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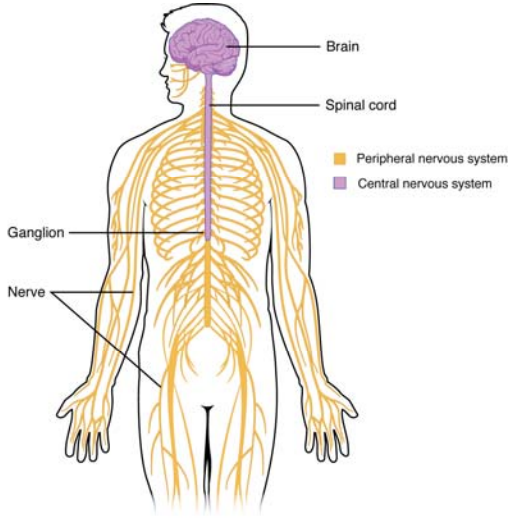
The nervous system

Functions of the Nervous System: The nervous system is composed of three major parts the sensory input portion, the central nervous system (or integrative portion), and the motor out put portion.

- **Sensory Input :** Sensory receptors throughout the body collect information from both the external environment and internal organs, sending it to the central nervous system (CNS).
- **Integration (Processing):** The brain and spinal cord process this information and interpret it and make necessary actions.
- **Motor Output (Response):** The system sends signals to muscles, glands, and organs to initiate movements, adjustments, or hormonal release.



Anatomically the nervous system has two divisions:

- **The central nervous system (CNS):** consists of the brain and spinal cord.
- **The peripheral nervous system (PNS):** consists of cranial nerves and spinal nerves.

- The nervous system consists of a vast number of cells called **neurons** , supported by a special type of connective tissue, neuroglia.
- Each neuron consists of a cell body and its processes, one axon and many dendrites.
- Neurons are commonly referred to simply as nerve cells.
- Bundles of axons bound together are called nerves.
- Neurons cannot divide and for survival they need a continuous supply of oxygen and glucose. Unlike many other cells, neurons can synthesis chemical energy (ATP) only from glucose.

Parts of the neuron:

- **The cell body (soma):** contains the nucleus and is essential for the continued life of the neuron. neuron cell bodies are found in the central nervous system (brain and spinal cord) or close to it in the trunk of the body (trunk ganglia). In these locations, cell bodies are protected by bones. There are no cell bodies in the arms and legs, which are much more subject to injury.

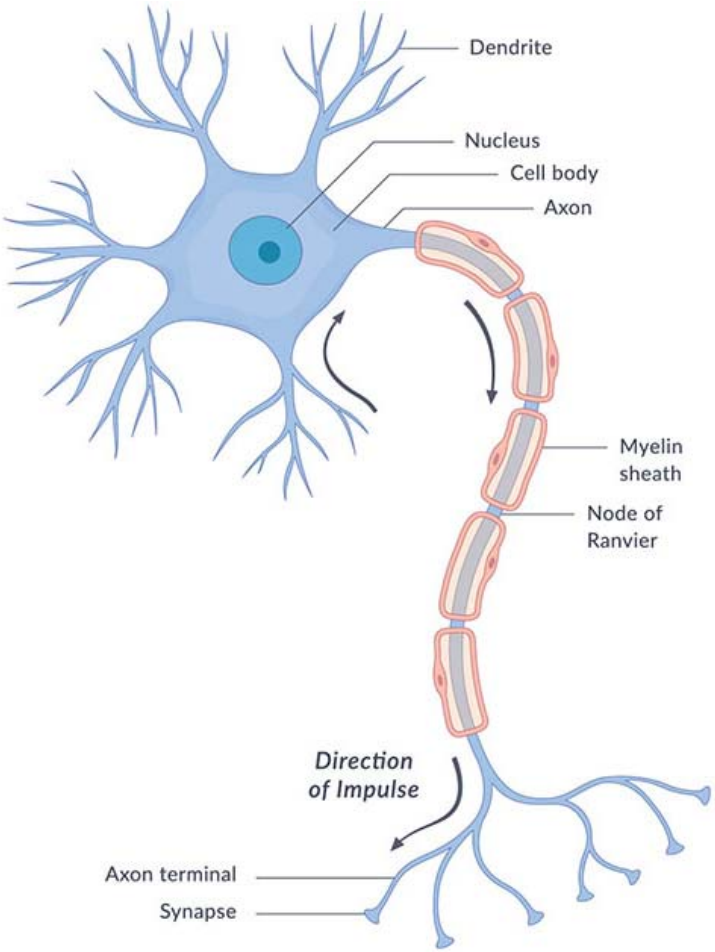
- **Dendrites** are processes (extensions) that transmit impulses toward the cell body.

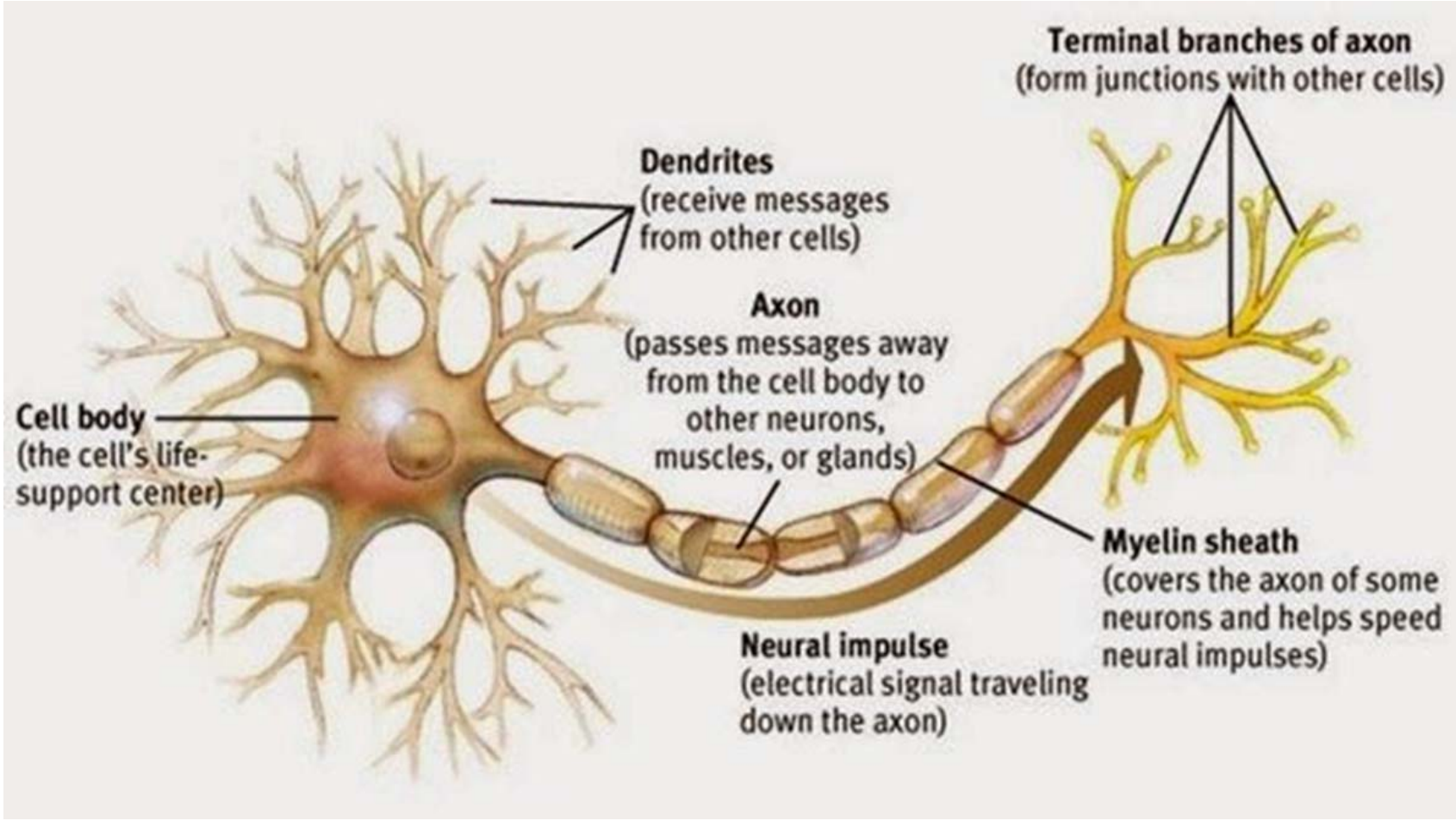
- **The one axon:** transmits impulses away from the cell body.

