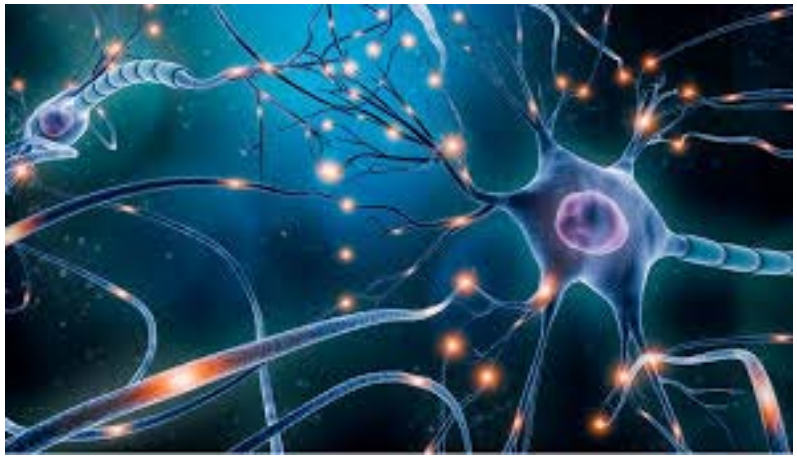
Assist. Lec.: Safa Jalil AL-Yassiri

Nervous system

The functions of the nervous system:

1. To detect changes and feel sensations.
2. To initiate appropriate responses to changes.
3. To organize information for immediate use and store it for future use.



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 synthesise chemical energy (ATP) only from glucose.

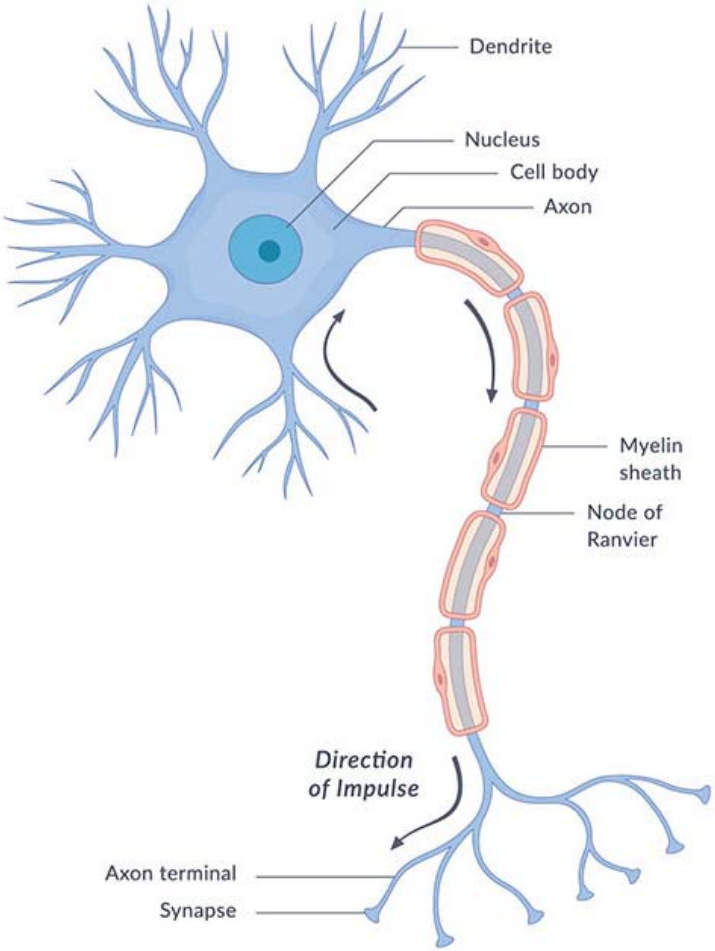
Nerve cells are called neurons, or nerve fibers. Whatever their specific functions, all neurons have the same physical parts.

- **The cell body** contains the nucleus and is essential for the continued life of the neuron. neuron cell bodies are found in the central nervous system or close to it in the trunk of the body. In these locations, cell bodies are protected by bone. 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 and dendrites are "wrapped" in specialized cells called **Schwann cells** surround the neuron processes, enclosing them in several layers of Schwann cell membrane. These layers are the **myelin sheath**; myelin is a phospholipid that electrically insulates neurons from one another. Without the myelin sheath, neurons would short-circuit, just as electrical wires would if they were not insulated.



- The nuclei and cytoplasm of the Schwann cells are wrapped around the outside of the myelin sheath and are called **the neurolemma**, which becomes very important if nerves are damaged. If a peripheral nerve is severed and reattached precisely by microsurgery, the axons and dendrites may regenerate through the tunnels formed by the neurolemmas. The Schwann cells are also believed to produce a chemical growth factor that stimulates regeneration. Although this regeneration may take months, the nerves may eventually reestablish their proper connections, and the person may regain some sensation and movement in the once-severed limb.

