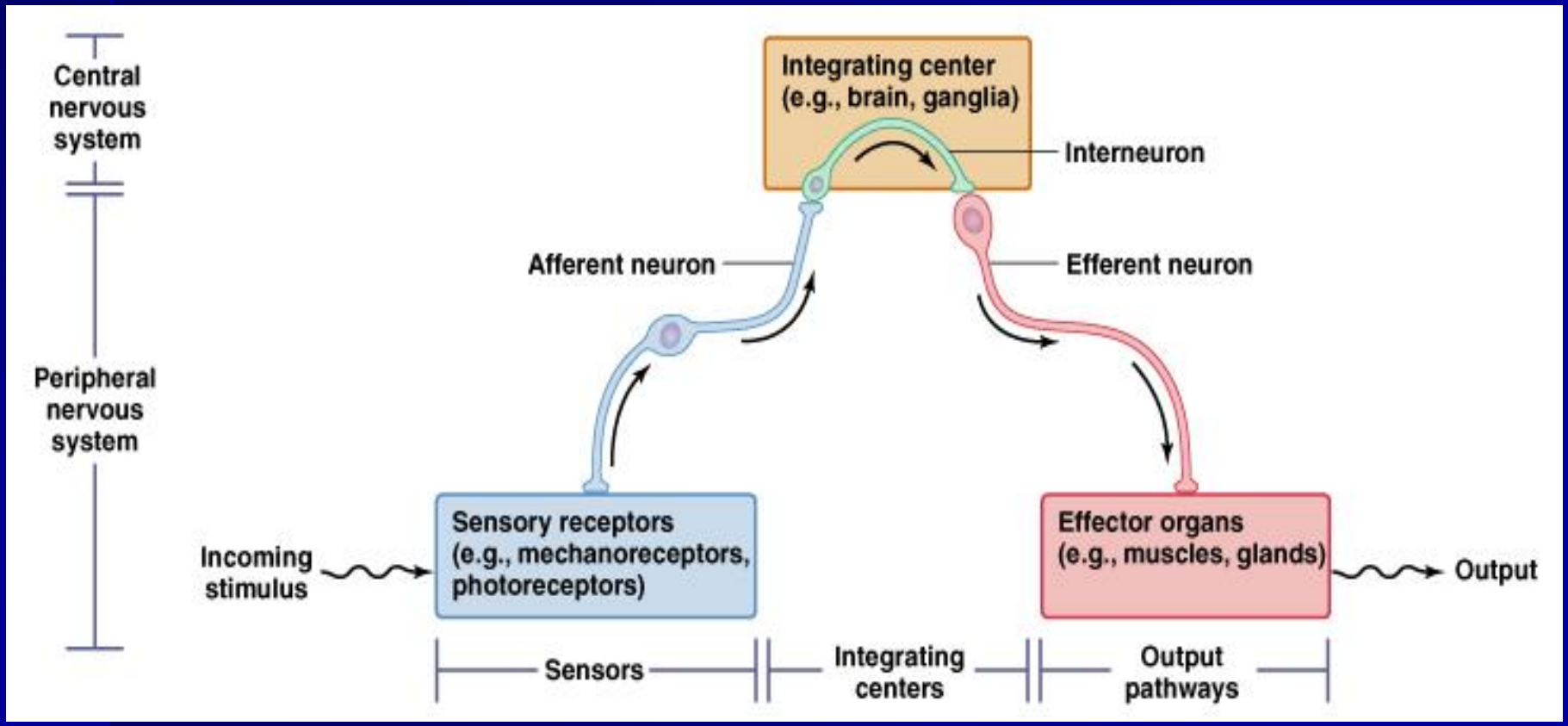
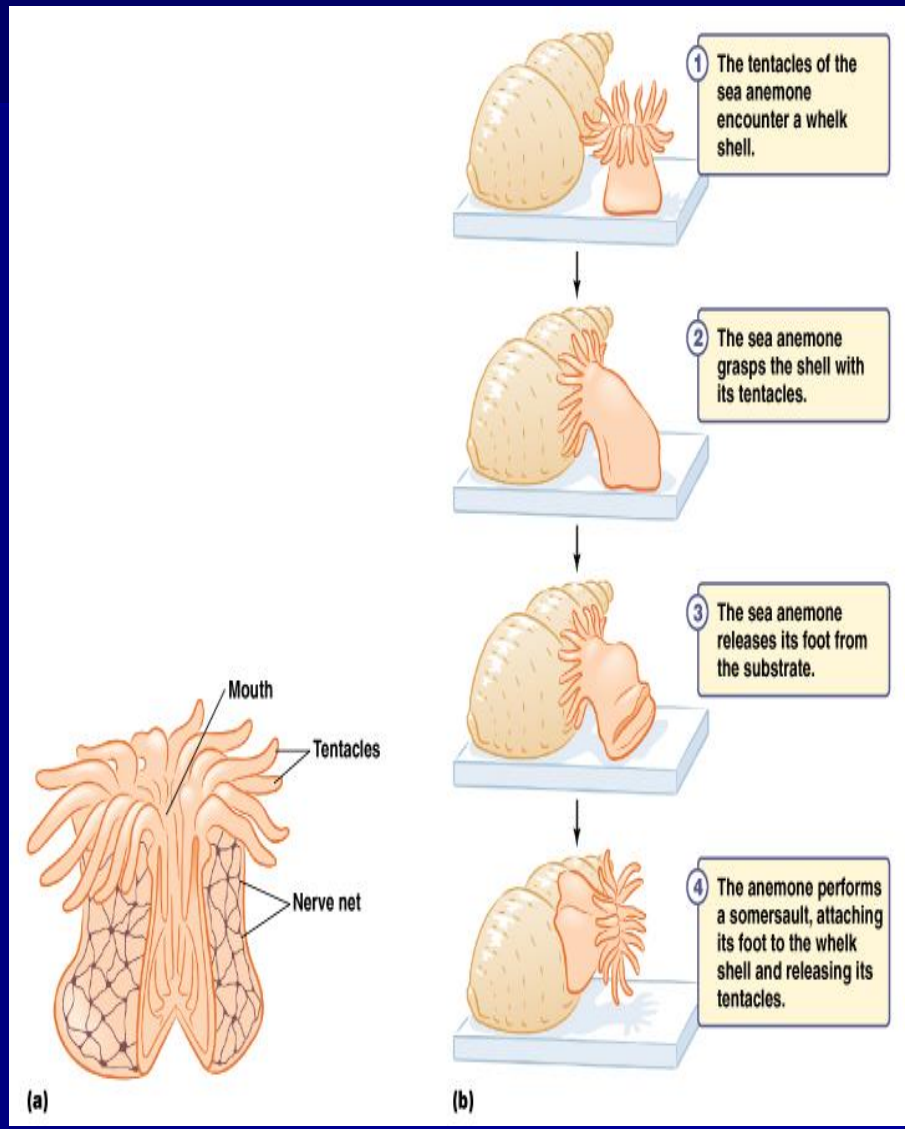
Overview of the Nervous System

- One of the body's homeostatic control systems
- Contains sensors, integrating centers, and output pathways
- More interneurons in a pathways → greater ability to integrate information



Cnidarians

- Most nervous systems are organized into three functional divisions
- Cnidarians are an exception
- Their nervous system is an interconnected web or *nerve net*
- Neurons are not specialized into different divisions
- Neurons are functionally bipolar and impulses radiate out from the stimulus
- Can still perform complex behaviors