- In the peripheral nervous system, axons are "wrapped" in specialized cells called **Schwann cells** , enclosing in several layers of Schwann cell membrane. These layers are the **myelin sheath**;

- **Myelin** is a phospholipid that electrically insulates neurons from one another, and fast conduction of nerve impulses..

- The spaces between adjacent Schwann cells, or segments of the myelin sheath, are called **nodes of Ranvier**. These nodes which assist the rapid transmission of nerve impulses.

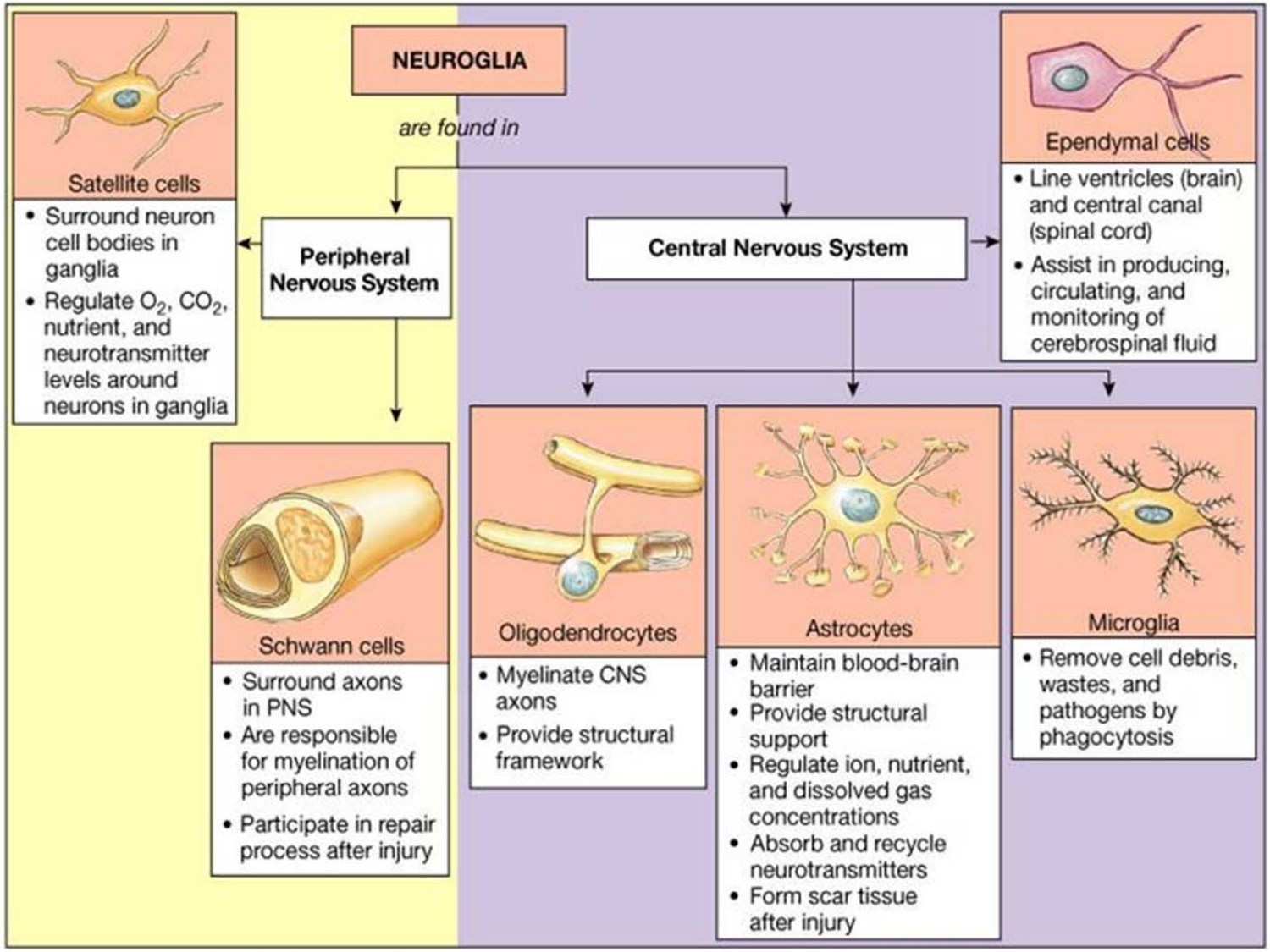



Terminal branches of axon
(form junctions with other cells)
Dendrites
(receive messages
from other cells)
Axon
(passes messages away
from the cell body to
other neurons,
muscles, or glands)
Cell body
(the cell's life-
support center)
Myelin sheath
(covers the axon of some
neurons and helps speed
neural impulses)
Neural impulse
(electrical signal traveling
down the axon)

- The neurons of the central nervous system are supported by four types of non-excitable glial cells that make up a quarter to a half of the volume of brain tissue. Unlike nerve cells these continue to replicate throughout life.

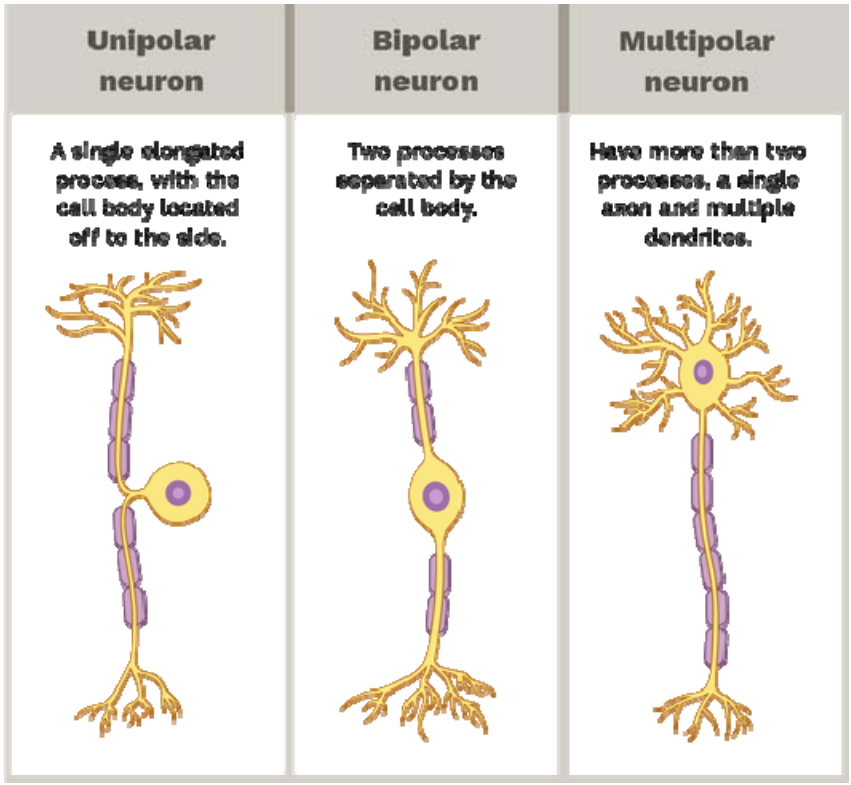
- Glial cells do not conduct electrical impulses, but they support, nourish, protect, and insulate neurons. In fact, glial cells outnumber neurons in many parts of the nervous system and participate in development, maintenance and repair.

- They are astrocytes, oligodendrocytes, microglia and ependymal cells.



Structural classification of neurons:

- Is based upon the number of processes that extend out from the cell body. Three major groups arise from this classification: **multipolar**, **bipolar,** and **unipolar** neurons.
- **Multipolar neurons:** are defined as having three or more processes that extend out from the cell body.
- **Bipolar neurons:** have only two processes that extend in opposite directions from the cell body. they are found in sensory organs like the retina
- **Unipolar neurons:** have a single, short process that extends from the cell body and then branches into two more processes that extend in opposite directions



Neurons are functionally classified into three main types based on the direction they transmit impulses relative to the central nervous system (CNS):

1. **Sensory neurons or (afferent neurons):**
- Carry impulses from receptors to the central nervous system. Receptors detect external or internal changes and send the information to the CNS in the form of impulses by way of the afferent neurons.
- The central nervous system interprets these impulses as a sensation.

2. **Motor neurons or (efferent neurons):**
- Carry impulses from the central nervous system to effectors.
- The two types of effectors are muscles and glands.
- In response to impulses, muscles contract or relax and glands secrete.