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

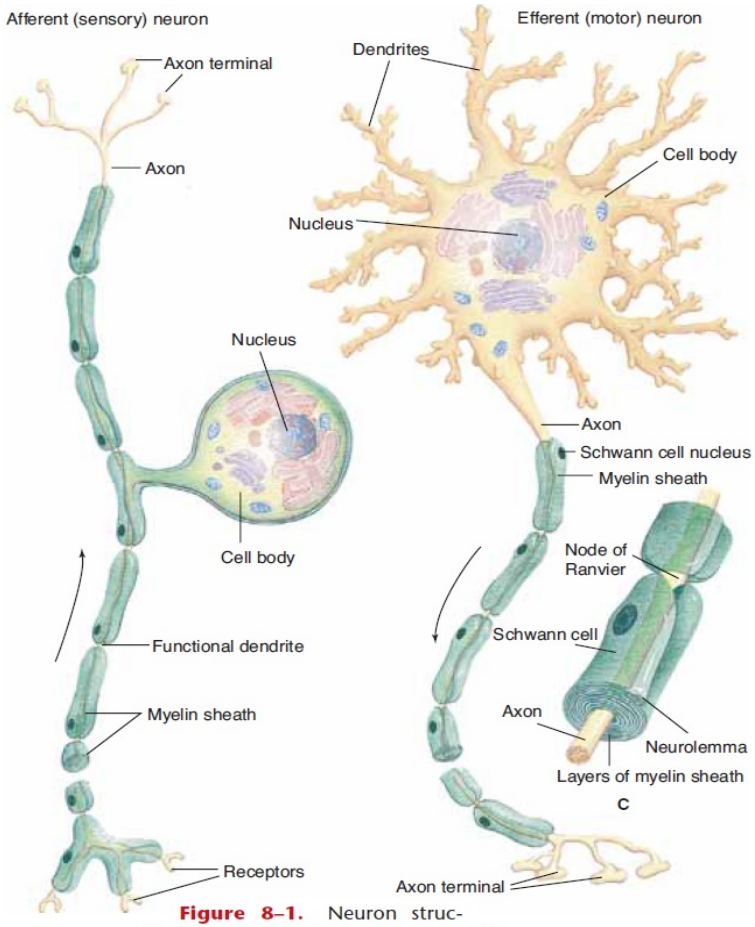
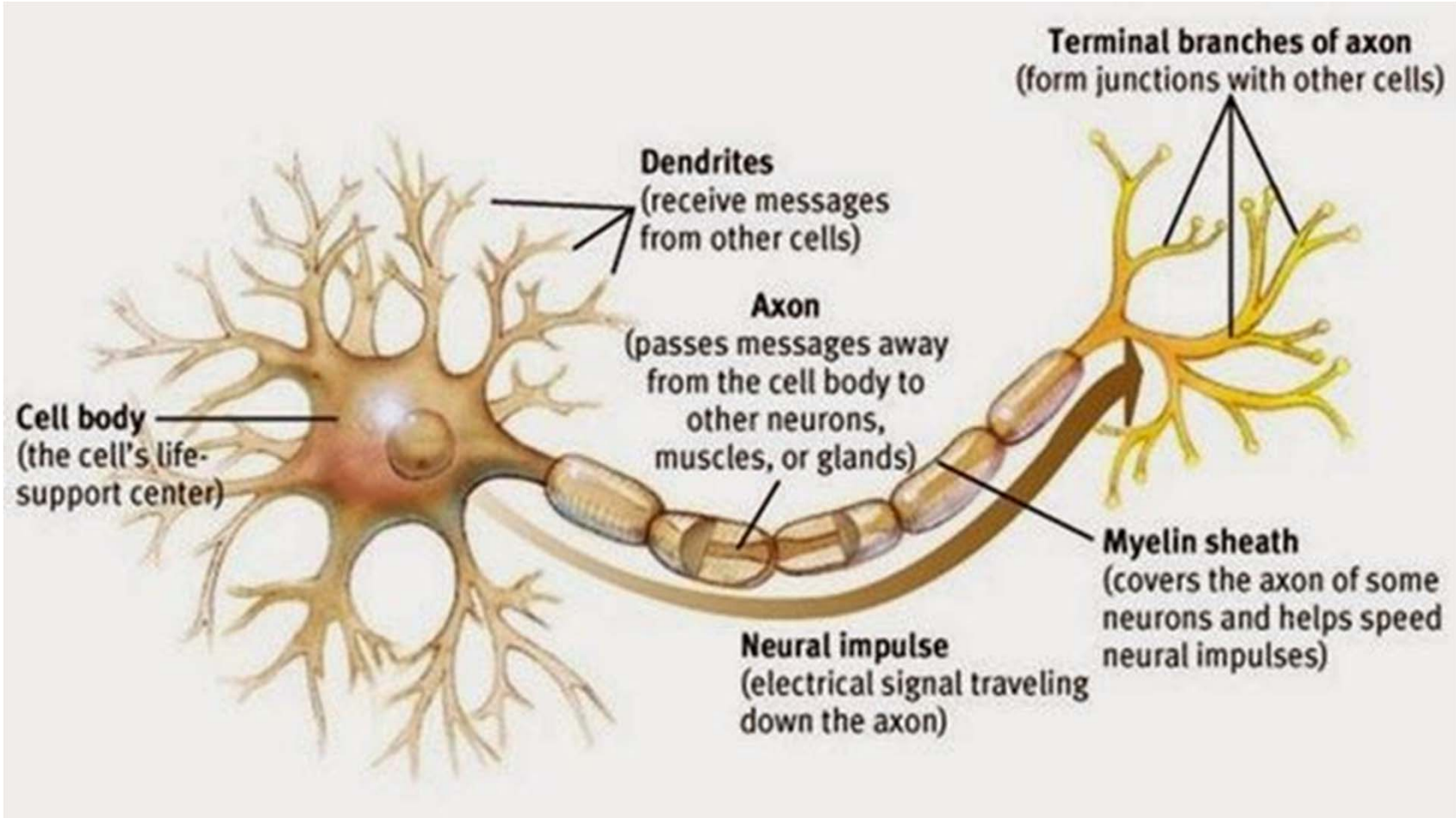
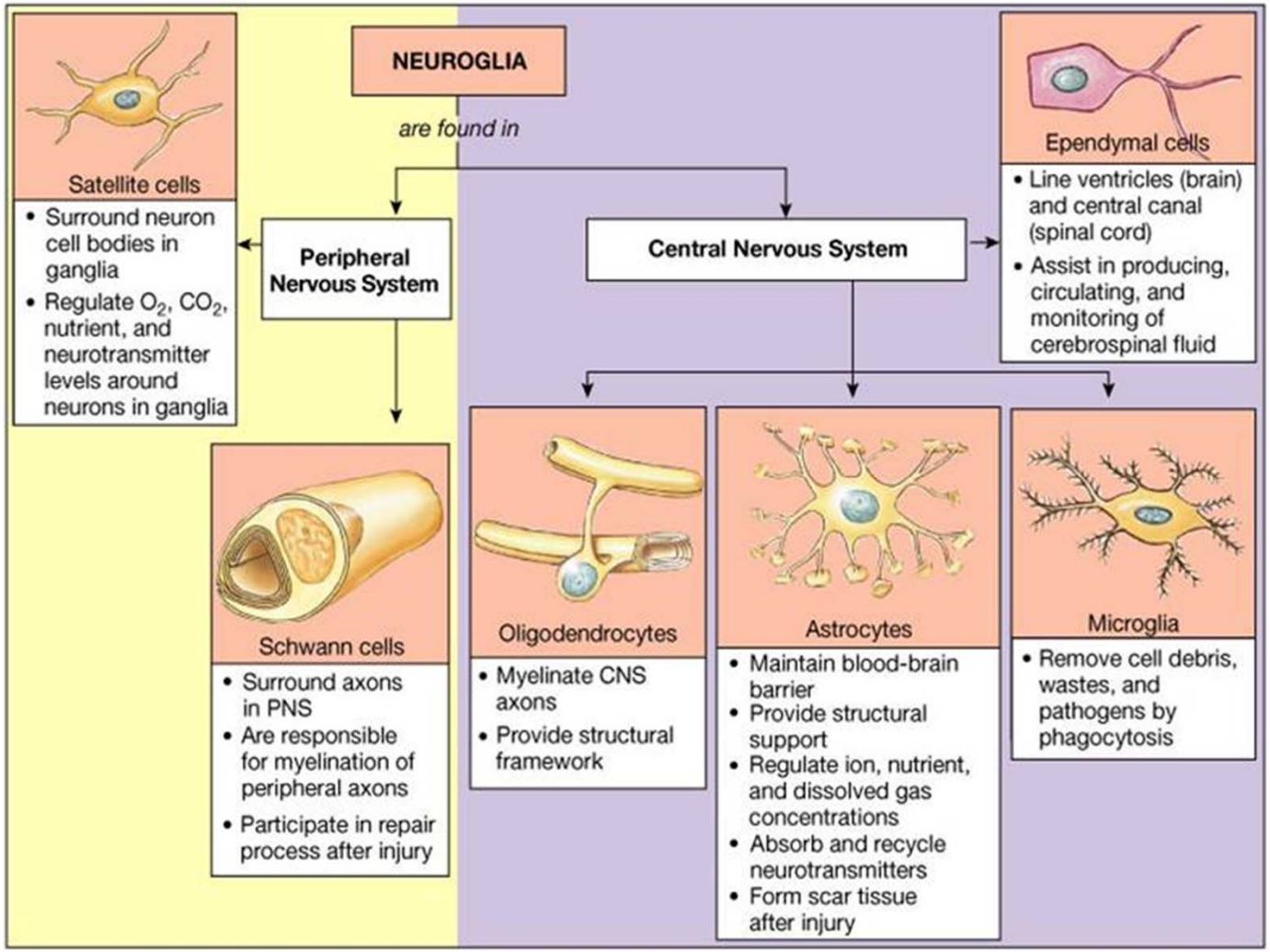


Figure 8–1. Neuron structure. (**A**) A typical sensory neuron. (**B**) A typical motor neuron. The arrows indicate the direction of impulse transmission. (**C**) Details of the myelin sheath and neurolemma formed by Schwann cells.
QUESTION: The axon terminal of the motor neuron would be found at what kinds of effectors?


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



Types of neurons:

Neurons may be classified into three groups: sensory neurons, motor neurons, and interneurons.

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. Sensory neurons from receptors in skin, skeletal muscles, and joints are called somatic; those from receptors in internal organs are called visceral sensory neurons.

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. Motor neurons linked to skeletal muscle are called somatic; those to smooth muscle, cardiac muscle, and glands are called visceral.

