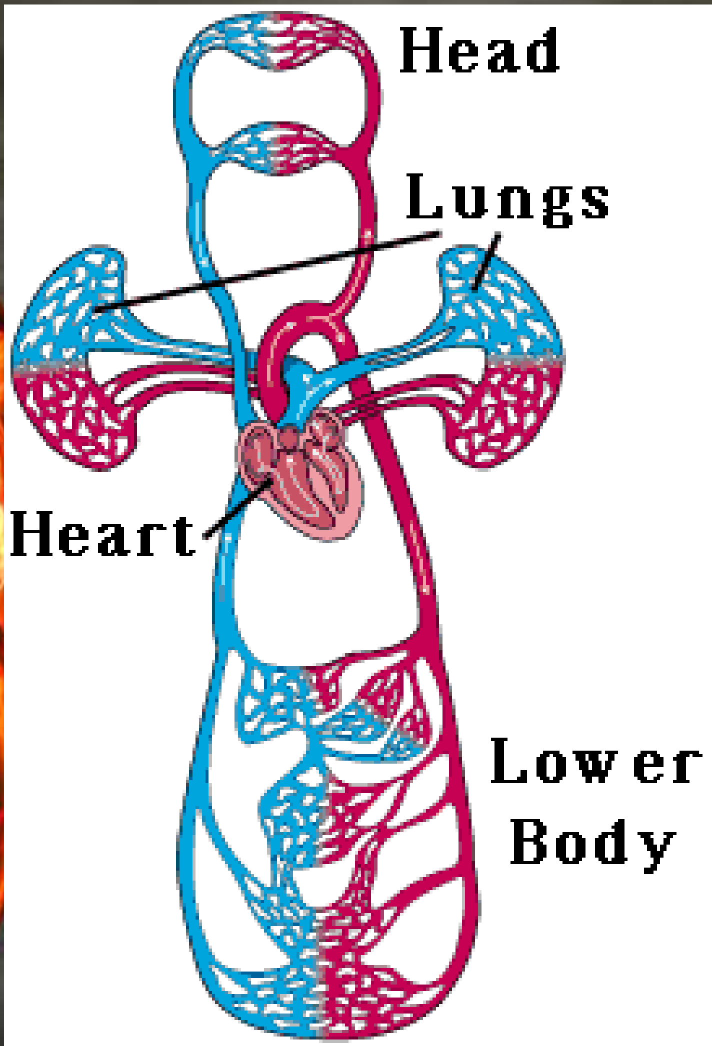
Circulatory System

The **Circulatory System** is responsible for transporting materials throughout the entire body.



- **Arteries** are tubes that carry blood *away from the heart*
- **Veins** are tubes that return blood *to the heart*
- **Capillaries** connect arteries and veins. They are tiny tubes that exchange food, oxygen and wastes between blood and body cells.
- **Pulmonary circulation** is the movement of blood between the heart and lungs
- **Coronary circulation** is the movement of blood from within the heart chambers to the heart tissues themselves
- **Systemic circulation** is the movement of blood between the heart and the rest of the body
- **Interstitial fluid** - is an isotonic solution which bathes and surrounds the cells of multicellular.

Functions of the Circulatory System

- The circulatory system functions in the
  - delivery of oxygen,
  - Delivery of nutrient molecules
  - Delivery of hormones
  - removal of carbon dioxide, ammonia and other metabolic wastes
- 3 parts of the Circulatory system
  - pulmonary circulation - the lungs (pulmonary),
  - coronary circulation - the heart (coronary),
  - systemic circulation - the rest of the body (systemic)

Parts of the Circulatory System

The circulatory System is divided into three major parts:

- The Heart
- The Blood
- The Blood Vessels

The Heart

- The **Heart** is an amazing organ. It's job is to pump your blood and keep the blood moving throughout your body.
- Your heart beats about 100,000 times in one day and about 35 million times in a year. During an average lifetime, the human heart will beat more than 2.5 billion times

Enclosed in a protective sac called the pericardium.