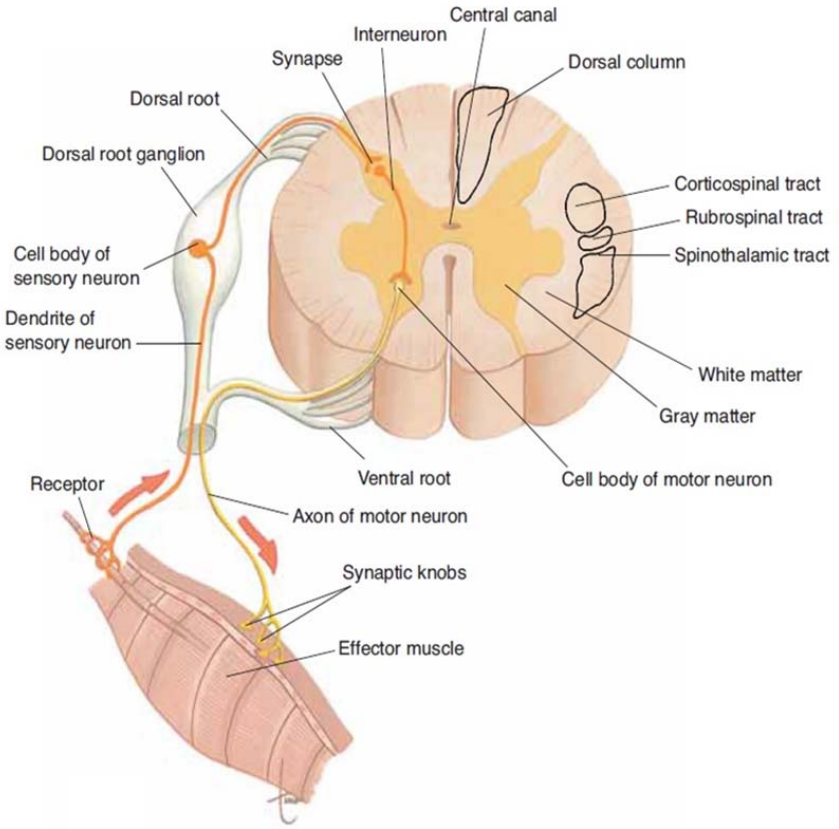
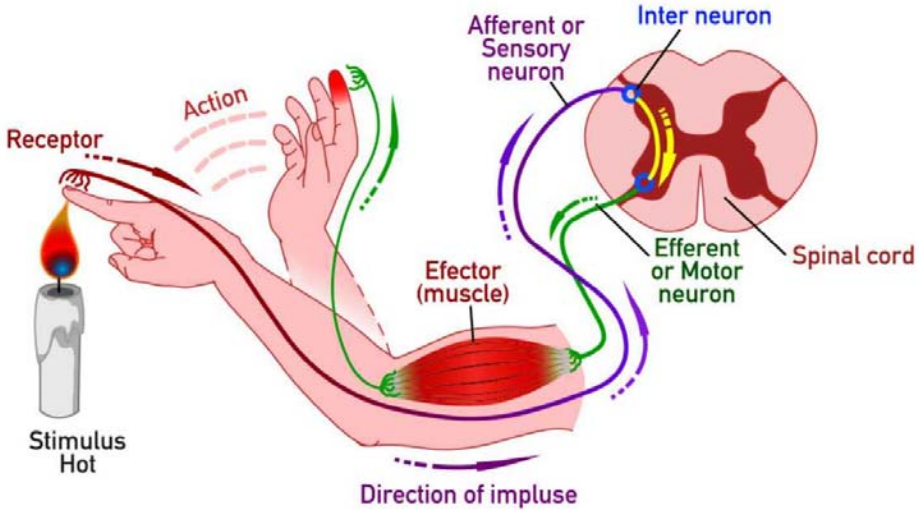
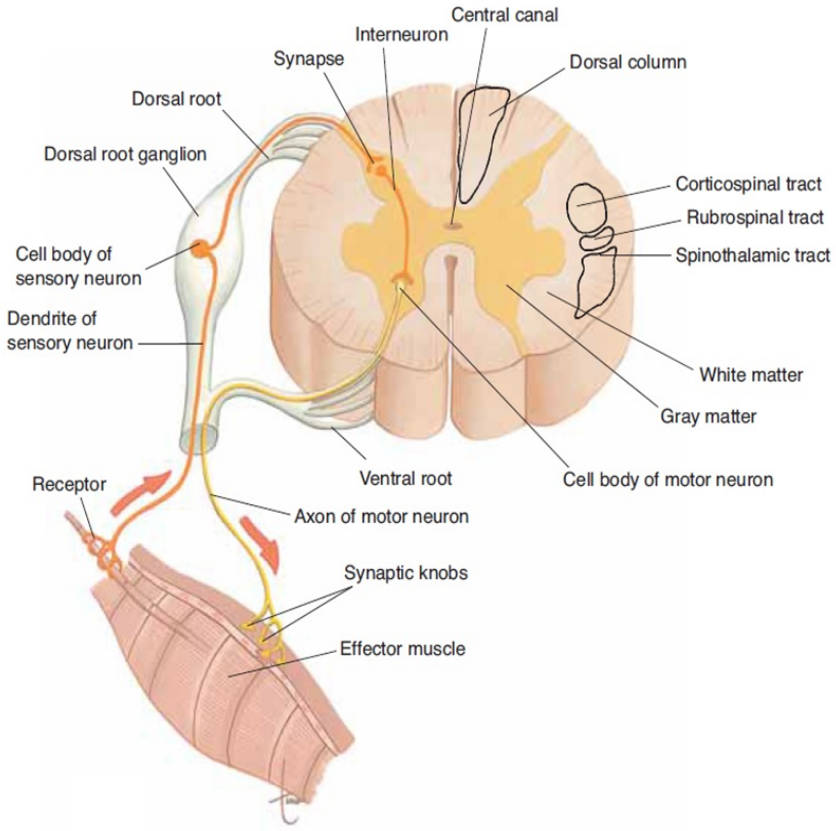


Figure 8–3. Cross-section of the spinal cord and the three types of neurons. Spinal nerve roots and their neurons are shown on the left side. Spinal nerve tracts are shown in the white matter on the right side. All tracts and nerves are bilateral (both sides).

3. Interneurons

Interneurons are neural intermediaries found in brain and spinal cord. They pass signals from sensory neurons and other interneurons to motor neurons and other interneurons. Often, they form complex circuits that help to react to external stimuli.