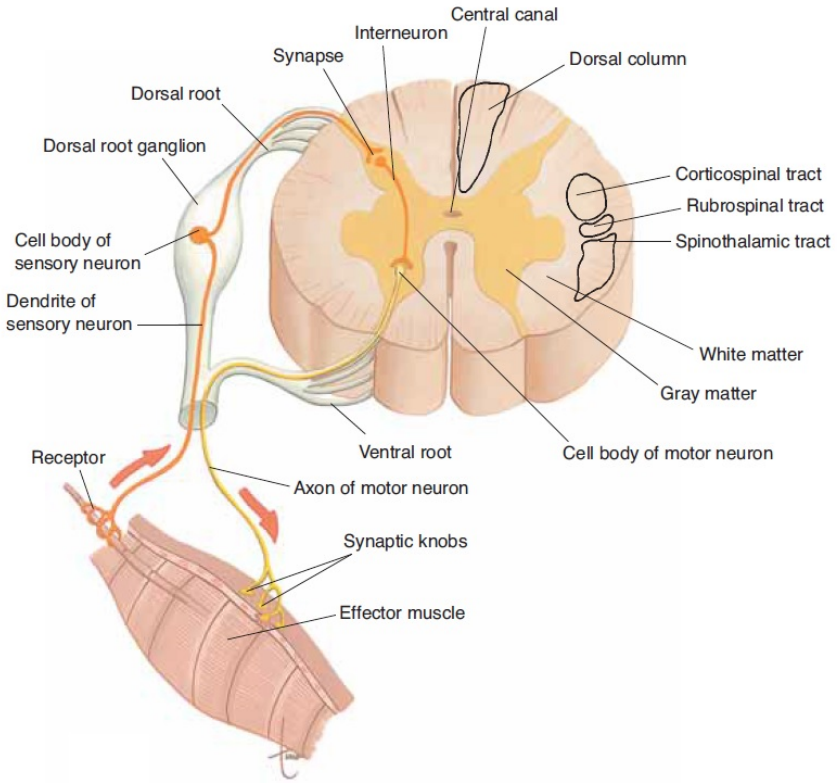
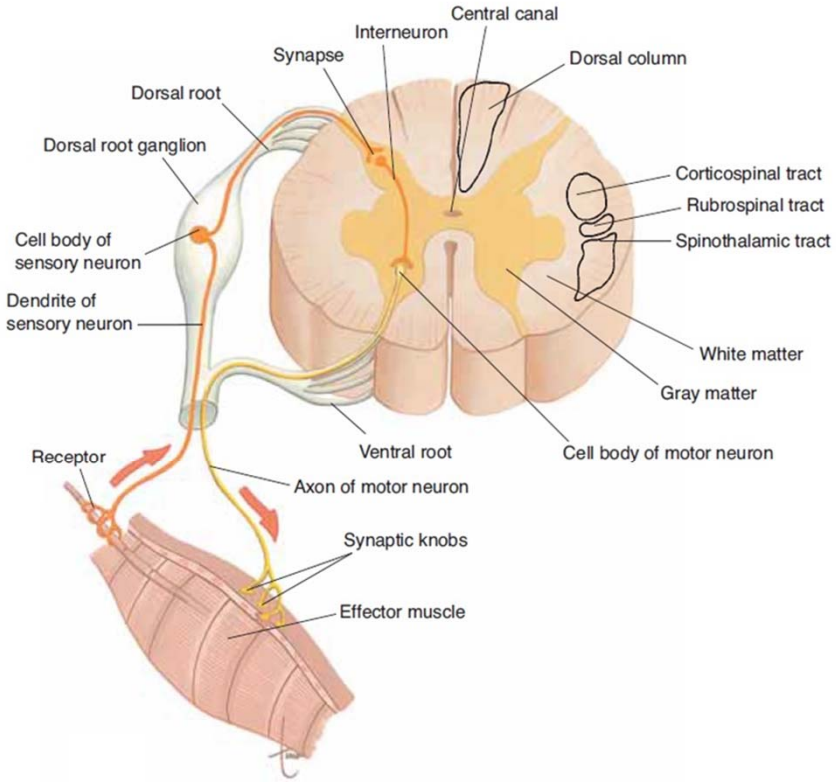


Figure 8–3. Cross-section of the spinal cord and the three types of neurons. Spinal nerve roots and their neurons are shown on the left side. Spinal nerve tracts are shown in the white matter on the right side. All tracts and nerves are bilateral (both sides).
QUESTION: The dorsal column is an ascending tract, and the corticospinal tract is descending. Explain what this means.

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.

For instance, when you touch something sharp like a cactus, sensory neurons in your fingertips send a signal to interneurons in your spinal cord. Some interneurons pass the signal on to motor neurons in your hand, which allows you to move your hand away. Other interneurons send a signal to the pain center in your brain, and you experience pain.



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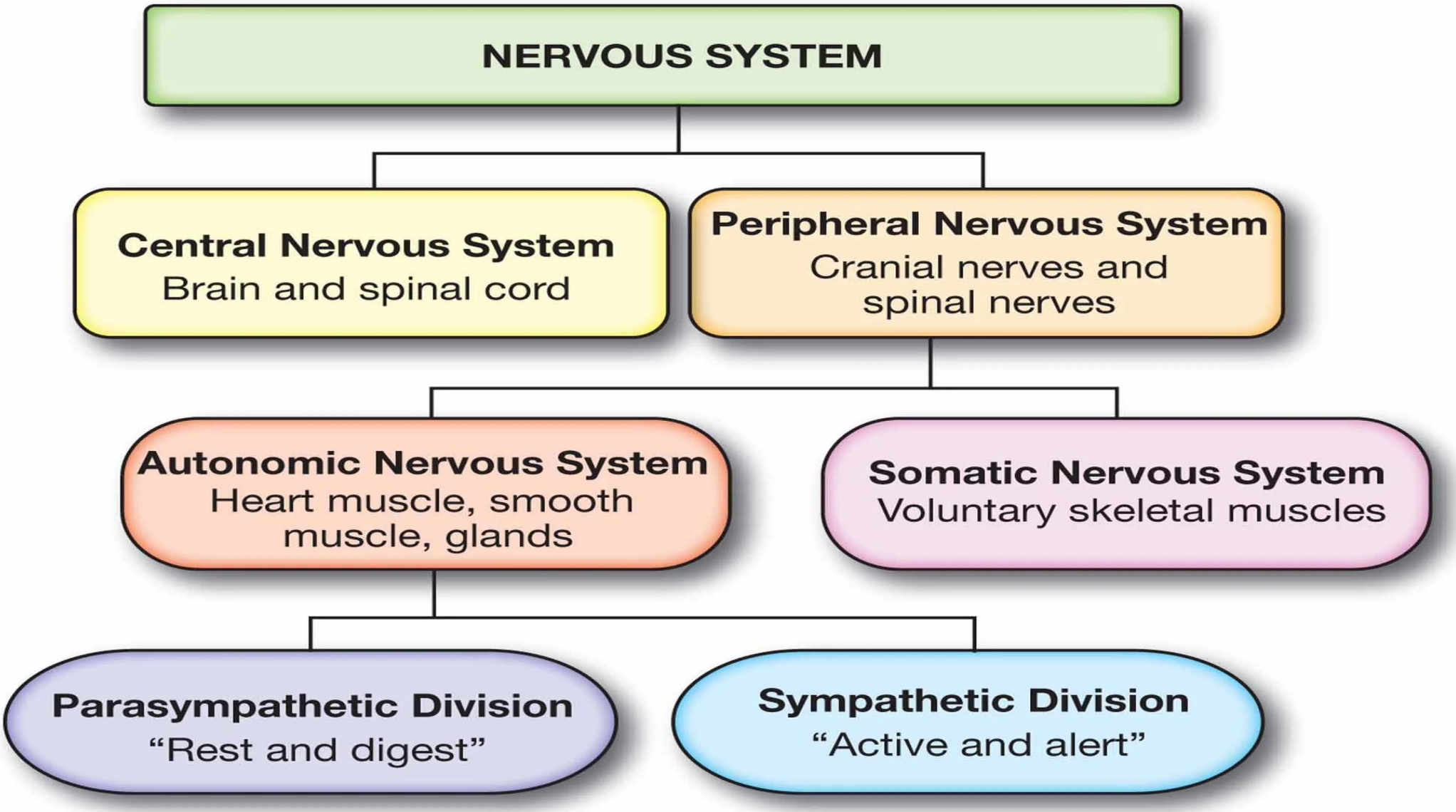
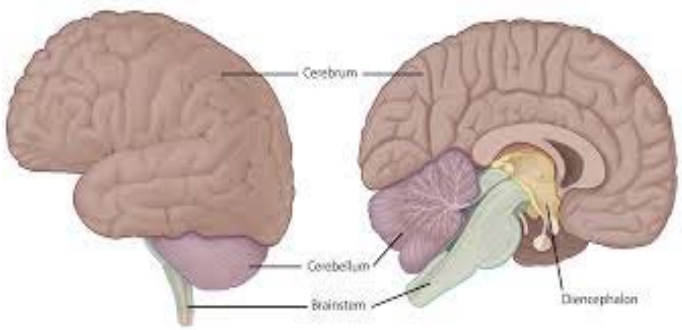