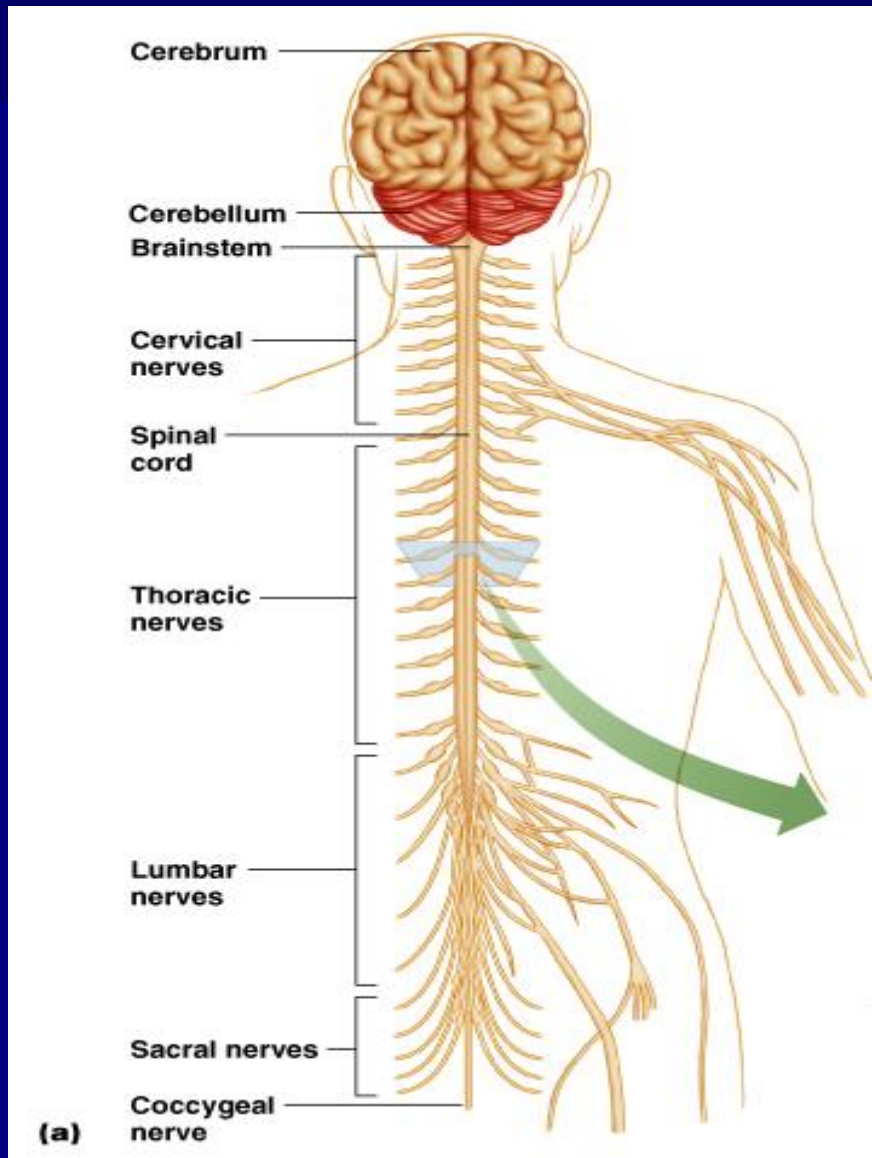


Nervous System Terms

- *Bilaterally symmetrical* – anterior and posterior end and a right and left side
- *Cephalization* - sense organs are concentrated at the anterior end
- *Brain* – a complex integrating center made up of clusters of *ganglia*
- *Ganglia* – groupings of neuronal cell bodies
- *Nuclei* – groupings or neuronal cell bodies within the brain
- *Tracts* – groupings of axons within the brain
- *Nerves* – axons of afferent and efferent neurons

The Vertebrate Central Nervous System

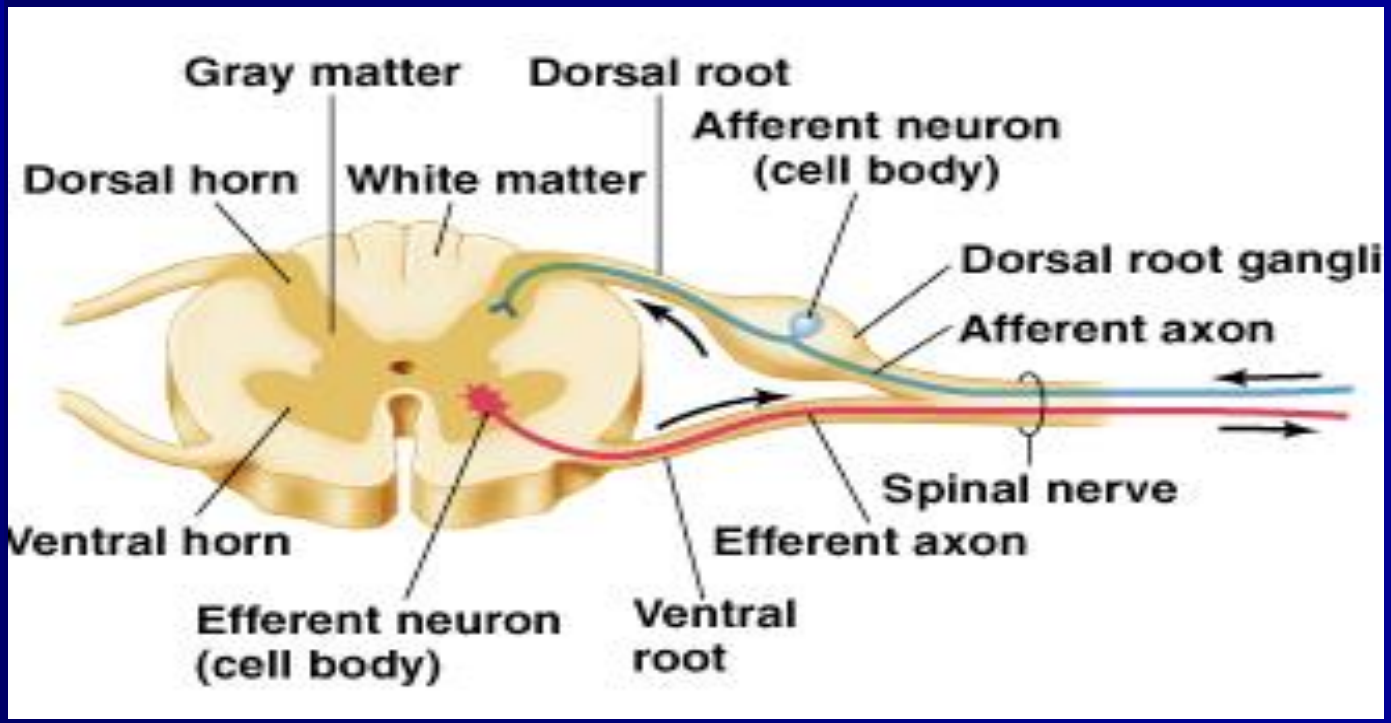
- Among the most highly *cephalized* animals
- Unique in having a hollow dorsal nerve cord
- Portion of nervous system is encased within cartilage or bone
- *Central nervous system (CNS)* – brain and spinal cord
- *Peripheral nervous system* (PNS) – rest of the nervous system