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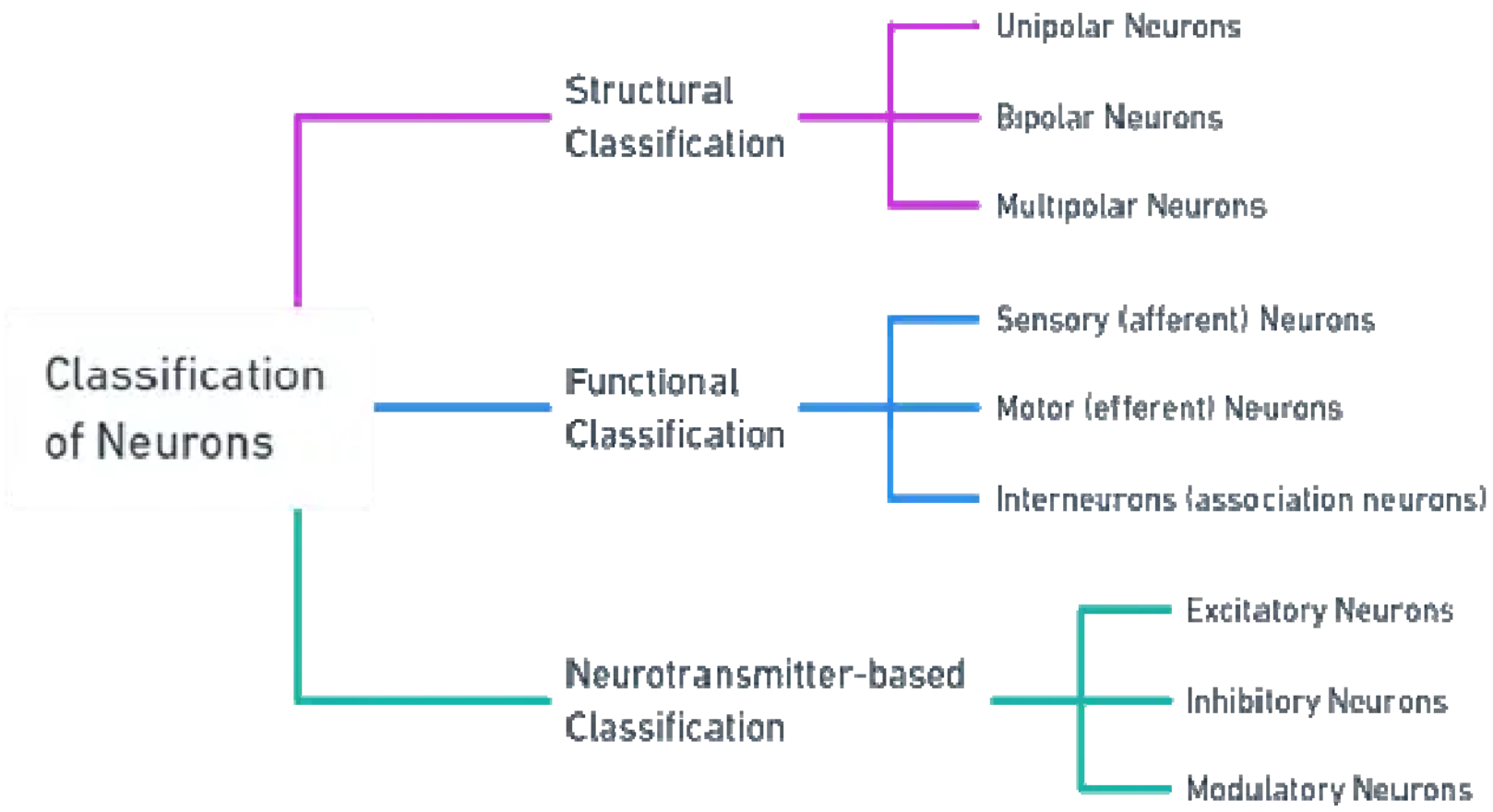
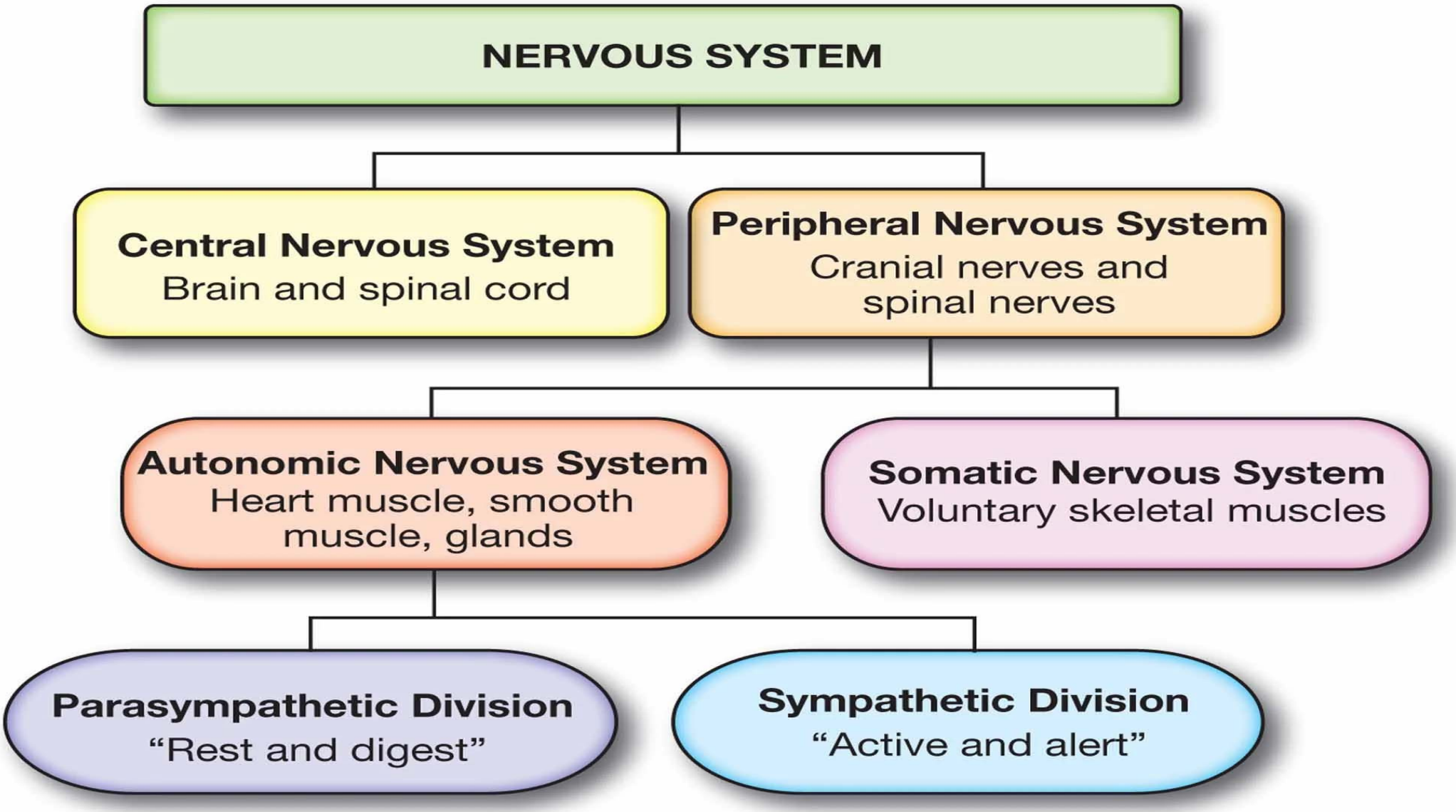
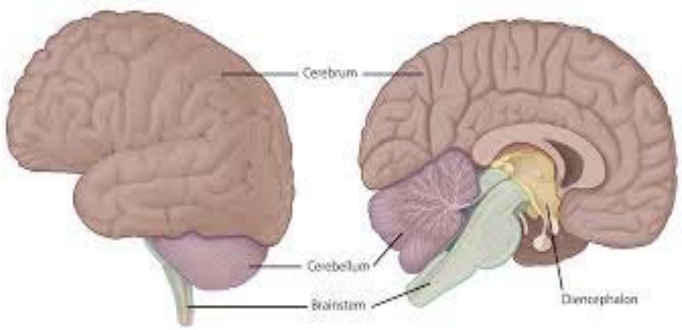

Classification of Neurons
Structural Classification
Unipolar Neurons
Bipolar Neurons
Multipolar Neurons
Functional Classification
Sensory (afferent) Neurons
Motor (efferent) Neurons
Interneurons (association neurons)
Neurotransmitter-based Classification
Excitatory Neurons
Inhibitory Neurons
Modulatory Neurons


NERVOUS SYSTEM
Central Nervous System
Brain and spinal cord
Peripheral Nervous System
Cranial nerves and spinal nerves
Autonomic Nervous System
Heart muscle, smooth muscle, glands
Somatic Nervous System
Voluntary skeletal muscles
Parasympathetic Division
"Rest and digest"
Sympathetic Division
"Active and alert"

Brain: The brain is composed of the cerebrum, cerebellum, diencephalon and brainstem:

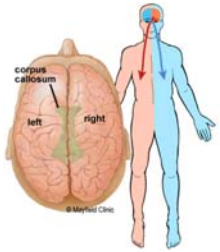


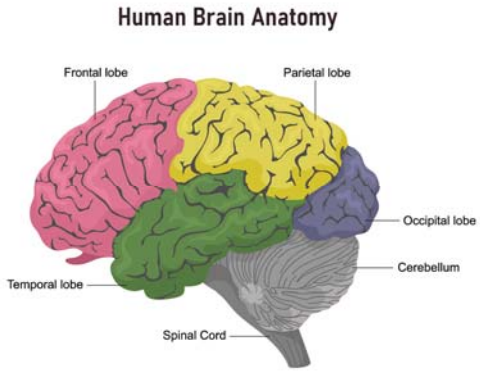
Cerebrum:

- Is the largest part of the brain and is composed of two hemispheres. It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement.

- The cerebrum consists of an outer cerebral cortex (gray matter) and an internal region of cerebral (white matter).

- The cerebrum is divided into two halves, the right and left hemispheres. They are joined by a bundle of fibers called the **corpus callosum** (a broad band of white matter containing axons that extend between the hemispheres) that transmits messages from one side to the other.