•In the walls of the heart, two layers of tissue form a sandwich around a thick layer of muscle called the myocardium.

•Contractions of the myocardium pump blood through the circulatory system.

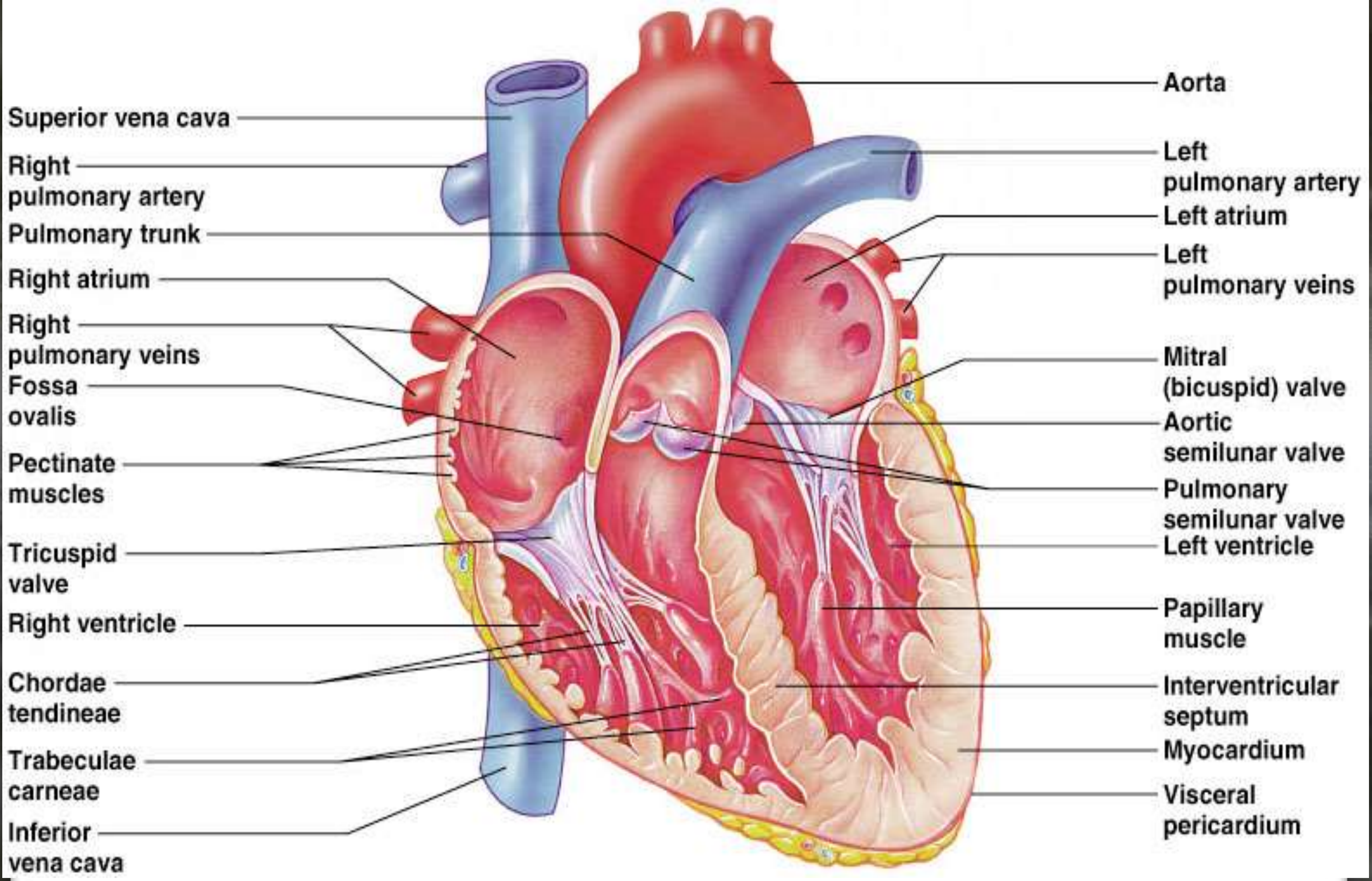
•The right and left sides of the heart are separated by a septum, or wall.