Cranial and Spinal Nerves

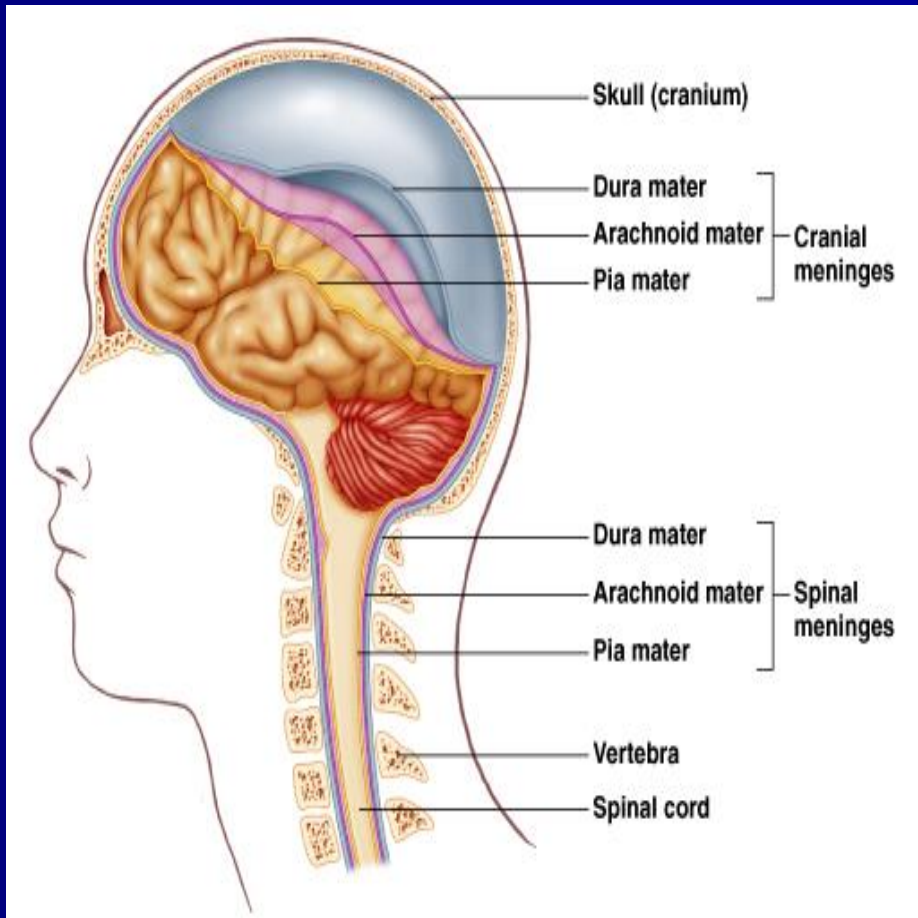
- Cranial nerves
  - Exit directly from the braincase
  - 12 pairs (labeled with roman numerals)
  - Some are afferent and some are efferent
- Spinal nerves
  - Emerge from the spinal cord
  - Named based on the region of the spine where they originate

- Brain and spinal cord contain two types of tissue
  - Gray matter – neuronal cell bodies
  - White matter – bundles of axons and their myelin sheaths
- Spinal chord white matter is on the surface and gray matter is inside (opposite for cerebral cortex)



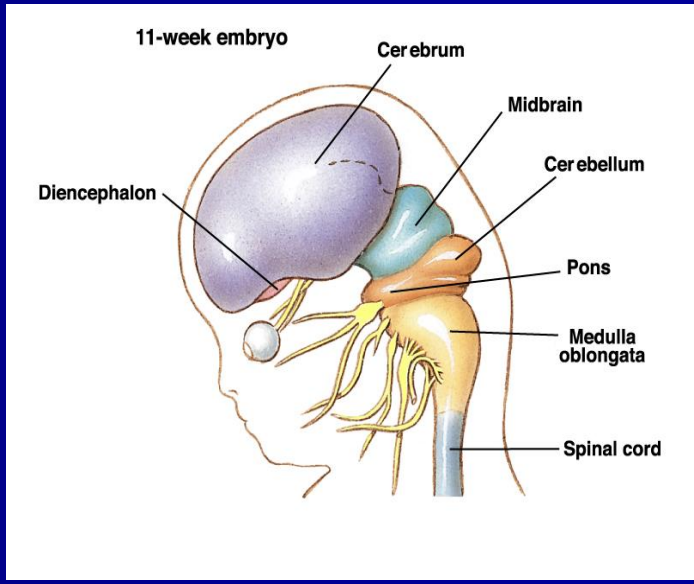
The CNS is Isolated

- *Meninges* – layers of connective tissue that surround the brain and spinal cord
- Number of layers vary across taxa (fish have one, mammals have three)
- *Cerebral spinal fluid (CSF)* fills the space within the meninges and acts as a shock absorber
- *Blood-brain barrier* – tight junctions in brain capillaries prevent material from leaking out of the bloodstream and into the CNS



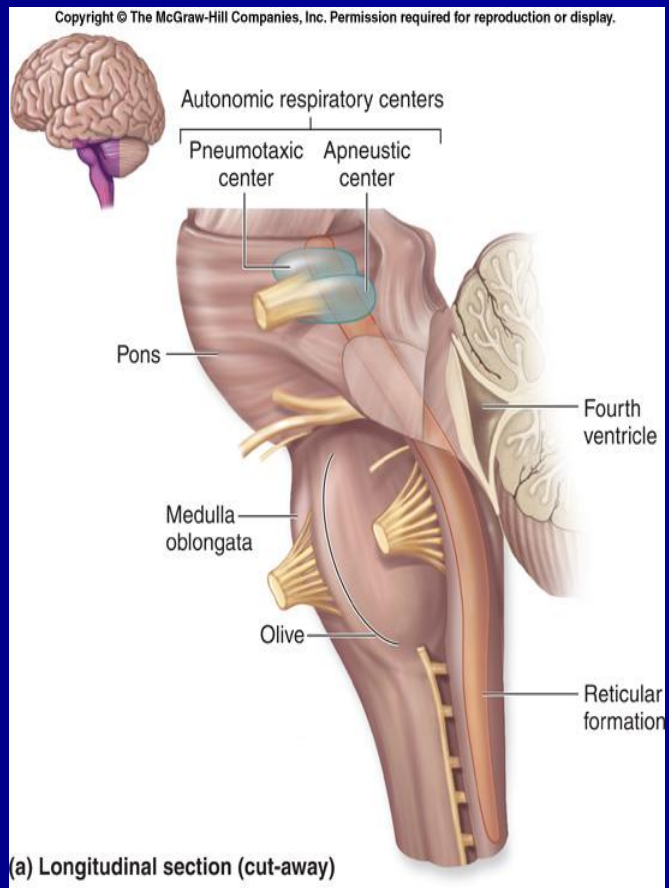
The Vertebrate Brain

- The brain is an extension of the spinal cord
- It is hollow inside and central cavities called *ventricles* contains CSF
- Three main regions
  - Rhombencephalon (hindbrain)
    - Reflexes and involuntary behaviors
  - Mesencephalon (midbrain)
    - Coordination of sensory information
    - Relay center in mammals
  - Prosencephalon (forebrain)
    - Integration of olfactory information with other senses
    - Regulation of body temperature, reproduction, eating, emotion
    - Learning and memory in mammals



Hindbrain

- Three regions
- *Pons* – located above the medulla
  - Pathway between the medulla, the cerebellum, and the forebrain
  - Controls alertness and initiates sleep and dreaming
- *Cerebellum* – two hemispheres at the back of the brain
  - Responsible for motor coordination
  - Contains half of the neurons in the brain
- *Medulla oblongata* – located at the top of the spinal cord
  - Regulates breathing, heart rate, diameter of blood vessels, and blood pressure
  - Contain pathways between the spinal cord and the brain
  - Many cross over (e.g., left to right)