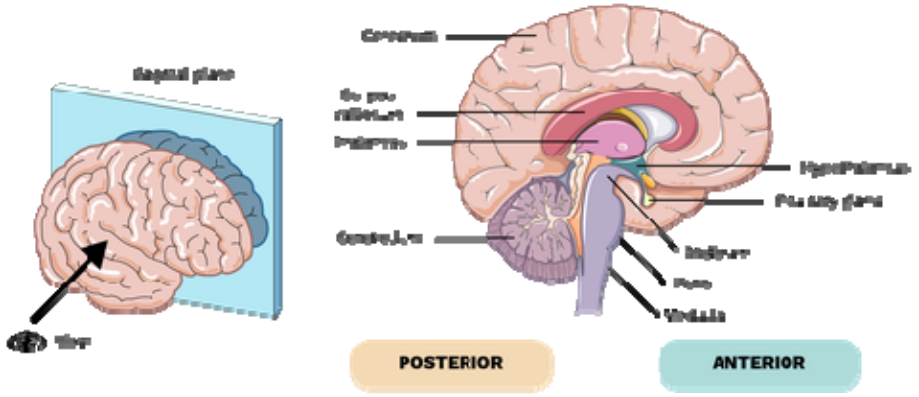




- Each cerebral hemisphere can be further subdivided into several lobes: **frontal, parietal, temporal and occipital lobes.**

The Diencephalon: The diencephalon forms a central core of brain tissue just superior to the midbrain. It is almost completely surrounded by the cerebral hemispheres. it includes the thalamus, hypothalamus and epithalamus.

- **Thalamus:** It has several functions, such as the relaying of sensory and motor signals to the cerebral cortex and the regulation of consciousness, sleep and alertness.



- **Hypothalamus:**
  - **Control autonomic nervous system**: such as heart rate, breathing, blood pressure and body temperature.
  - **Hormonal production**: It produces hormones oxytocin and vasopressin (antidiuretic hormone).
  - **Regulation of emotional and behavioral patterns**: It regulates emotional responses such as mood, sex drive, fear, and aggression. It also controls essential homeostatic behaviors like hunger, thirst, sleep-wake cycles, and satiety.

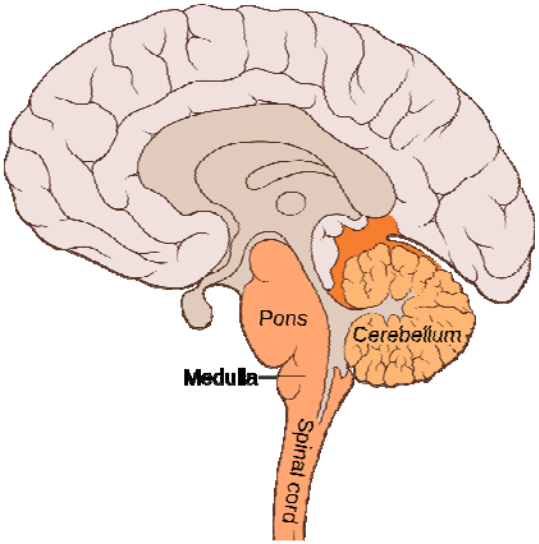
- **Epithalamus:** consists of the pineal gland secretes melatonin, which is thought to promote sleep and to help set the body's biological clock.

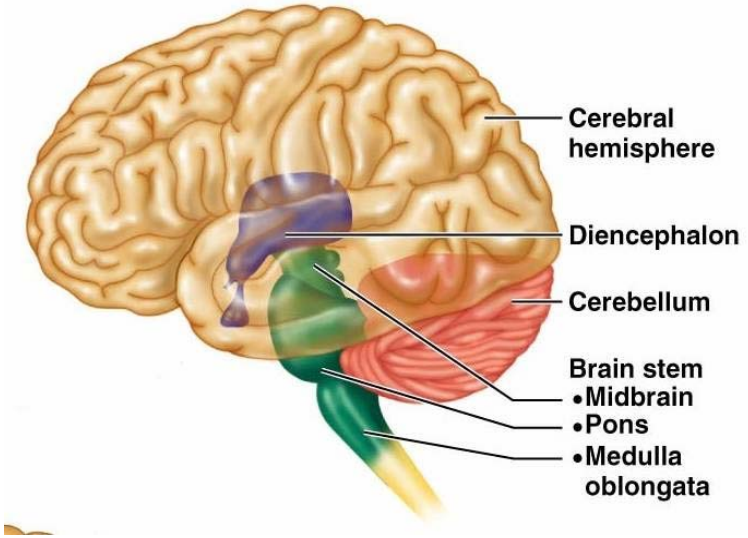
Cerebellum:

The cerebellum regulates coordination of voluntary movement, muscle tone, stopping movements, and equilibrium; contributes to sensations involving texture and weight.

Brainstem: It consists of three structures:

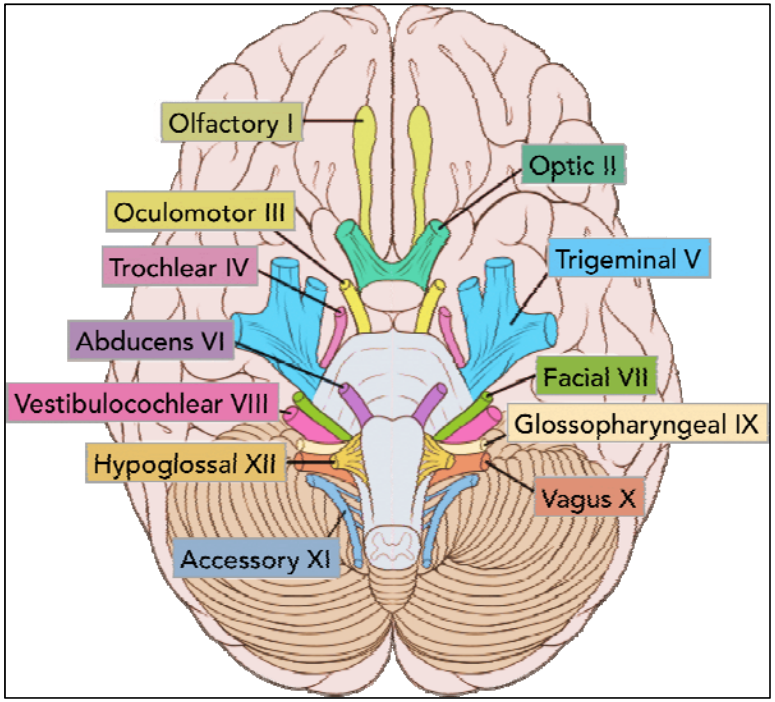
- **Medulla oblongata:** regulates the vital functions of heart rate, breathing and blood pressure; regulates reflexes of coughing, sneezing, swallowing, and vomiting.
- **Pons:** contains respiratory centers that work with those in the medulla
- **Midbrain:** contains centers for visual reflexes, auditory reflexes, and righting (equilibrium) reflexes





Cranial nerves:

- The brain communicates with the body through the spinal cord and twelve pairs of cranial nerves. Ten of the twelve pairs of cranial nerves that control hearing, eye movement, facial sensations, taste, swallowing and movement of the face, neck, shoulder and tongue muscles originate in the **brainstem**. The cranial nerves for smell and vision originate in the **cerebrum.**
- some sensory, some motor and some mixed. Their names and numbers are:



- I. Olfactory: sensory
- II. Optic: sensory
- III. Oculomotor: motor
- IV. Trochlear: motor
- V. Trigeminal: mixed
- VI. Abducent: motor
- VII. Facial: mixed
- VIII. Vestibulocochlear (auditory): sensory
- IX. Glossopharyngeal: mixed
- X. Vagus: mixed
- XI. Accessory: motor
- XII. Hypoglossal: motor.

Spinal nerves:

- There are 31 pairs of spinal nerves are mixed nerves, those that emerge from the spinal cord. The nerves are named according to their respective vertebrae.
- 8 cervical pairs, 12 thoracic pairs, 5 lumbar pairs, 5 sacral pairs, and 1 coccygeal pair.
- In general, the cervical nerves supply the back of the head, neck, shoulders, arms and diaphragm.
- The first thoracic nerve also contributes to nerves in the arms. The remaining thoracic nerves supply the trunk of the body.
- The lumbar and sacral nerves supply the hips, pelvic cavity, and legs.