NERVOUS SYSTEM
Central Nervous System
Brain and spinal cord
Peripheral Nervous System
Cranial nerves and spinal nerves
Autonomic Nervous System
Heart muscle, smooth muscle, glands
Somatic Nervous System
Voluntary skeletal muscles
Parasympathetic Division
"Rest and digest"
Sympathetic Division
"Active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

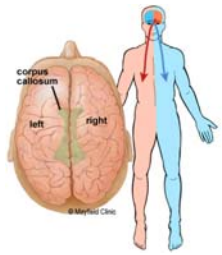
Brain: The brain is composed of the cerebrum, cerebellum, Diencephalon and brainstem:



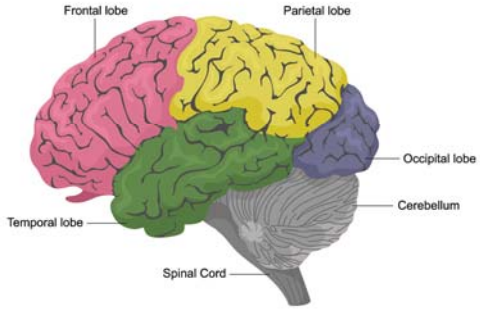
Cerebrum:

- 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 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.



Human Brain Anatomy



- Each hemisphere controls the opposite side of the body. If a stroke occurs on the right side of the brain, your left arm or leg may be weak or paralyzed.

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

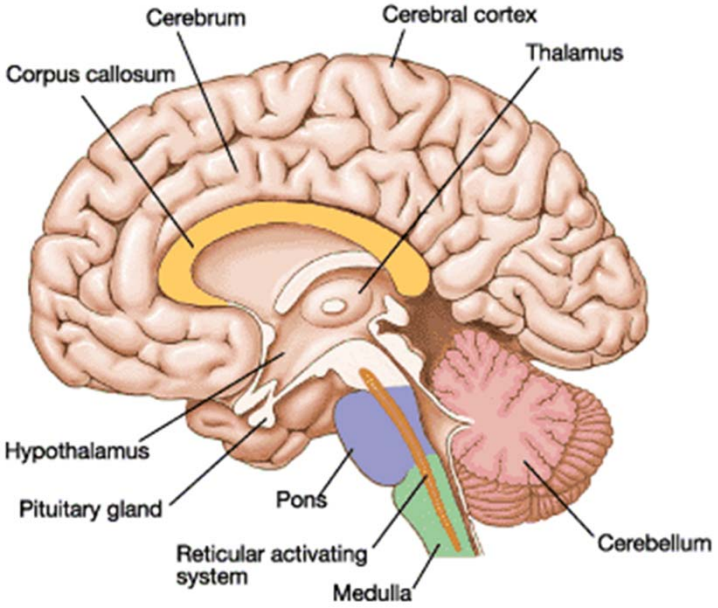
- The cerebral hemispheres have distinct fissures, which divide the brain into lobes. Each hemisphere has 4 lobes: **frontal, temporal, parietal, and occipital**.

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 and hypothalamus.

- **Thalamus:** plays a role in maintenance of consciousness.

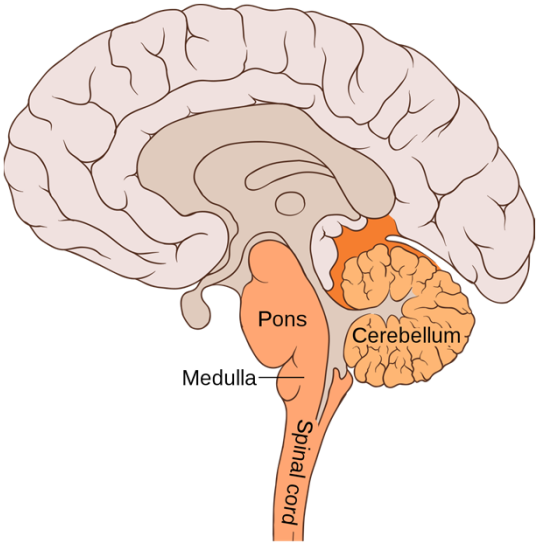
- **Hypothalamus:**

  - Produces antidiuretic hormone (ADH), which increases water reabsorption by the kidneys.
  - Produces oxytocin, which promotes uterine contractions for labor and delivery.
  - Produces releasing hormones that regulate the secretions of the anterior pituitary gland.
  - Regulates body temperature.
  - Regulates food intake
  - Integrates the functioning of the autonomic nervous system (ANS)
  - Promotes visceral responses to emotional situations; acts as a biological clock that regulates body rhythm.



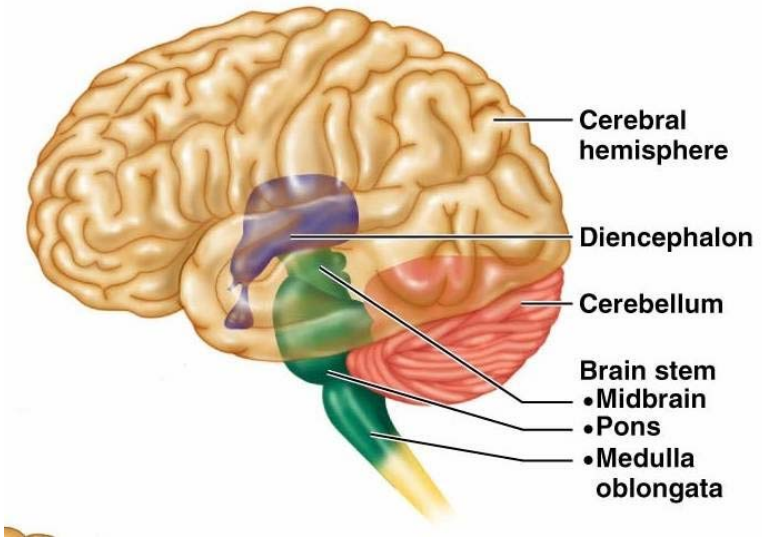
Cerebellum:

- The cerebellum occupies the inferior and posterior aspects of the cranial cavity.
- It consists of two lateral hemispheres and a medial, constricted vermis.
- It connects to the brainstem by three pairs of cerebellar peduncles.
- The cerebellum regulates coordination of voluntary movement, muscle tone, stopping movements, and equilibrium; contributes to sensations involving texture and weight.



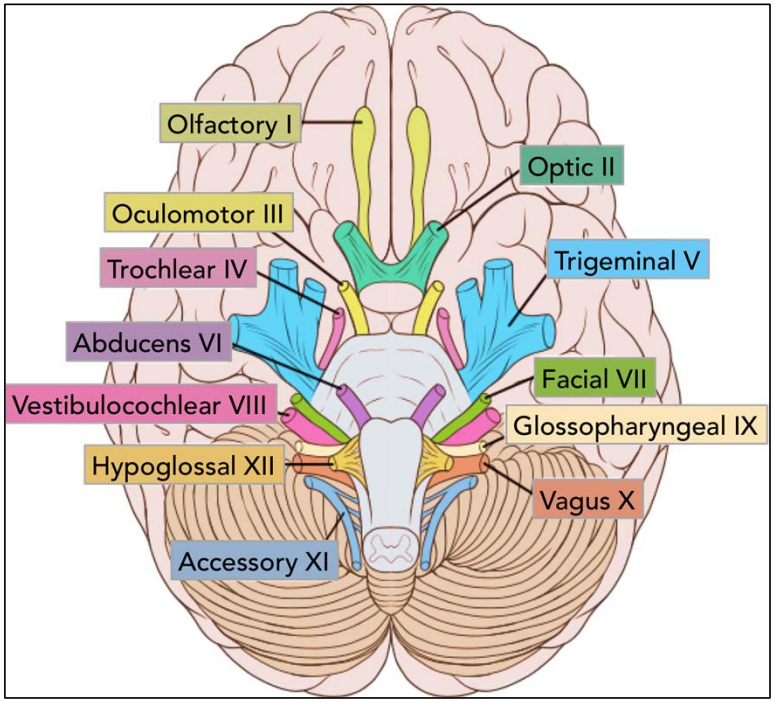
Brainstem: It consists of three structures:

- **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
- XL Accessory: motor
- XII. Hypoglossal: motor.