Midbrain

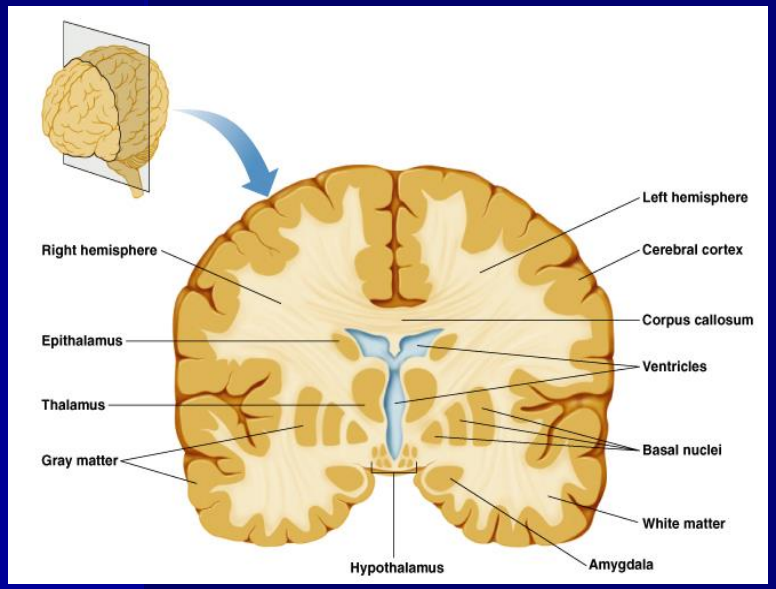
- Primary center for coordinating and initiating behavioral responses in fish and amphibians
- Size and function reduced in mammals
  - Primarily serves as a relay center
- Sometimes grouped with the pons and medulla and termed the *brainstem*

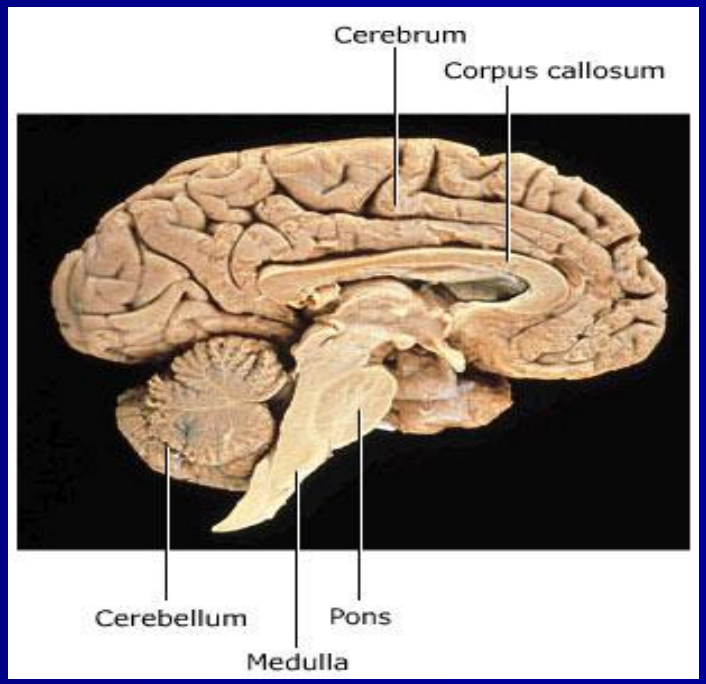
Forebrain

- Involved in processing and integrating sensory information, and in coordinating behavior
- Main regions
  - Cerebrum
  - Thalamus
  - Epithalamus
  - Hypothalamus

Cerebrum

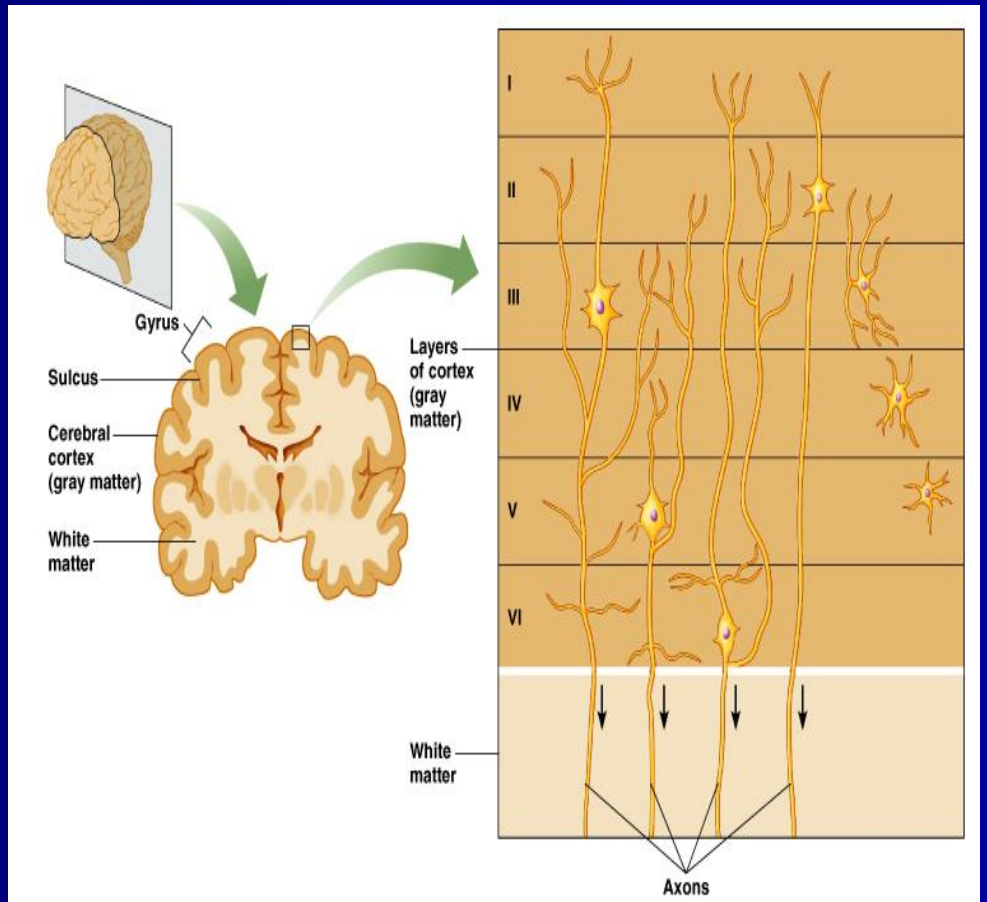
- Outer layer is the cortex
- Divided into two cerebral hemispheres
  - Left side controls the right side of the body
  - Right side controls the left side of the body
- Connected by the *corpus callosum*