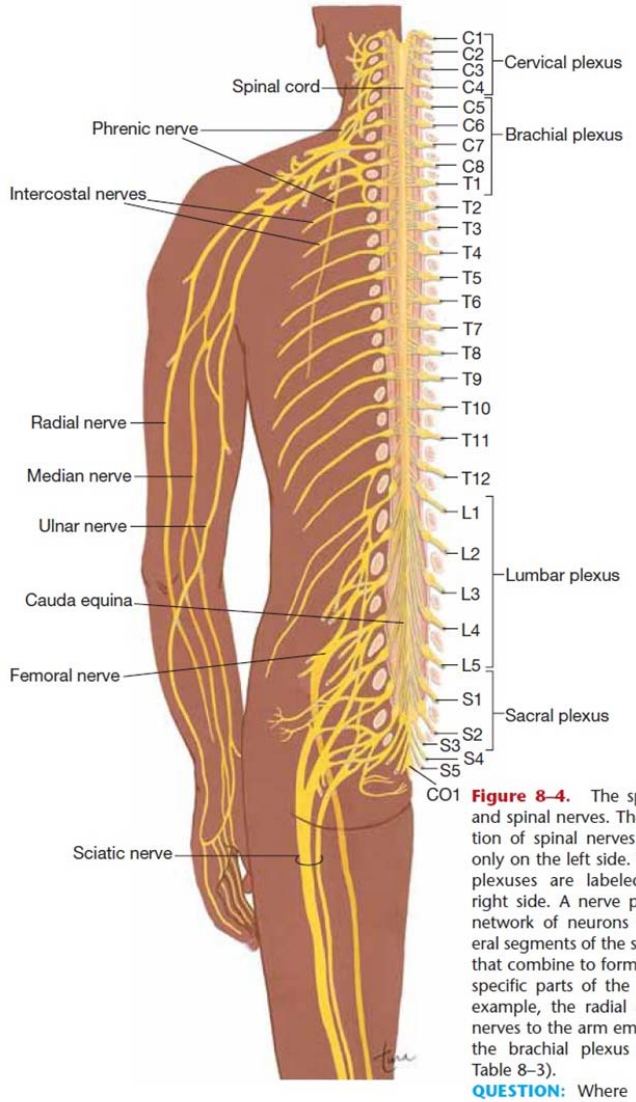


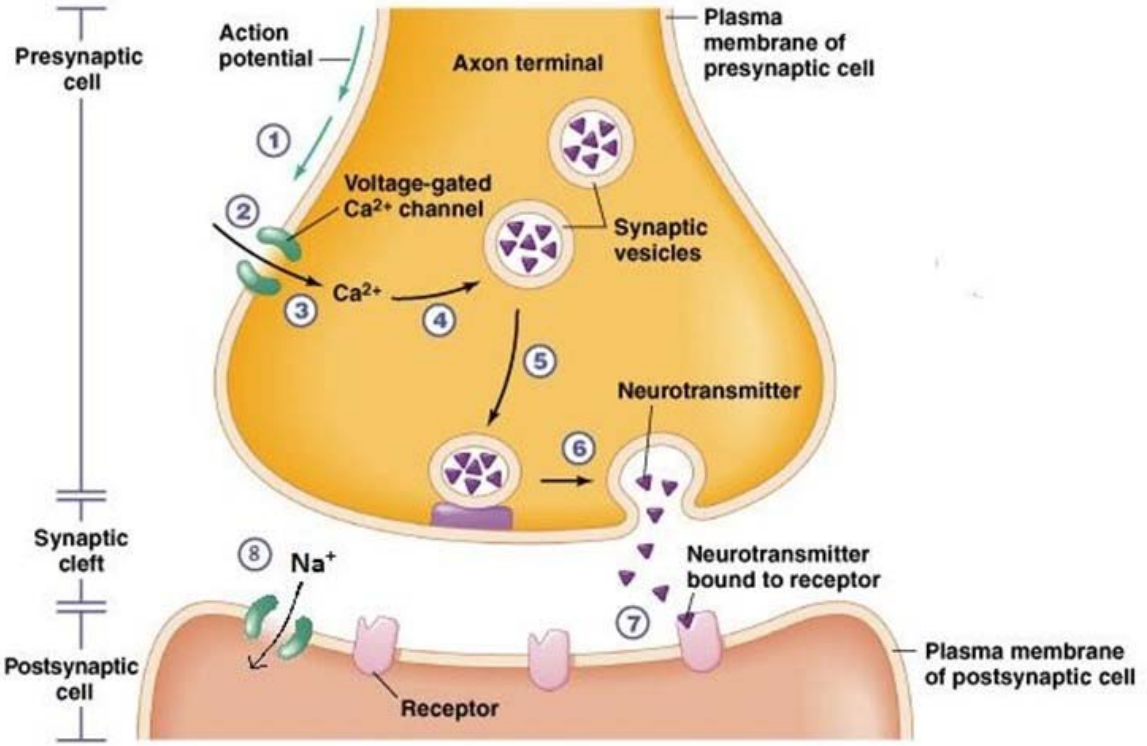
Figure 8–4. The spinal cord and spinal nerves. The distribution of spinal nerves is shown only on the left side. The nerve plexuses are labeled on the right side. A nerve plexus is a network of neurons from several segments of the spinal cord that combine to form nerves to specific parts of the body. For example, the radial and ulnar nerves to the arm emerge from the brachial plexus (see also Table 8–3).
QUESTION: Where does the spinal cord end? Why is this important clinically?

Synapses:

- Neurons that transmit impulses to other neurons do not actually touch one another. There is a tiny gap between them, called the synaptic cleft .
- The small gap or space between the axon of one neuron and the dendrites or cell body of the next neuron is called the synapse. Within the synaptic knob (terminal end) of the presynaptic axon is a chemical neurotransmitter that is released into the synapse by the arrival of an electrical nerve impulse.

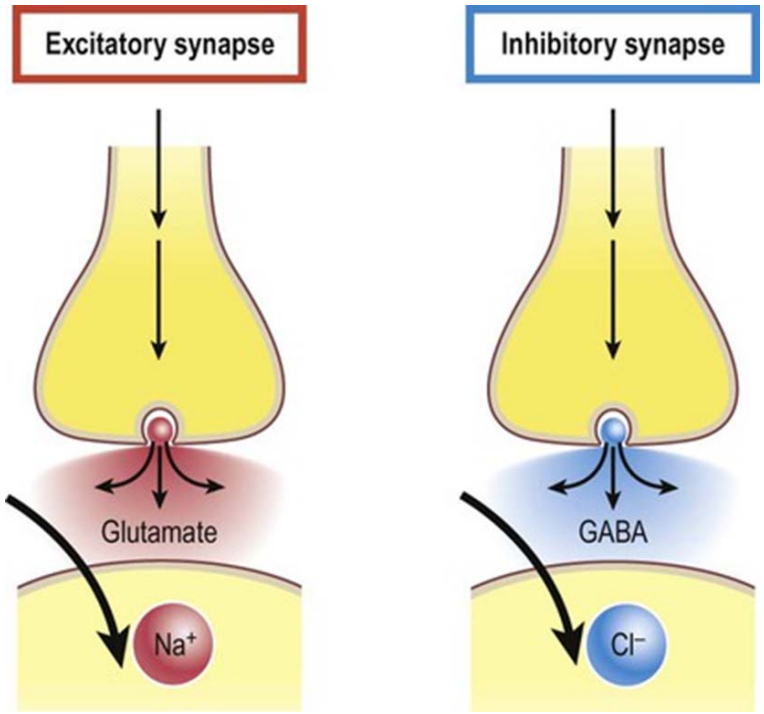
- **The neurotransmitter** diffuses across the synapse, combines with specific receptor sites on the cell membrane of the postsynaptic neuron, and there generates an electrical impulse that is, in turn, carried by this neuron's axon to the next synapse, and so forth.

- A nerve impulse cannot go backward across a synapse because there is no neurotransmitter released by the dendrites or cell body.



- Many synapses are termed **excitatory**, because the neurotransmitter causes the postsynaptic neuron to depolarize (become more negative outside as Na+ ions enter the cell) and transmit an electrical impulse to another neuron, muscle cell or gland.

- Some synapses, however, are **inhibitory**, meaning that the neurotransmitter causes the postsynaptic neuron to hyperpolarize (become even more positive outside as K+ ions leave the cell or Cl- ions enter the cell) and therefore not transmit an electrical impulse.



Peripheral Nervous System (PNS):

Peripheral Nervous System (PNS): is the lateral part of the nervous system that develops from the central nervous system which connects different parts of the body with the CNS. We carry out both voluntary and involuntary actions with the help of peripheral nerves.

Classification of the peripheral nervous system:

- **Somatic nervous system (SNS):** It is controls the voluntary actions in the body by transmitting impulses from CNS to skeletal muscle cells.