Name and no.	Central connection	Peripheral connection	Function
I. Olfactory (sensory)	Smell area in temporal lobe of cerebrum through olfactory bulb	Mucous membrane in roof of nose.	Sense of smell
II. Optic (sensory)	Sight area in occipital lobe of cerebrum Cerebellum	Retina of the eye	Sense of sight
III. Oculomotor (motor)	Nerve cells near floor of aqueduct of midbrain	Superior, inferior and medial rectus muscles of the eye Ciliary muscles of the eye Circular muscle fibers of the iris	Moving the eyeball Focusing Regulating the size of the pupil
IV. Trochlear (motor)	Nerve cells near floor of aqueduct of midbrain	Superior oblique muscles of the eye	Movement of the eyeball
V. Trigeminal (mixed)	Motor fibers from the pons Sensory fibers from the trigeminal ganglion	Muscles of mastication Sensory to gums, cheek, lower jaw, iris, cornea	Chewing Sensation from the face
VI. Abducent (motor)	Floor of fourth ventricle	Lateral rectus muscle of the eye	Movement of the eye
VII. Facial (mixed)	Pons	Sensory fibers to the tongue Motor fibers to the muscles of the face	Sense of taste Movements of facial expression

VIII. Vestibulocochlear (sensory) (a) Vestibular (b) Cochlear	Cerebellum Hearing area of cerebrum	Semicircular canals in the inner ear. Organ of Corti in cochlea	Maintenance of balance Sense of hearing
IX. Glossopharyngeal (mixed)	Medulla oblongata	Parotid gland Back of tongue and pharynx	Secretion of saliva Sense of taste Movement of pharynx
X. Vagus (mixed)	Medulla oblongata	Pharynx, larynx; organs, glands ducts, blood vessels in the thorax and abdomen	Movement and secretion
XI. Accessory (motor)	Medulla oblongata	Sternocleidomastoid, trapezius, laryngeal and pharyngeal muscles	Movement of the head, shoulders, pharynx and larynx
XII. Hypoglossal (motor)	Medulla oblongata	Tongue	Movement of tongue

Spinal nerves:

- There are 31 pairs of spinal 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 very small coccygeal pair.
- In general, the cervical nerves supply the back of the head, neck, shoulders, arms, and diaphragm (the phrenic nerves).
- 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.
- Notice that the lumbar and sacral nerves hang below the end of the spinal cord (in order to reach their proper openings to exit from the vertebral canal); this is called the cauda equina, literally, the "horse's tail.

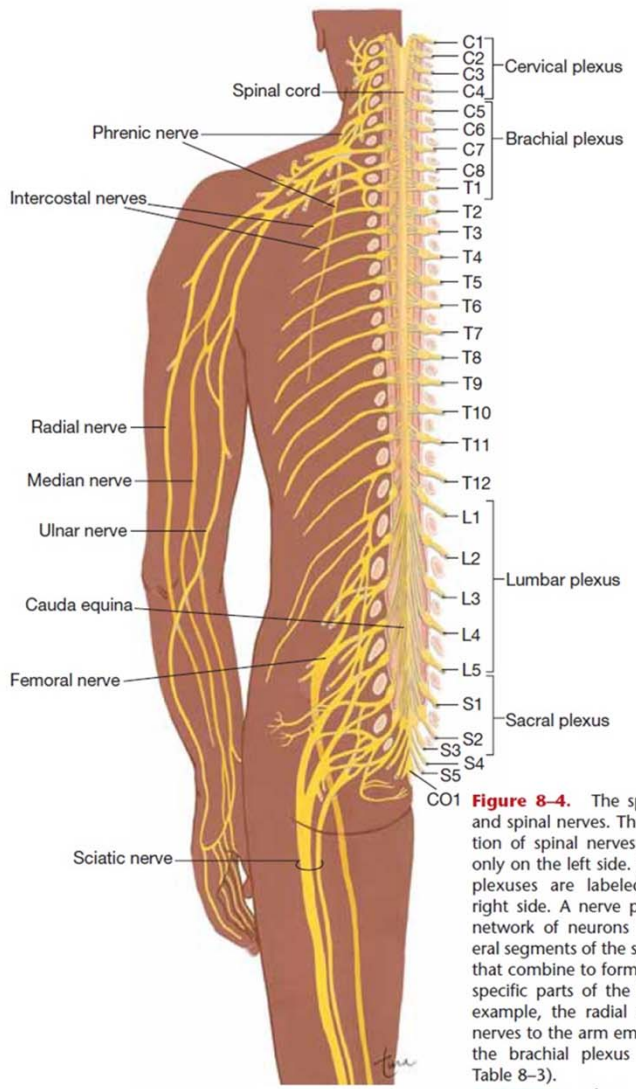
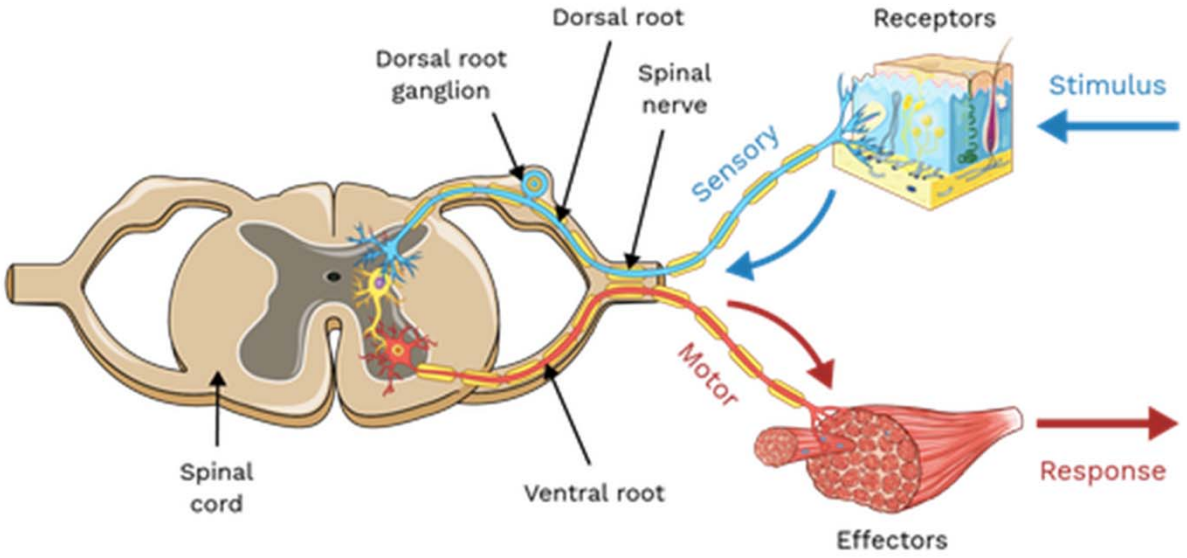
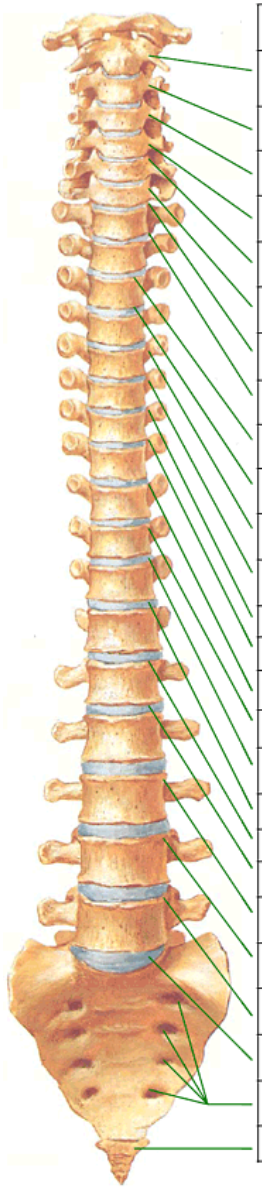


Figure 8–4. The spinal cord and spinal nerves. The distribution of spinal nerves is shown only on the left side. The nerve plexuses are labeled on the right side. A nerve plexus is a network of neurons from several segments of the spinal cord that combine to form nerves to specific parts of the body. 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?