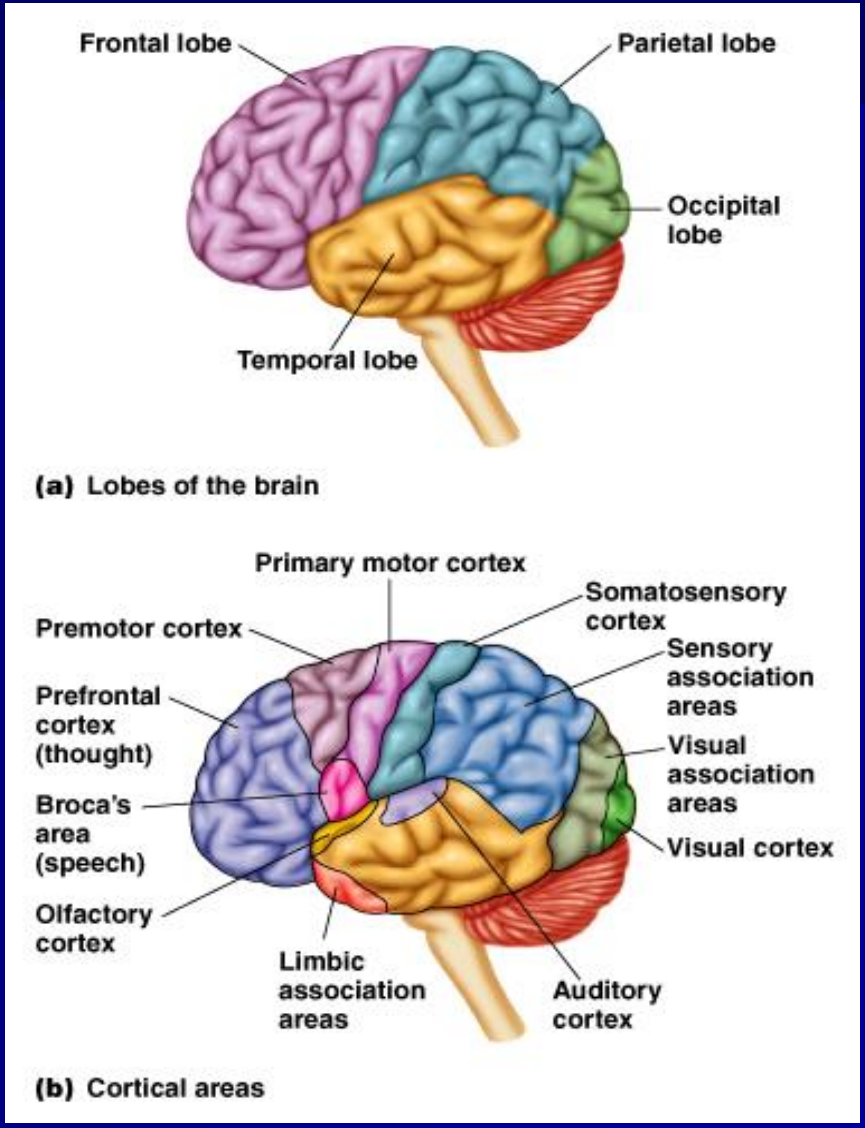
Cortex

- Integrates and interprets sensory information and initiates voluntary movements
- Has taken over many of the midbrain functions in lower vertebrates
- Six layers
- Isocortex (outer layer) is necessary for cognition and higher brain functions
  - More folded in more advanced mammals
  - *Gyri* – folds
  - *Sulci* – grooves



Cortical Lobes

- Based on the names of the overlying bones or function

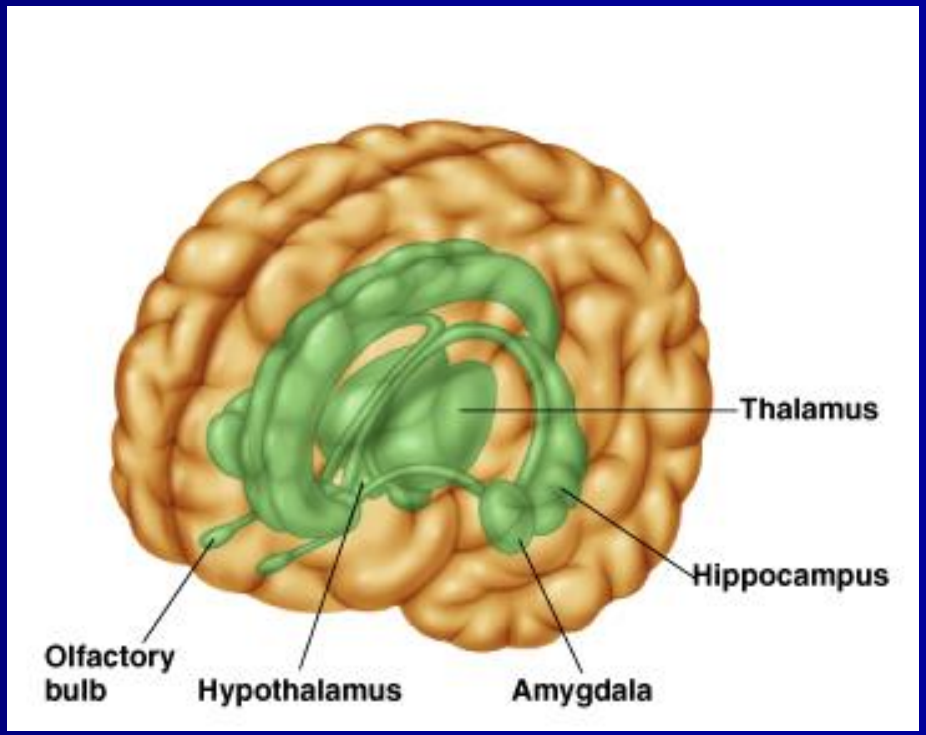


Hypothalamus

- Located at the base of the forebrain
- Maintains homeostasis
- Interacts with the autonomic nervous system
- Regulates secretion of pituitary hormones

Limbic System

- A network of connected structures that lie between the cortex and the rest of the brain
- Influences emotions, motivation, and memory
- Sometimes called the "*emotional brain*"
- Includes the hypothalamus and other parts
  - *Amygdala* – aggression and fear responses
  - *Hippocampus* – converts short-term memory to long-term memory
  - *Olfactory bulbs* – sense of smell