- **Autonomic nervous system (ANS):** involved in involuntary actions like regulation of physiological functions (digestion, respiration, salivation, etc.). It is a self-regulating system which conveys the impulses from the CNS to the smooth muscles and involuntary organs (heart, bladder and pupil).

The autonomic nervous system can be further divided into:

- Sympathetic nervous system.
- Parasympathetic nervous system.

The autonomic or involuntary part of the nervous system:

- Controls the functions of the body carried out 'automatically', i.e. initiated in the brain below the level of the cerebrum. Although stimulation does not occur voluntarily the individual may be conscious of its effects, e.g. an increase in the heart rate. The effects of autonomic control are rapid and essential for homeostasis.

The effector organs are:

- smooth muscle
- cardiac muscle
- glands.

Effects of autonomic stimulation include:

- Changes in rate and force of the heartbeat.
- Stimulation or depression of secretion of glands
- Vasoconstriction or vasodilatation
- Bronchoconstriction or bronchodilation
- Changes in size of the pupils of the eyes.

The autonomic nervous system is divided into two divisions:

- ❑ Sympathetic (thoracolumbar outflow).
- ❑ Parasympathetic (craniosacral outflow).

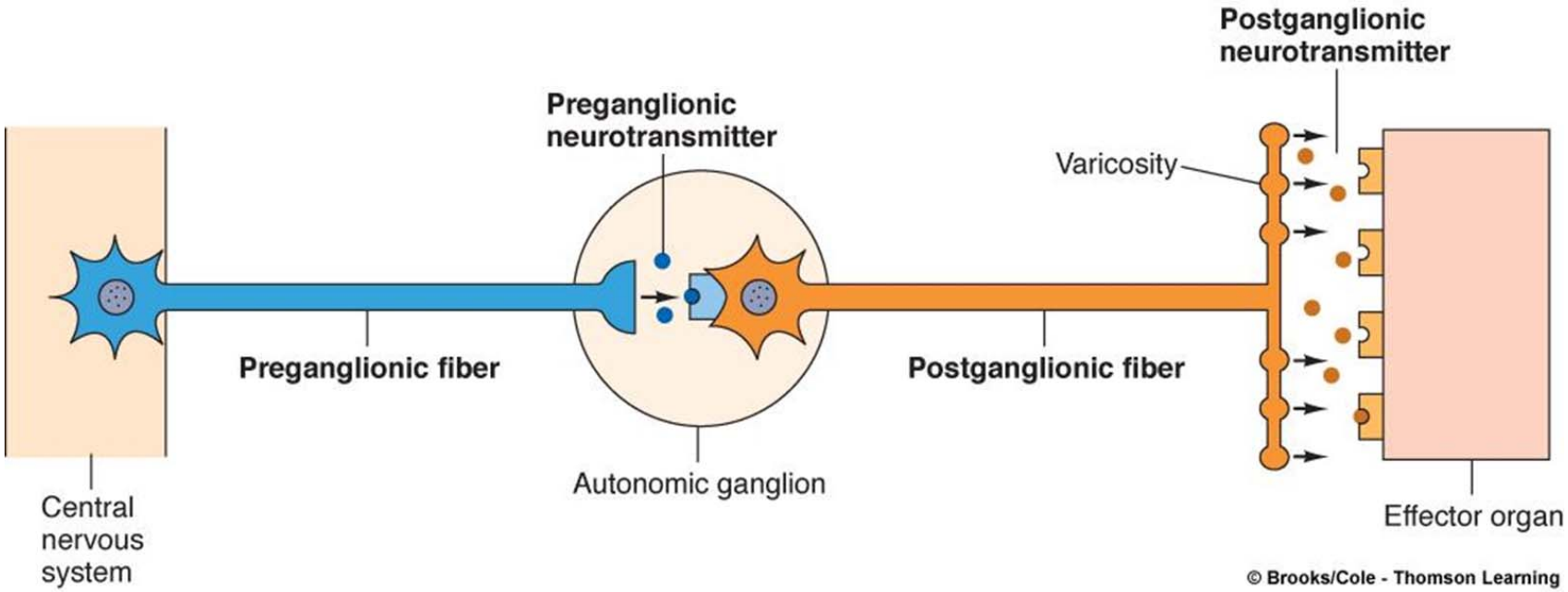
The two divisions have both structural and functional differences. They normally work in an opposing manner, enabling or restoring balance of involuntary functions, maintaining homeostasis.

Sympathetic activity tends to predominate in stressful situations and parasympathetic activity during rest.

An autonomic nerve pathway from the central nervous system to a visceral effector consists of two motor neurons that synapse in a ganglion outside the CNS.

The first neuron is called the **preganglionic neuron**, from the CNS to the ganglion.

The second neuron is called the **postganglionic neuron**, from the ganglion to the visceral effector. The ganglia are actually the cell bodies of the postganglionic neurons.



Sympathetic division:

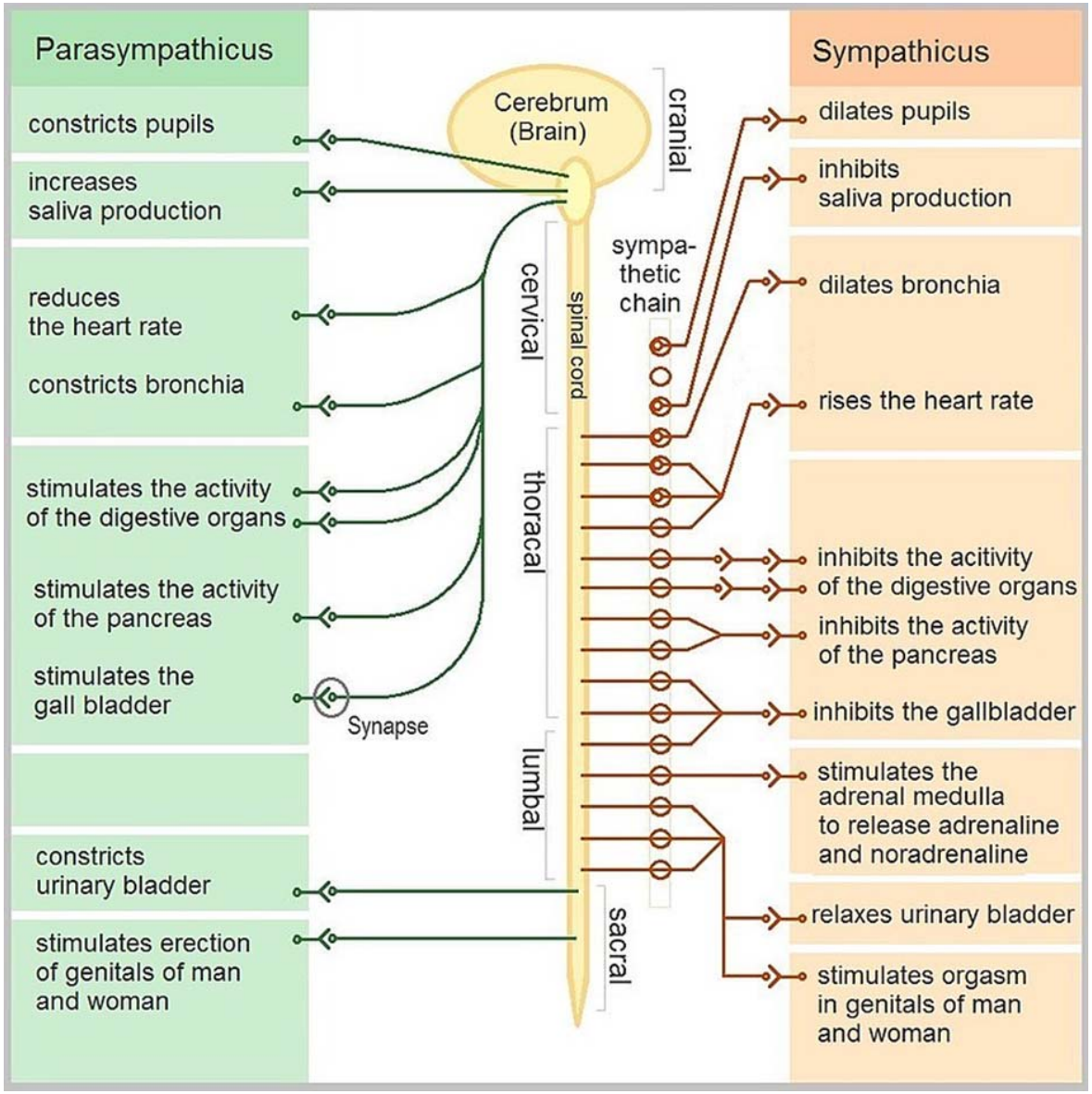
- Another name for the sympathetic division is **thoracolumbar division** because the preganglionic neurons have their cell bodies in the lateral horns of the gray matter in the 12 thoracic segments and the first two (and sometimes three) lumbar segments of the spinal cord.
- Within the ganglia are the synapses between preganglionic and postganglionic neurons; the postganglionic axons then go to the visceral effectors.
- One preganglionic neuron often synapses with many postganglionic neurons to many effectors. This anatomic arrangement has physiological importance: The sympathetic division brings about widespread responses in many organs.