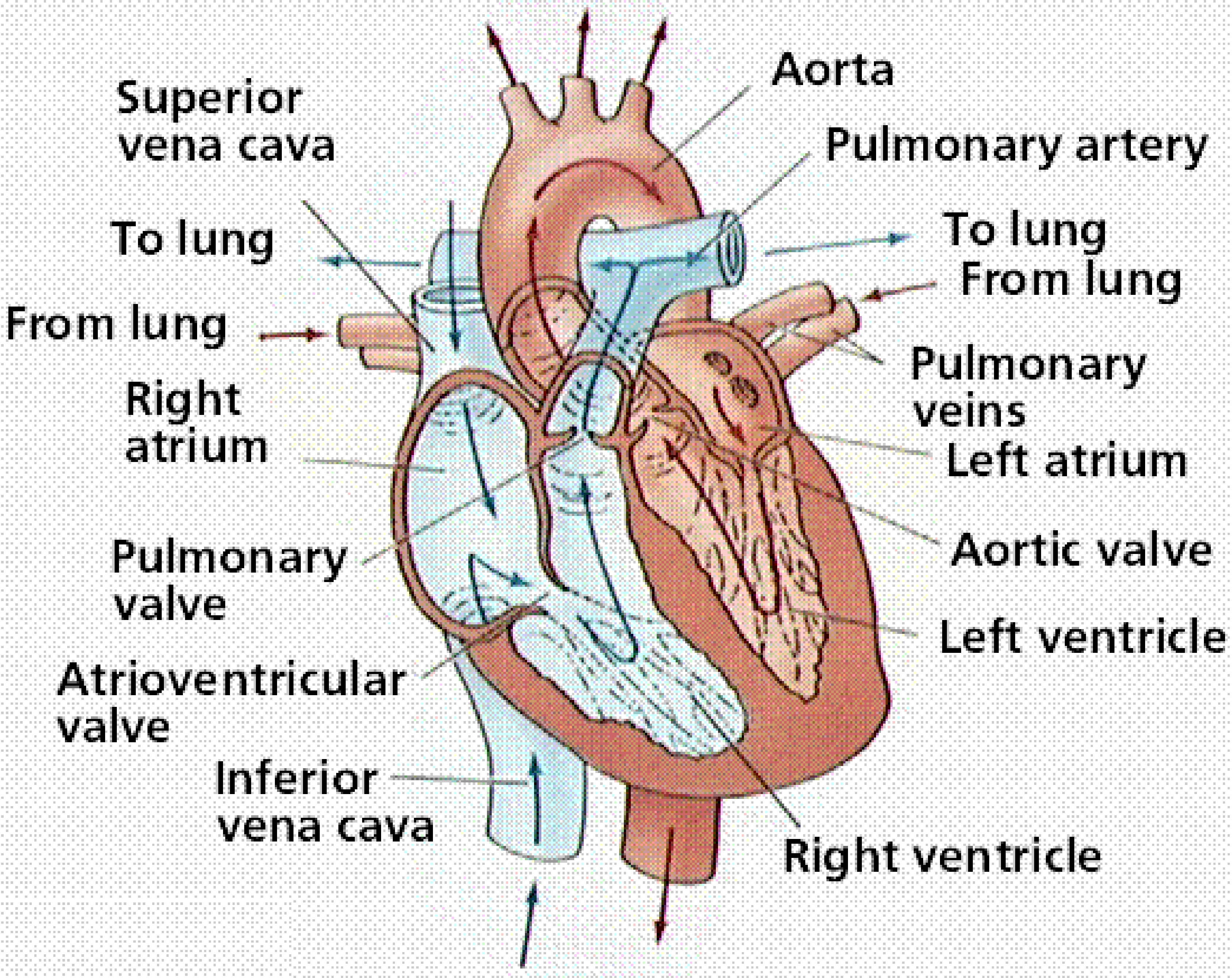
•The septum prevents the mixing of oxygen rich and oxygen poor blood.