- Each spinal nerve has two roots, which are neurons entering or leaving the spinal cord. The dorsal root is made of sensory neurons that carry impulses into the spinal cord. The dorsal root ganglion is an enlarged part of the dorsal root that contains the cell bodies of the sensory neurons. The term ganglion means a group of cell bodies outside the CNS. These cell bodies are within the vertebral canal and are thereby protected from injury.



- The ventral root is the motor root; it is made of the axons of motor neurons carrying impulses from the spinal cord to muscles or glands. The cell bodies of these motor neurons, as mentioned previously, are in the gray matter of the spinal cord. When the two nerve roots merge, the spinal nerve thus formed is a mixed nerve.



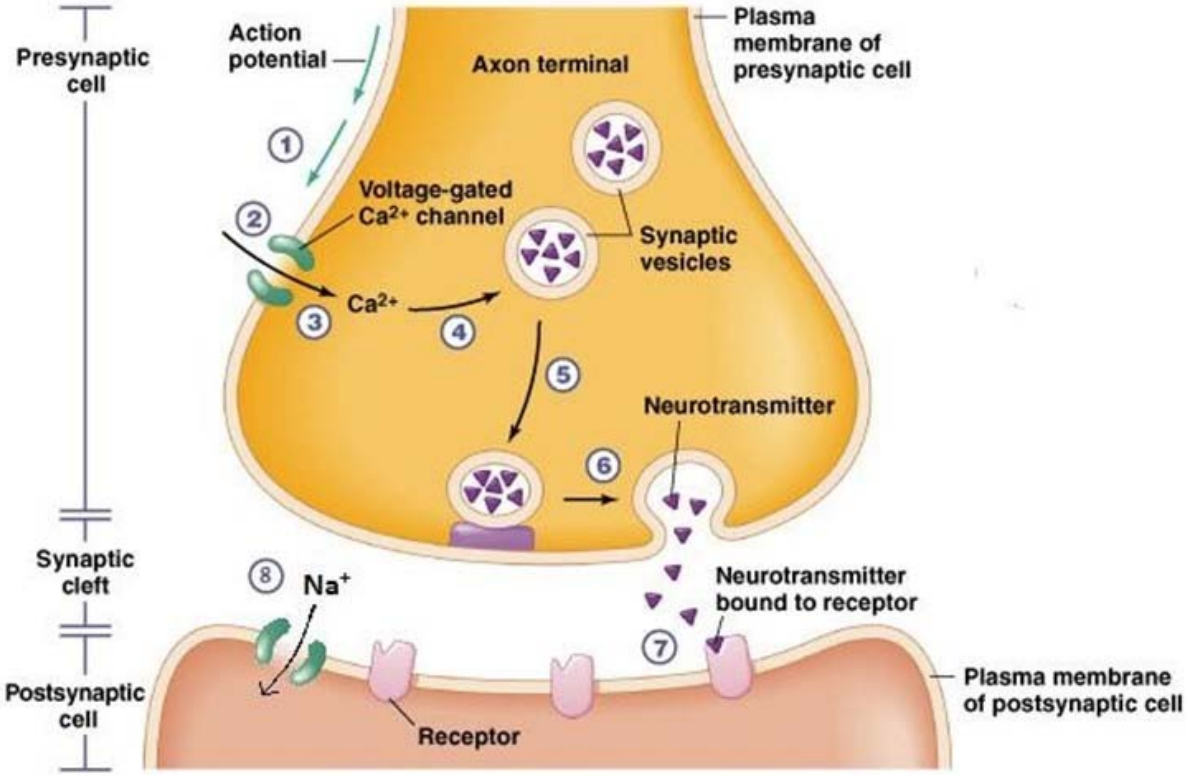
Spinal Bone	Nerve Supply	Common Warning Signs
C1	**Blood supply to the head, pituitary gland, scalp, bones of the face, brain, inner ear and middle ear.**	**• Headaches •insomnia •high blood pressure • Migraines • chronic fatigue • dizziness**
C2	Eyes, ears, sinuses, tongue, forehead	**• Sinusitis • ear aches • pain around the eyes • Vision problems • hearing problems**
C3	Cheeks, outer ear, face bones, teeth, facial nerves.	• Neuralgia • pimples • eczema
C4	Nose, lips, mouth, Eustachian tube	• Hay fever • runny nose • hearing loss • Adenoids
C5	Vocal cords, neck, glands, pharynx	• Sore throat • laryngitis • hoarseness
C6	Neck muscles, shoulders, tonsils	• Stiff neck • arm pain • tonsillitis • Persistent cough
C7	Thyroid gland, shoulder bursa, elbows	• Bursitis • colds • thyroid conditions
T1	Forearms, hands, wrists, fingers, esophagus, trachea	• Arm and hand pain • difficulty breathing • shortness of breath • asthma
T2	Heart, coronary arteries	• Heart conditions • chest conditions
T3	Lungs, bronchial tubes, pleura, chest	• Bronchitis • pleurisy • pneumonia • congestion
T4	Gallbladder	• Gallbladder conditions • jaundice • shingles
T5	Liver, solar plexus, circulation	• Liver conditions • blood pressure conditions • poor circulation
T6	Stomach	• Indigestion • heartburn • dyspepsia
T7	Pancreas, duodenum	• Ulcers • gastritis
T8	Spleen	• Lower resistance
T9	Adrenal glands	• Allergies • chronic fatigue
T10	Kidneys	• Kidney problems • hardening of the arteries • fatigue • nephritis
T11	Kidneys, ureters	• Skin conditions • eczema • pimples
T12	Small intestines, lymph circulation	• Rheumatism • gas pains
L1	Large intestines, inguinal rings	• Colitis • diarrhea • hernia
L2	Appendix, abdomen, thigh	• Cramps • varicose veins • leg pain
L3	Sex organs, uterus, bladder, knees	• Menstrual pains • irregular periods • miscarriages • impotency • knee pain
L4	Prostate gland, lower back	• Back pain • difficulty, painful or frequent urination
L5	Lower back, buttocks, thighs, legs, feet, sciatic nerve, large intestine	• Back pain • leg pain •constipation
Sacrum	Hip bones, buttocks	• Sacroiliac conditions • back pain • hip pain
Coccyx	Rectum, anus	• Hemorrhoids • tail bone pain

Synapses:

- Neurons that transmit impulses to other neurons do not actually touch one another.
- 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.

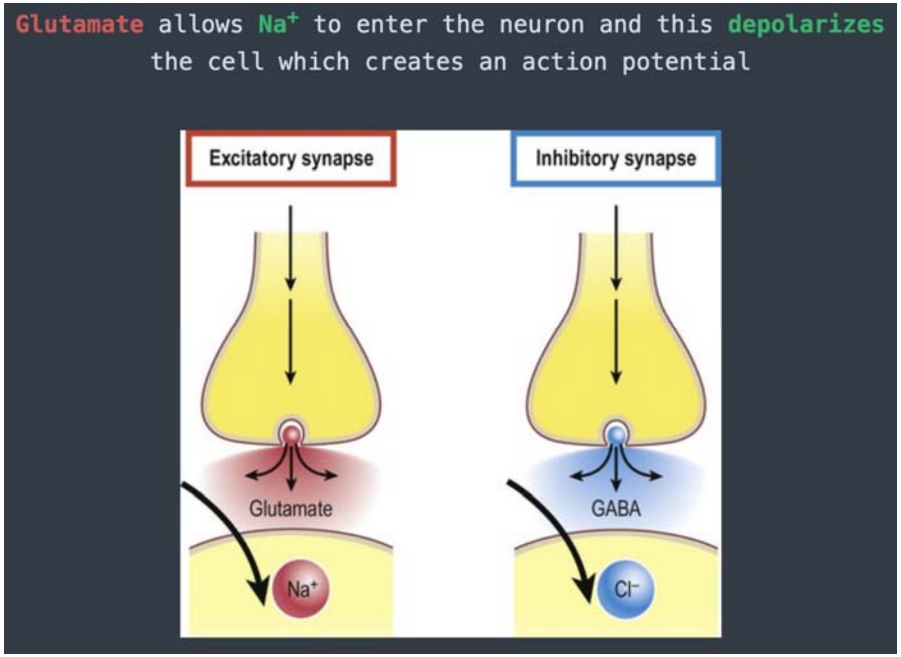
- A chemical inactivator at the cell body or dendrite of the postsynaptic neuron quickly inactivates the neurotransmitter. This prevents unwanted, continuous impulses, unless a new impulse from the first neuron releases more neurotransmitter.