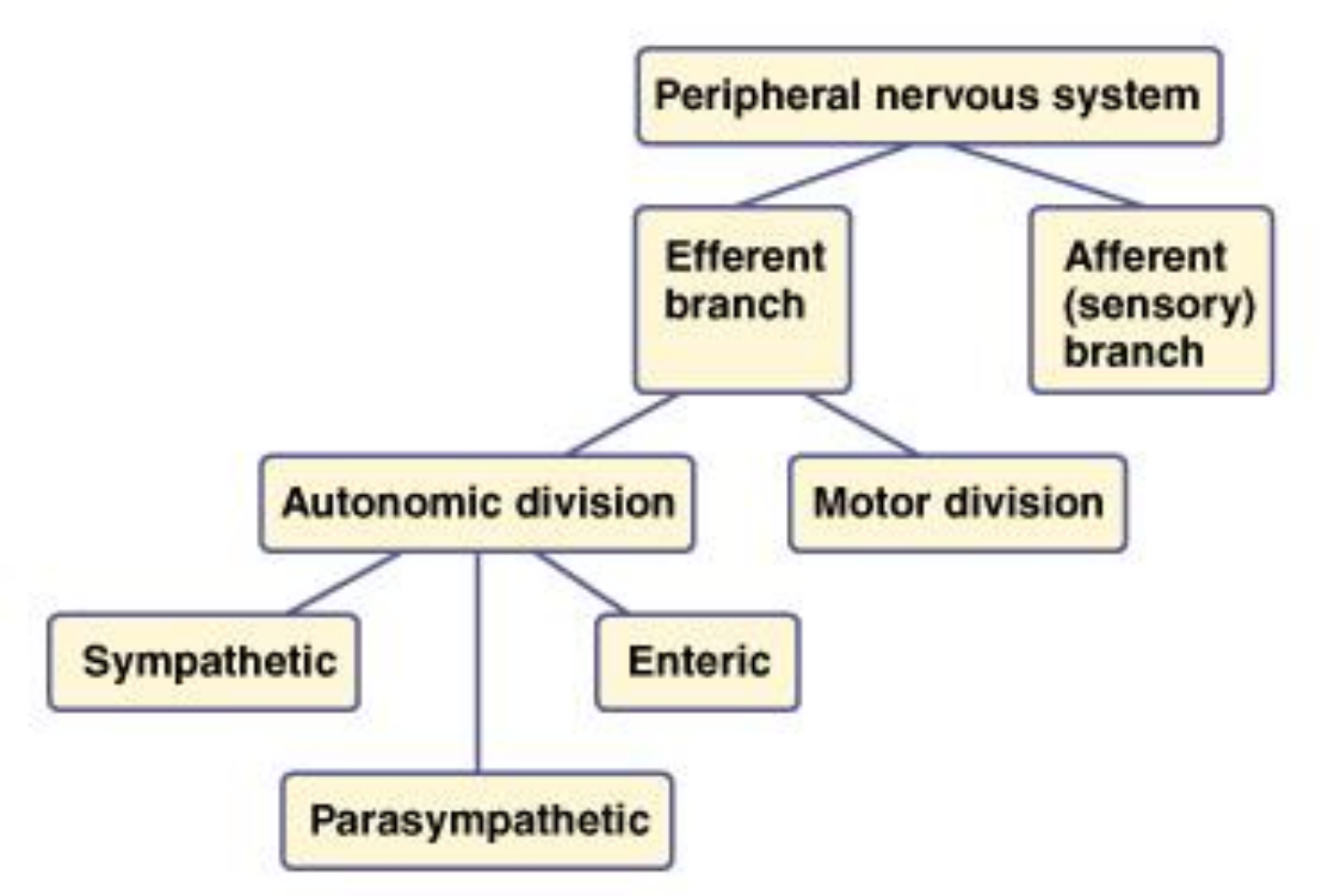
Thalamus

- Large grouping of gray matter above the hypothalamus
- Part of the *reticular formation*
- Receives input from the limbic system and all senses except olfaction
- Relays information to the cortex
- Acts as a filter

Epithalamus

- Located above the thalamus
- Contains
  - *Habenular nuclei* – communicates with the tegmentum of the midbrain
  - *Pineal complex* – Establishes *circadian rhythms* and secretes *melatonin*

Peripheral Nervous System Divisions



Autonomic Pathways

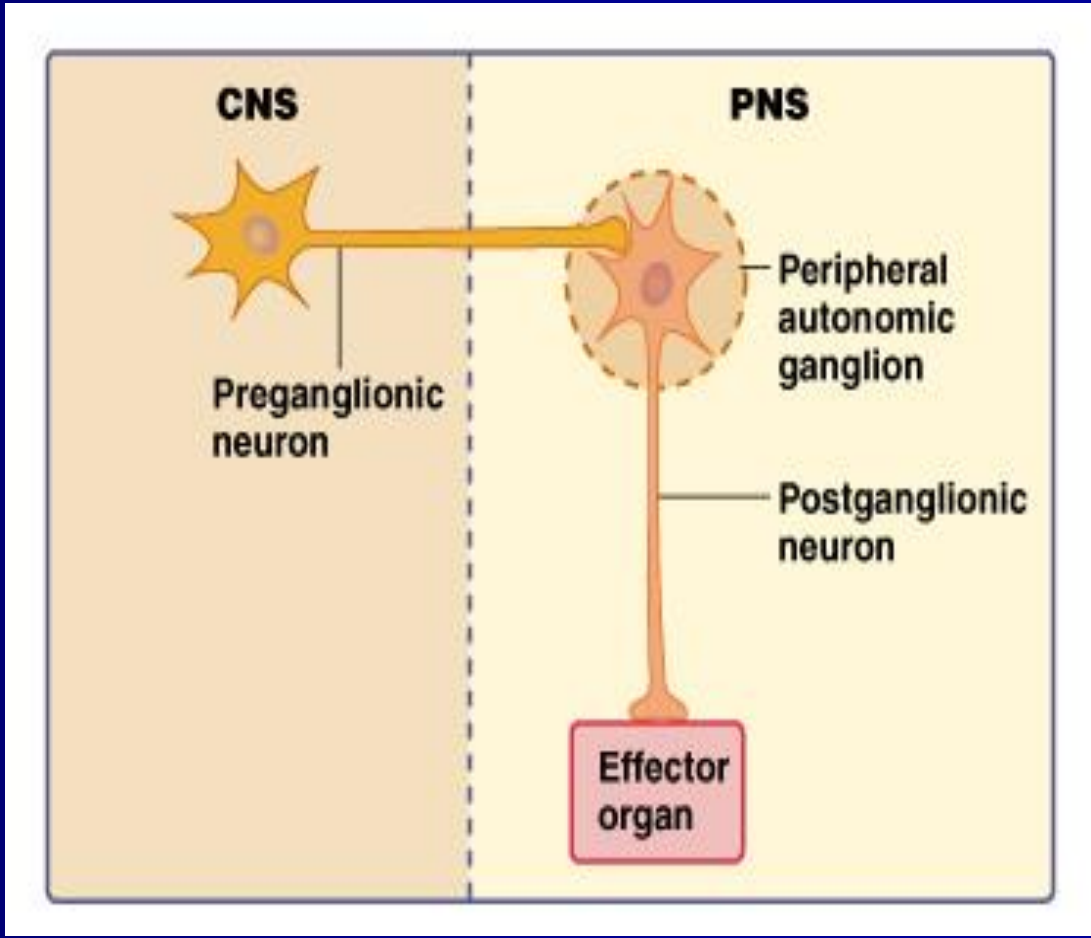
- Involved in homeostasis
- "*Involuntary nervous system*"
- Systems
- Sympathetic
  - Most active during periods of stress or physical activity
  - "Fight-or-flight" system
- Parasympathetic
  - Most active during periods of rest
  - "Resting and digesting" system
- Enteric
  - Independent of other two systems
  - Affects digestion by innervating the GI tract, pancreas, and gall bladder

Maintaining Homeostasis

- Balancing of the sympathetic and parasympathetic systems
- Three features of maintaining homeostasis
  - *Dual innervation* – most internal organs receive input from both systems
  - *Antagonistic action* – one system stimulates while the other inhibits
  - *Basal tone* – Even under resting conditions autonomic neurons produce APs

Similarities in Autonomic Pathways

- Pathways contain two neurons in series
  - *Preganglionic* – may synapse with many postganglionic neurons and *intrinsic* neurons
  - *Postganglionic* – release neurotransmitter at the effector from *varicosities*
- These neurons synapse with each other in the *autonomic ganglia*