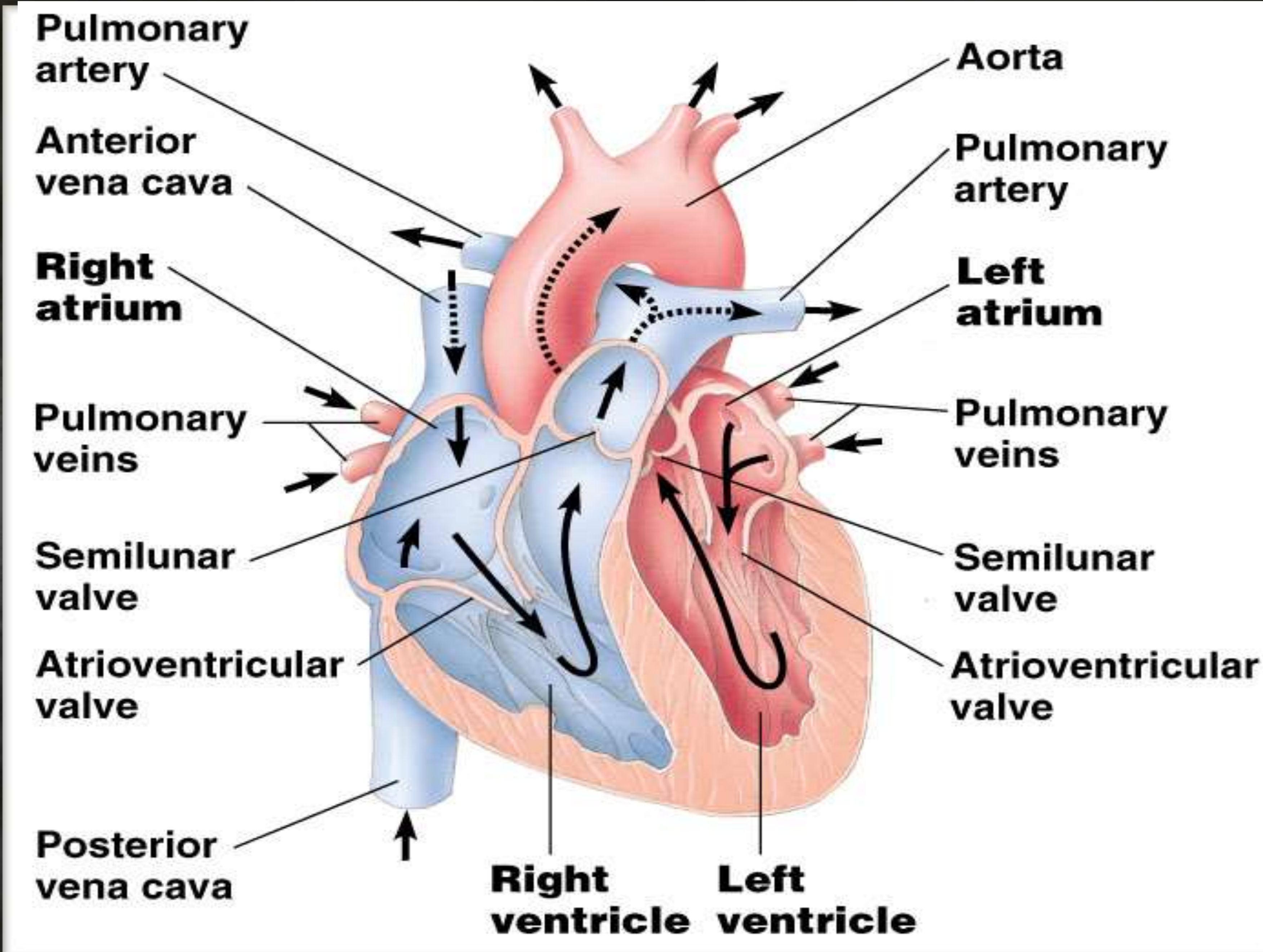
Healthy Heart

- It is your job to keep your heart healthy and there are three main things you need to remember in order to keep your heart healthy.
  - Exercise on a regular basis. Get outside and play. Keep that body moving (walk, jog, run, bike, skate, jump, swim).
  - Eat Healthy. Stay away from high fat foods and have your cholesterol checked regularly
  - Don't Smoke! Don't Smoke! Don't Smoke! Don't Smoke! Don't Smoke!