- The sympathetic division is dominant in stressful situations, which include anger, fear, or anxiety, as well as exercise. the “fight or flight” response.

- The heart rate increases, vasodilation in skeletal muscles supplies them with more oxygen, the bronchioles dilate to take in more air, and the liver changes glycogen to glucose to supply energy.

- At the same time the digestive secretions decrease and peristalsis slows; these are not important in a stress situation. Vasoconstriction in the skin and viscera shunts blood to more vital organs such as the heart, muscles, and brain.

- **Neurotransmitters:** Norepinephrine is released by most sympathetic postganglionic neurons.


Parasympathicus
constricts pupils
increases saliva production
reduces the heart rate
constricts bronchia
stimulates the activity of the digestive organs
stimulates the activity of the pancreas
stimulates the gall bladder
Synapse
constricts urinary bladder
stimulates erection of genitals of man and woman
Cerebrum (Brain)
cranial
cervical
thoracal
lumbal
sacral
spinal cord
sympa-thetic chain
Sympathicus
dilates pupils
inhibits saliva production
dilates bronchia
rises the heart rate
inhibits the acitivity of the digestive organs
inhibits the activity of the pancreas
inhibits the gallbladder
stimulates the adrenal medulla to release adrenaline and noradrenaline
relaxes urinary bladder
stimulates orgasm in genitals of man and woman

Parasympathetic division:

- The other name for the parasympathetic division is the **craniosacral division** because the cell bodies of preganglionic neurons are located in the nuclei of four cranial nerves in the brainstem (III, VII, IX, and X) and in the lateral gray matter of the second through fourth sacral segments of the spinal cord.

- In the parasympathetic division, one preganglionic neuron synapses with just a few postganglionic neurons to only one effector. With this anatomic arrangement, very localized (one organ) responses are possible.

- The parasympathetic division dominates in relaxed (non-stress) situations to promote normal functioning of several organ systems. Digestion will be efficient, with increased secretions and peristalsis; defecation and urination may occur; and the heart will beat at a normal resting rate.

- **Neurotransmitters:** acetylcholine is released by all preganglionic neurons of both sympathetic and parasympathetic and by parasympathetic postganglionic neurons.

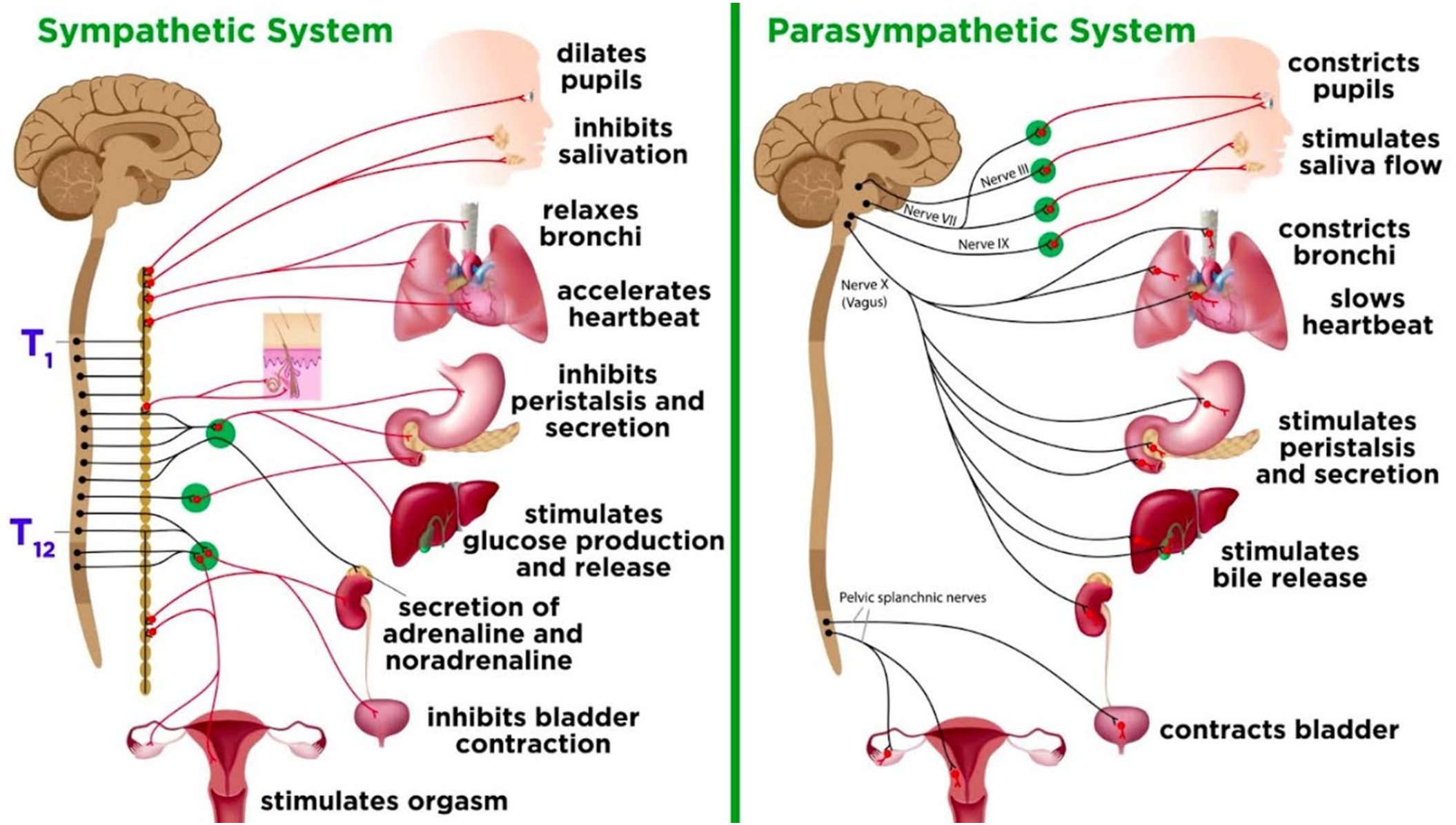

Sympathetic System
dilates pupils
inhibits salivation
relaxes bronchi
accelerates heartbeat
T1
inhibits peristalsis and secretion
T12
stimulates glucose production and release
secretion of adrenaline and noradrenaline
inhibits bladder contraction
stimulates orgasm
Parasympathetic System
constricts pupils
stimulates saliva flow
Nerve III
Nerve VII
Nerve IX
Nerve X (Vagus)
constricts bronchi
slows heartbeat
stimulates peristalsis and secretion
stimulates bile release
Pelvic splanchnic nerves
contracts bladder

Table 8–5 FUNCTIONS OF THE AUTONOMIC NERVOUS SYSTEM

Organ	Sympathetic Response	Parasympathetic Response
Heart (cardiac muscle)	• Increase rate	• Decrease rate (to normal)
Bronchioles (smooth muscle)	• Dilate	• Constrict (to normal)
Iris (smooth muscle)	• Pupil dilates	• Pupil constricts (to normal)
Salivary glands	• Decrease secretion	• Increase secretion (to normal)
Stomach and intestines (smooth muscle)	• Decrease peristalsis	• Increase peristalsis for normal digestion
Stomach and intestines (glands)	• Decrease secretion	• Increase secretion for normal digestion
Internal anal sphincter	• Contracts to prevent defecation	• Relaxes to permit defecation
Urinary bladder (smooth muscle)	• Relaxes to prevent urination	• Contracts for normal urination
Internal urethral sphincter	• Contracts to prevent urination	• Relaxes to permit urination
Liver	• Changes glycogen to glucose	• None
Pancreas	• Secretes glucagon	• Secretes insulin and digestive enzymes
Sweat glands	• Increase secretion	• None
Blood vessels in skin and viscera (smooth muscle)	• Constrict	• None
Blood vessels in skeletal muscle (smooth muscle)	• Dilate	• None
Adrenal glands	• Increase secretion of epinephrine and norepinephrine	• None