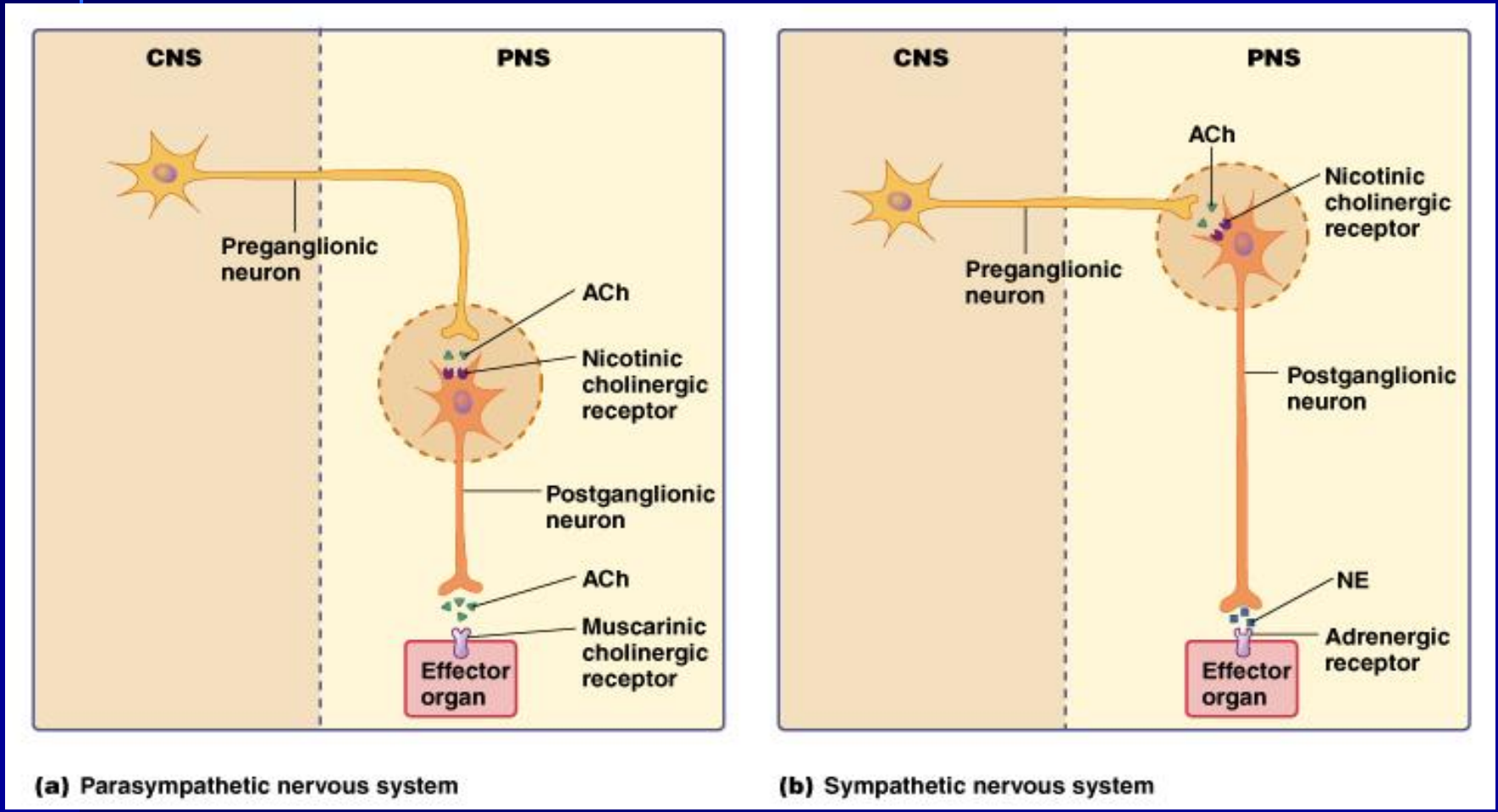


Differences in Autonomic Pathways

- Differences between the sympathetic (S) and parasympathetic (PS) branches
  - Preganglionic cell body location
    - S: thoracic and lumbar regions of the spinal cord
    - PS: hindbrain and sacral region of the spinal cord
  - Ganglia location
    - S: chain that runs close to the spinal cord
    - PS: close to the effector
  - Number of postganglionic neurons that synapse with a single preganglionic neuron
    - S: 10 or more
    - P: three or less