Gross Anatomy of Heart: Frontal




Superior vena cava
Aorta
Pulmonary artery
To lung
To lung
From lung
From lung
Pulmonary veins
Right atrium
Left atrium
Aortic valve
Pulmonary valve
Left ventricle
Atrioventricular valve
Inferior vena cava
Right ventricle


Pulmonary artery
Anterior vena cava
Right atrium
Pulmonary veins
Semilunar valve
Atrioventricular valve
Posterior vena cava
Right ventricle
Left ventricle
Aorta
Pulmonary artery
Left atrium
Pulmonary veins
Semilunar valve
Atrioventricular valve

Make up of the Heart

- Heart is made up of 4 chambers
  - Right and Left Atrium
  - Right and Left Ventricle
- Ventricles are larger then the atria
- Blood is brought back to the heart by veins and carried away from the heart by Arteries
- The heart is made up of special muscle cells that can carry an electrical impulse called cardiac muscle

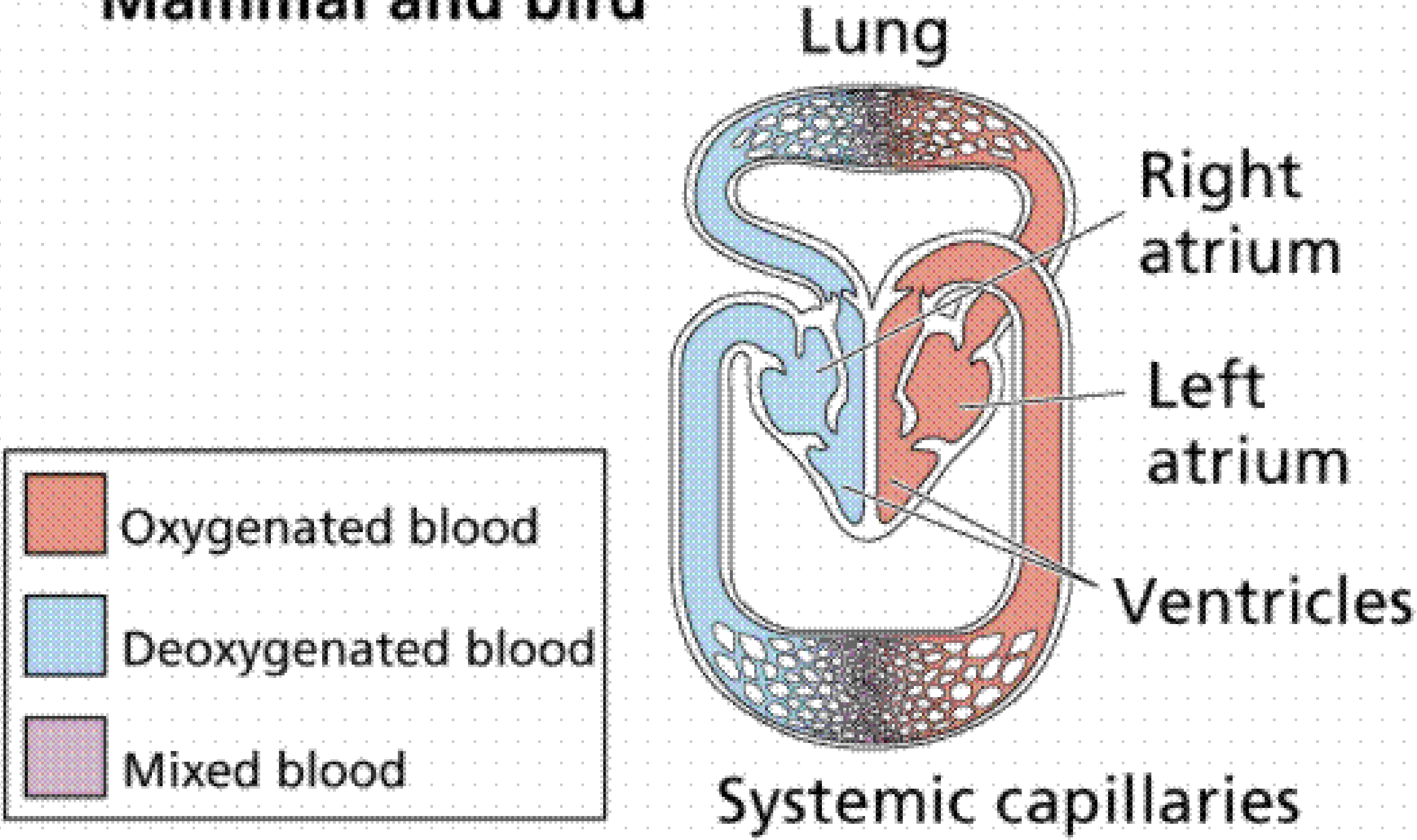
Cardiac Cycle

- The cardiac cycle consists of two parts:
  - systole - contraction of the heart muscle
  - diastole - relaxation of the heart muscle
- Atriums contract while ventricles relax.
- Ventricles contract while Atriums relax
- Heart valves limit flow to a single direction.