- **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.

- **Such inhibitory synapses are important, for example**, for slowing the heart rate, and for balancing the excitatory impulses transmitted to skeletal muscles. With respect to the skeletal muscles, this inhibition prevents excessive contraction and is important for coordination.



- A nerve impulse cannot go backward across a synapse because there is no neurotransmitter released by the dendrites or cell body. Neurotransmitters can be released only by a neuron's axon, which does not have receptor sites for it, as does the postsynaptic membrane.

- **An example of a neurotransmitter** is:

- **acetylcholine,** which is found at neuromuscular junctions, in the CNS, and in much of the peripheral nervous system. Acetylcholine usually makes a postsynaptic membrane more permeable to Na ions, which brings about depolarization of the postsynaptic neuron.

- **cholinesterase** is the inactivator of acetylcholine.

- There are many other neurotransmitters, especially in the central nervous system. These include:

- **dopamine, GABA, norepinephrine, glutamate, and serotonin**. Each of these neurotransmitters has its own chemical inactivator. Some neurotransmitters are reabsorbed into the neurons that secreted them; this process is called reuptake and also terminates the effect of the transmitter.

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).

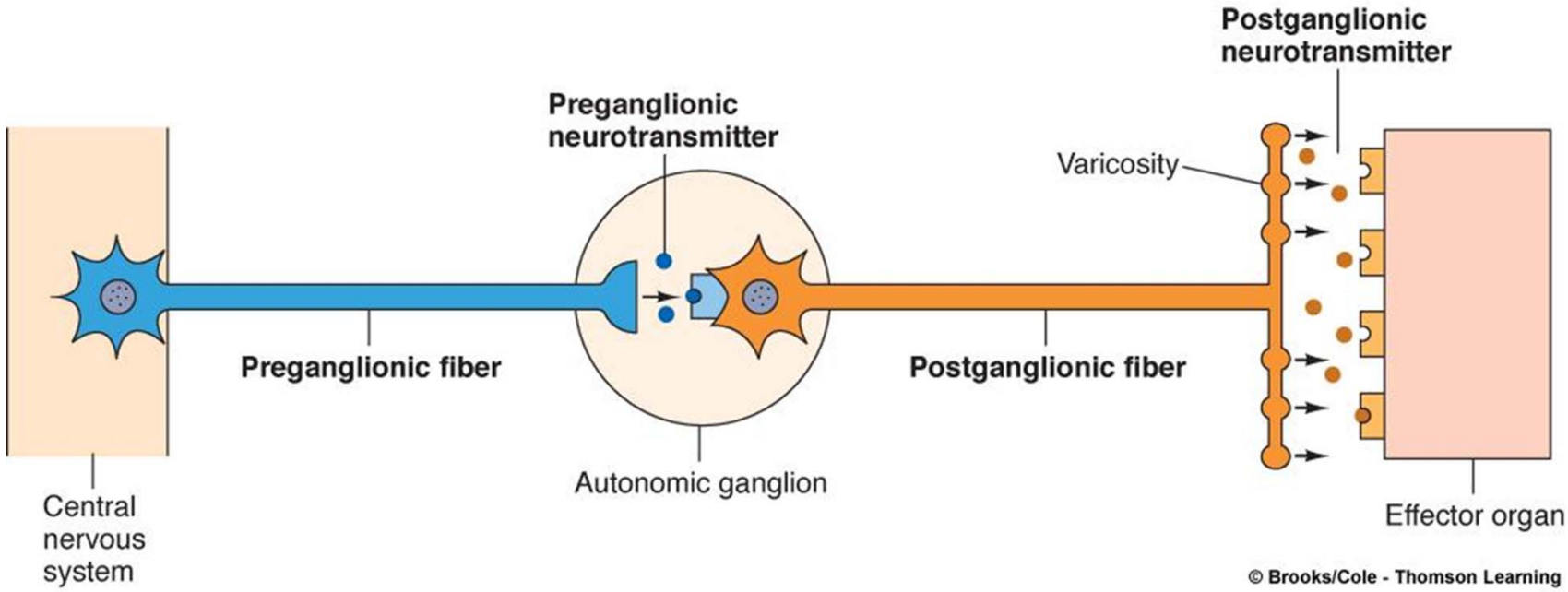
The two divisions have both structural and functional differences. They normally work in an opposing manner, enabling or restoring balance of involuntary functions, maintaining homeostasis.

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.


Postganglionic neurotransmitter
Preganglionic neurotransmitter
Varicosity
Preganglionic fiber
Postganglionic fiber
Autonomic ganglion
Central nervous system
Effector organ
© Brooks/Cole - Thomson Learning

Sympathetic division:

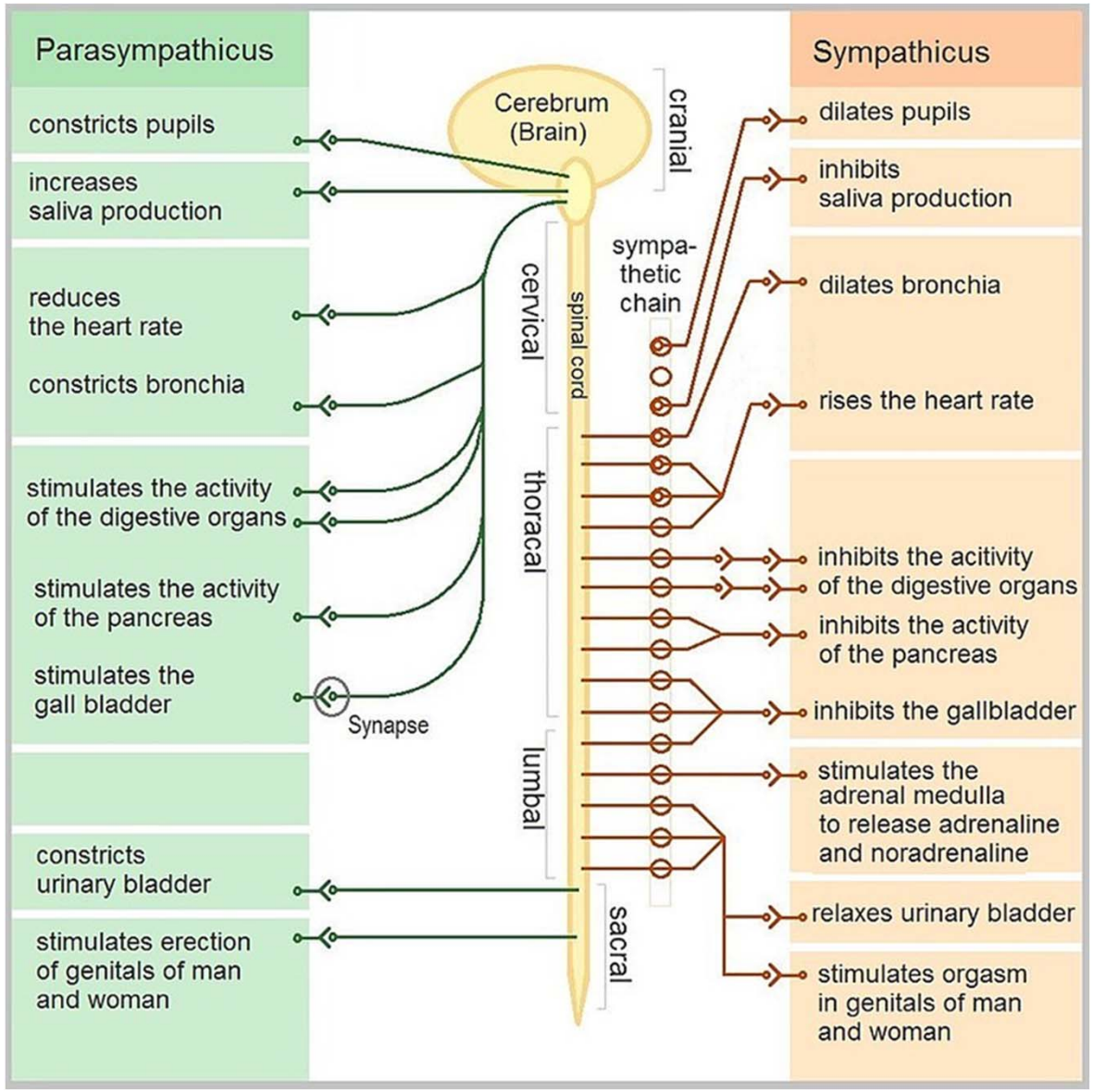
- Another name for the sympathetic division is thoracolumbar division, which tells us where the sympathetic preganglionic neurons originate.