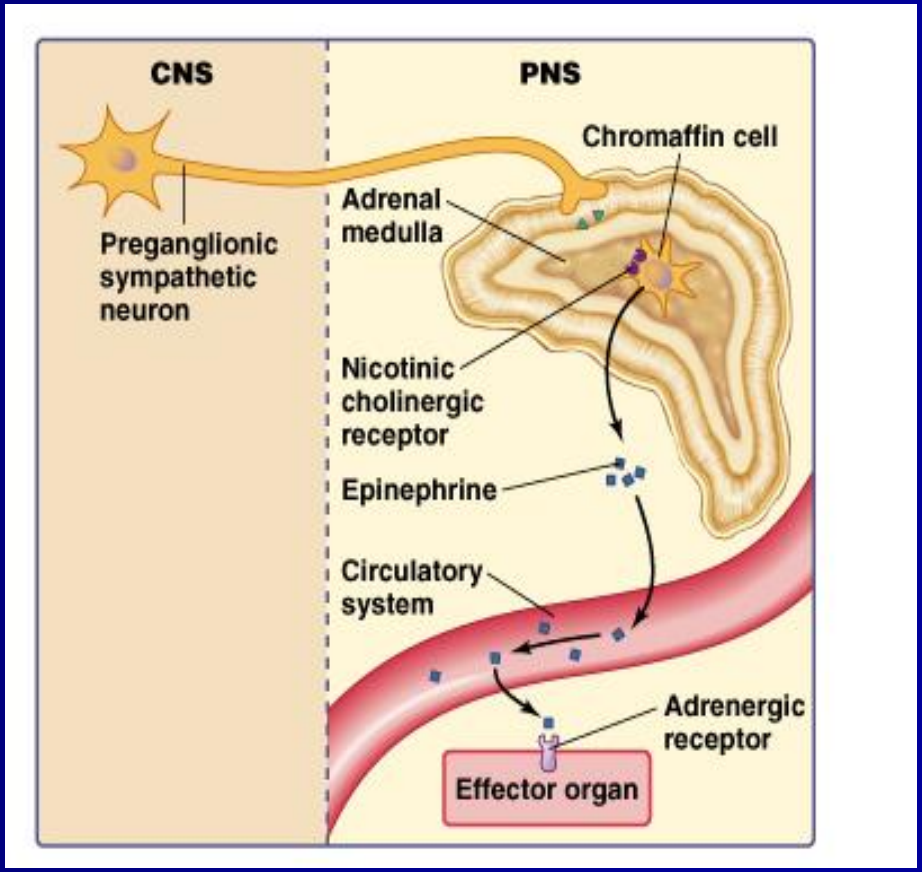
Differences in Autonomic Pathways

- Type of neurotransmitter released at the effector



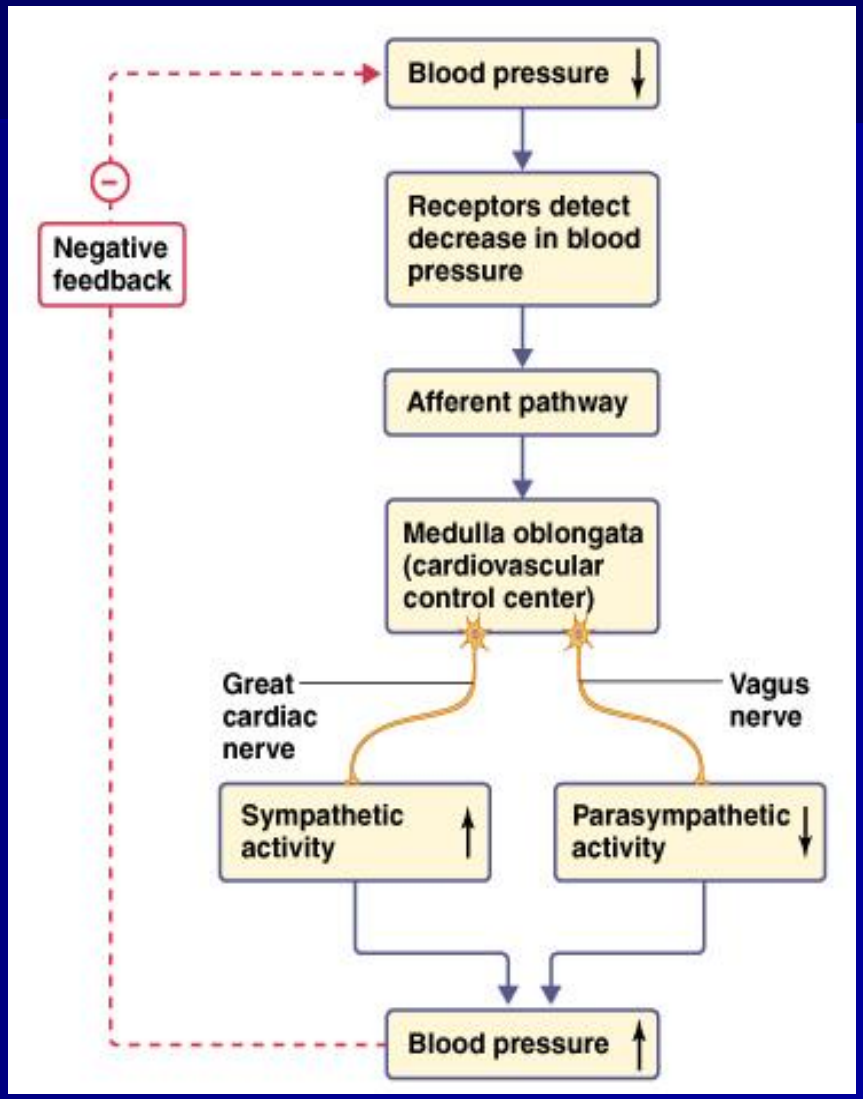
Only Sympathetic Innervation

- Some effectors receive only sympathetic innervation
  - Adrenal medulla – modified postganglionic neuron
  - Sweat glands
  - Arrector pili muscles in the skin
  - Kidneys
  - Most blood vessels



Reflex Arcs

- Most autonomic changes occur via simple neural circuits that do not involve conscious centers of the brain



Somatic Motor Pathways

- Control skeletal muscle
- Usually under conscious control
- The "*Voluntary nervous system*"
- Some pathways are not under conscious control, e.g., *knee-jerk* reflex

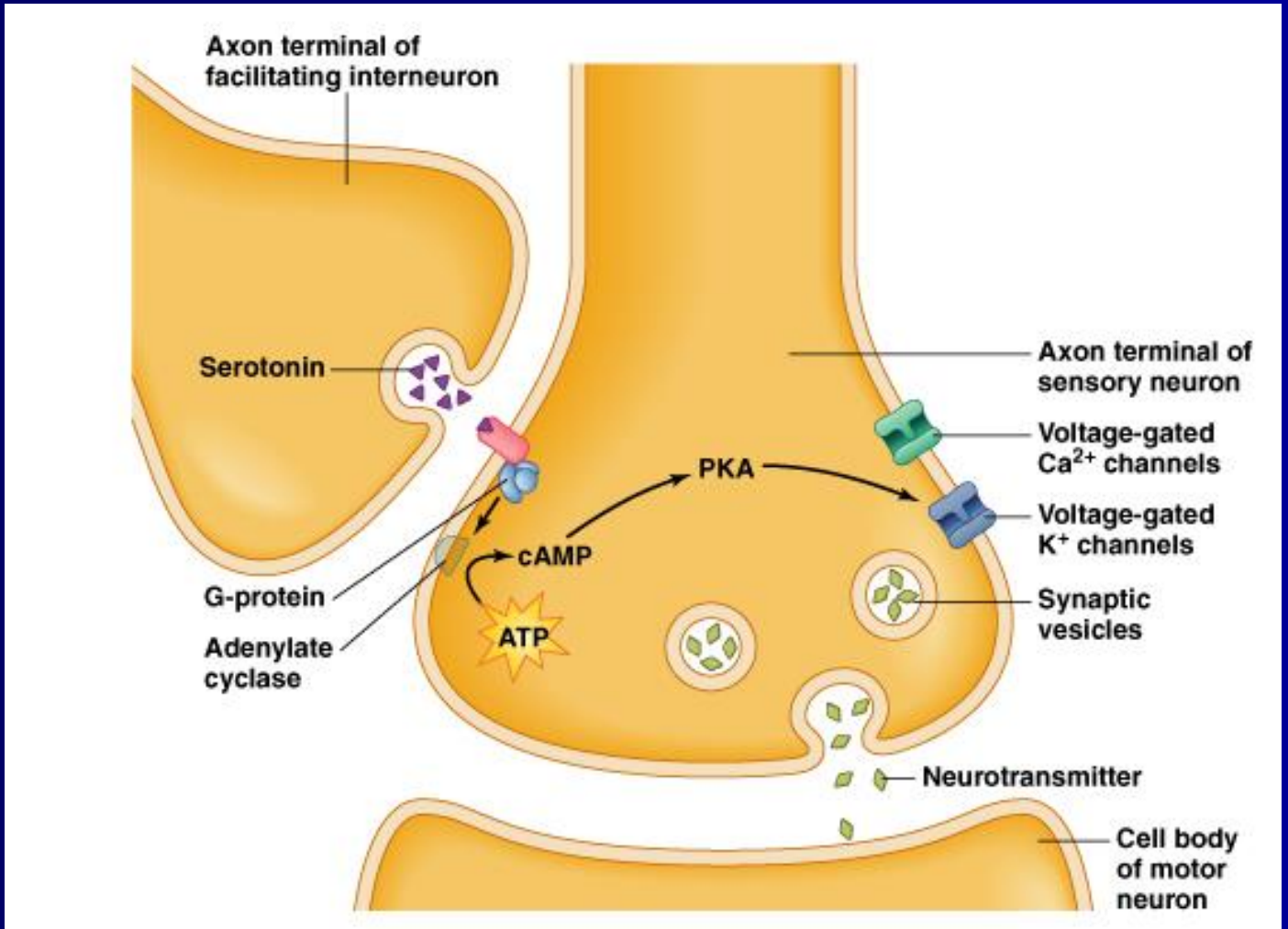
Somatic Pathway Characteristics

- Control only one type of effector, skeletal muscle
- Cell bodies are located in the CNS
- Monosynaptic, therefore very long
- Axons split into a cluster of axon terminals at the neuromuscular junction
- Synaptic cleft between the motor neuron and the muscle is very narrow
- Release the neurotransmitter *acetylcholine*
- Effect on the muscle is always excitatory

Learning and Memory

- Most animals can form memories and learn due to the *plasticity* of the nervous system
- *Learning* – process of acquiring new information
- *Memory* – retention and retrieval of information
- *Plasticity* – ability to change both synaptic connections and functional properties of neurons in response to stimuli

Serotonin Effects



Memory in Mammals

- The hippocampus is involved in long-term memory, but the memories are stored elsewhere
- *Long-term potentiation* – repetitive stimulation of hippocampal tissue leads to an increase in the response of the postsynaptic neuron