- One heartbeat, or cardiac cycle, includes atrial contraction and relaxation, ventricular contraction and relaxation, and a short pause.

Flow of Blood though the Heart

- Right Atrium – *deoxygenated blood*
- Right Ventricle – *deoxygenated blood*
- Pulmonary artery – *deoxygenated blood*
- **LUNGS – Deoxygenated → Oxygenated**
- Pulmonary vein – <u>oxygenated blood</u>
- Left Atrium – <u>oxygenated blood</u>
- Left Ventricle – <u>oxygenated blood</u>
- Aorta – <u>oxygenated blood to body</u>

Mammal and bird



Control of the beat

- The SA node (sinoatrial node) initiates heartbeat causes the artia to contract. The AV node (atrioventricular node) causes ventricles to contract. The SA node is sometimes called the pacemaker since it keeps heartbeat regular.
- lub-DUB. Sound familiar? If you listen to your heart beat, you'll hear two sounds. These "lub" and "DUB" sounds are made by the heart valves as they open and close.
- The first sound, "lub," occurs when increasing pressure of blood inside a ventricle forces the cusps of the AV valves to slam shut. the pressure of blood inside a ventricle causes the semilunar valves (pulmonary and aortic) to open.

The “dup” occurs when the ventricles relax, and blood in the arteries flows backward omentarily, causing the semilunar valves to close.