- Their cell bodies are in the thoracic segments and some of the lumbar segments of the spinal cord. Their axons extend to the sympathetic ganglia, most of which are located in two chains just outside the spinal column.

- 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.
- Norepinephrine is released by most sympathetic postganglionic neurons; the inactivator is COMT or MAO.


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:

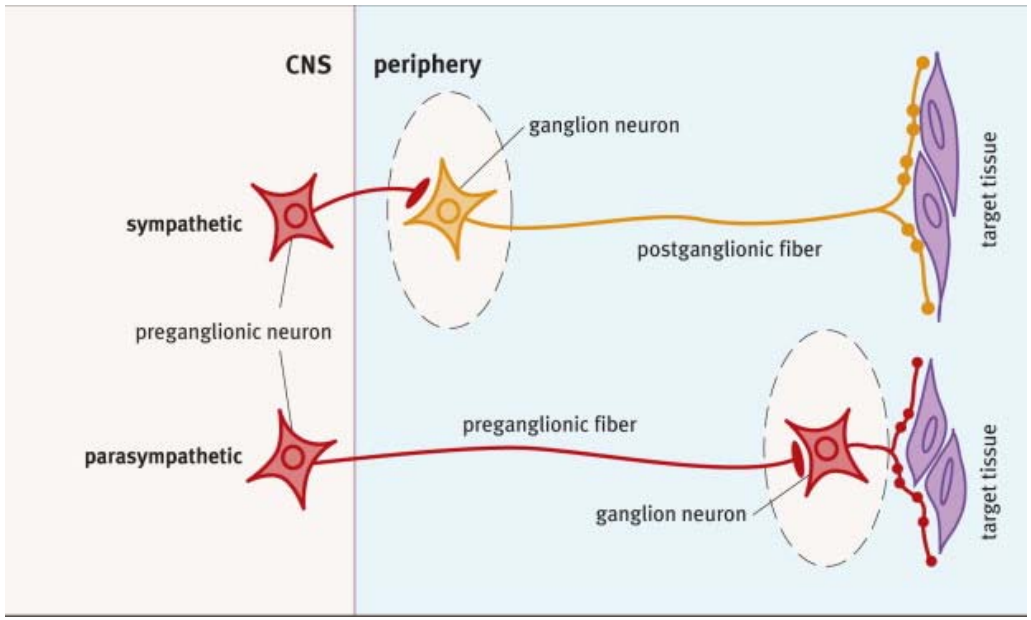
- The other name for the parasympathetic division is the craniosacral division.

- The cell bodies of parasympathetic preganglionic neurons are in the brain stem and the sacral segments of the spinal cord.
- Their axons are in cranial nerve pairs 3, 7, 9, and 10 and in some sacral nerves and extend to the parasympathetic ganglia.
- These ganglia are very close to or actually in the visceral effector, and contain the postganglionic cell bodies, with very short axons to the cells of the effector.

- 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 and by parasympathetic postganglionic neurons; the inactivator is cholinesterase.


CNS
periphery
ganglion neuron
sympathetic
postganglionic fiber
target tissue
preganglionic neuron
preganglionic fiber
parasympathetic
ganglion neuron
target tissue

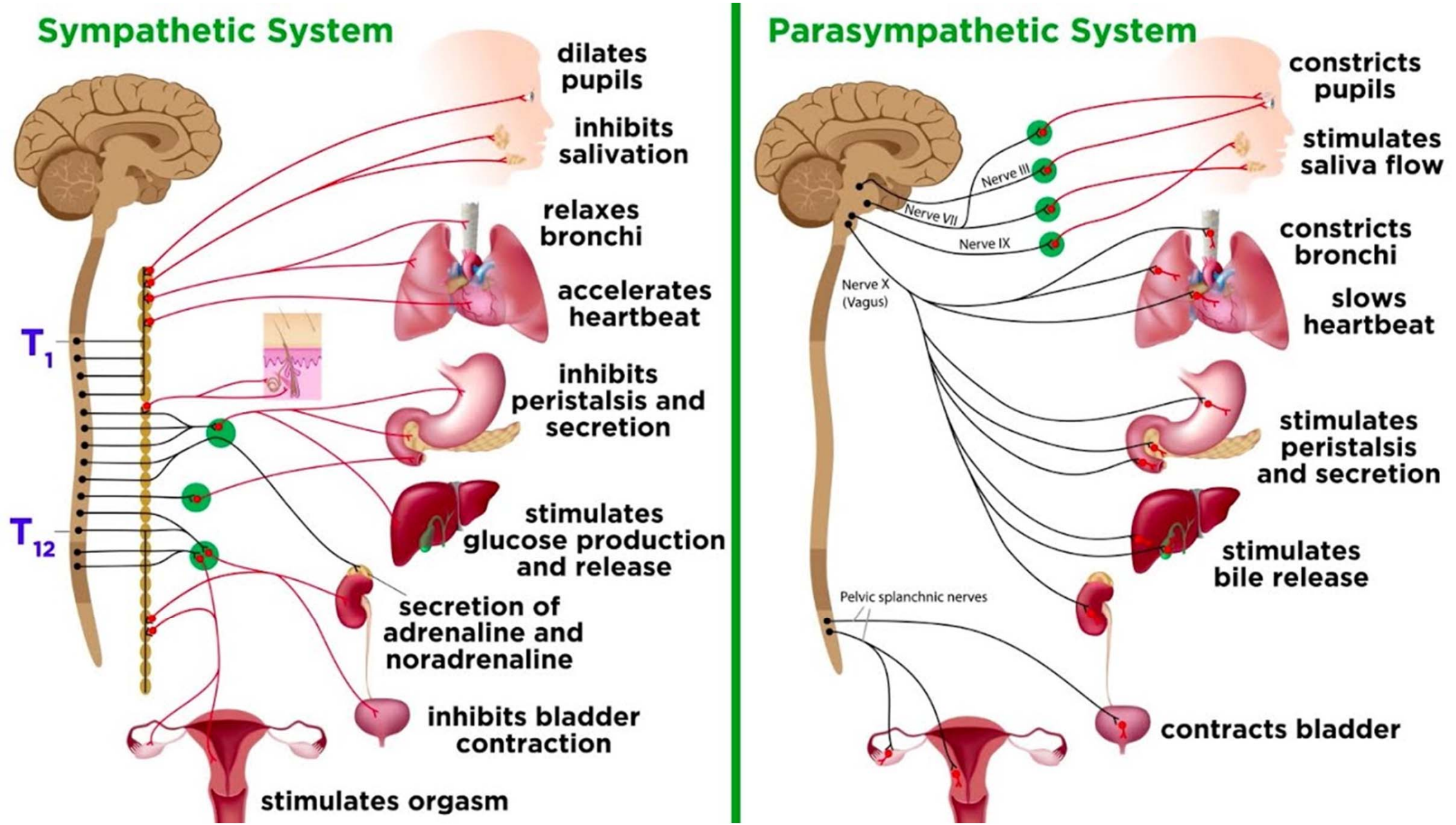

Sympathetic System
dilates pupils
inhibits salivation
relaxes bronchi
accelerates heartbeat
T1
inhibits peristalsis and secretion
T12
stimulates glucose production and release
secretion of adrenaline and noradrenaline
inhibits bladder contraction
stimulates orgasm
Parasympathetic System
constricts pupils
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