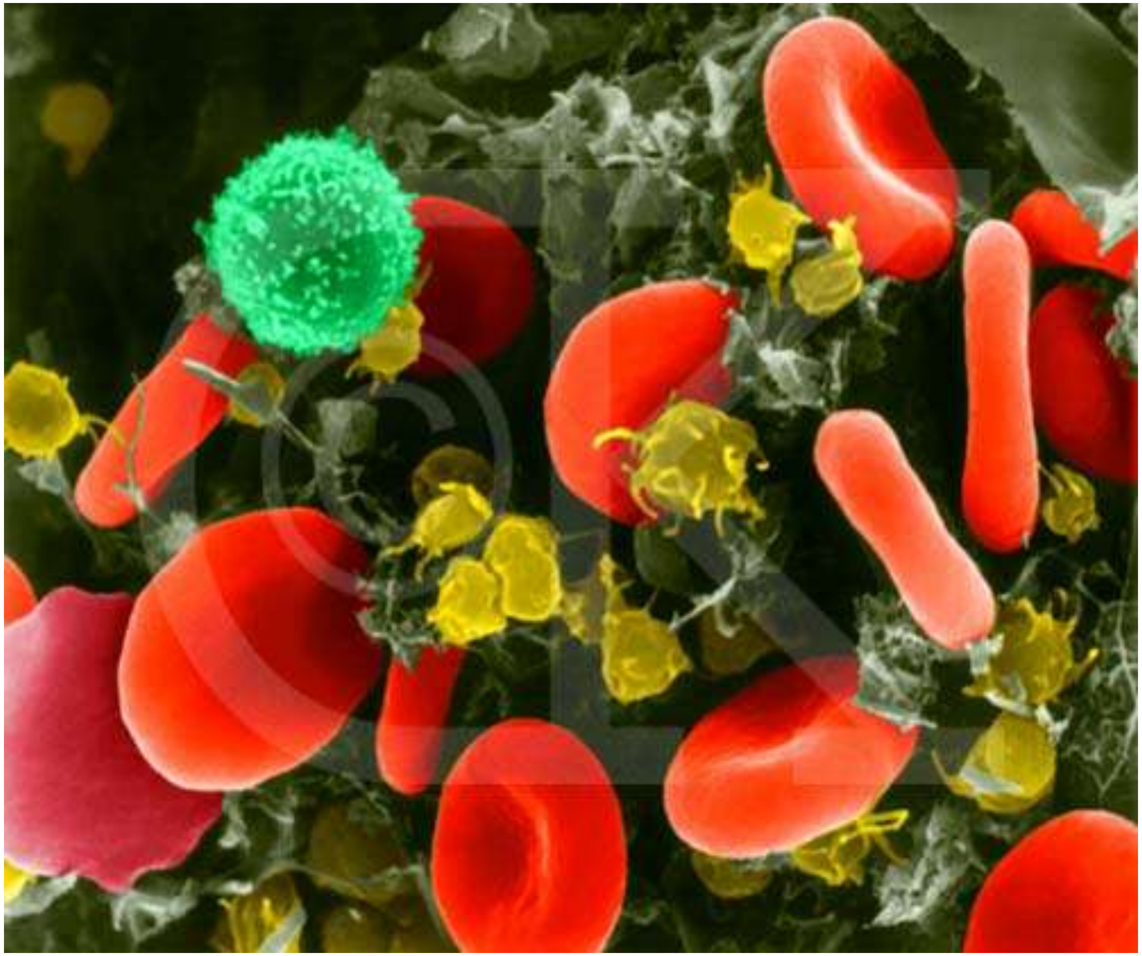
The Blood

- The blood is an amazing substance that is constantly flowing through our bodies.
- Blood is pumped by heart.
- Blood carries nutrients, water, oxygen and waste products to and from body cells.
- Body has about 5.6 liters (6 quarts) of blood. This 5.6 liters of blood circulates through the body three times every minute.

Make up of Blood

- Blood Consists of 60% Plasma and 40% cells and platelets
- Plasma – Liquid portion of blood
- Cells and Platelets:
  - Red Blood Cell (RBCs) or Erythrocytes
  - White Blood Cells (WBCs) or Leukocytes
  - Platelets – creates clots

Make up of Blood



Plasma

- Plasma is 90% water and 10% dissolved materials
  - including proteins, glucose, ions, hormones, and gases.
- It acts as a buffer, maintaining pH near 7.4. Plasma contains nutrients, wastes, salts, proteins, etc.

Red Blood Cells

- **Red Blood Cells** are responsible for carrying oxygen and carbon dioxide.
- Red Blood Cells pick up oxygen in the lungs and transport it to all the body cells.
- After delivering the oxygen to the cells it gathers up the carbon dioxide and transports carbon dioxide back to the lungs where it is removed from the body when we exhale.

Life Span of an RBC

- Life-span of an erythrocyte is only 120 days, after which they are destroyed in liver and spleen.

White Blood Cells (leukocytes)

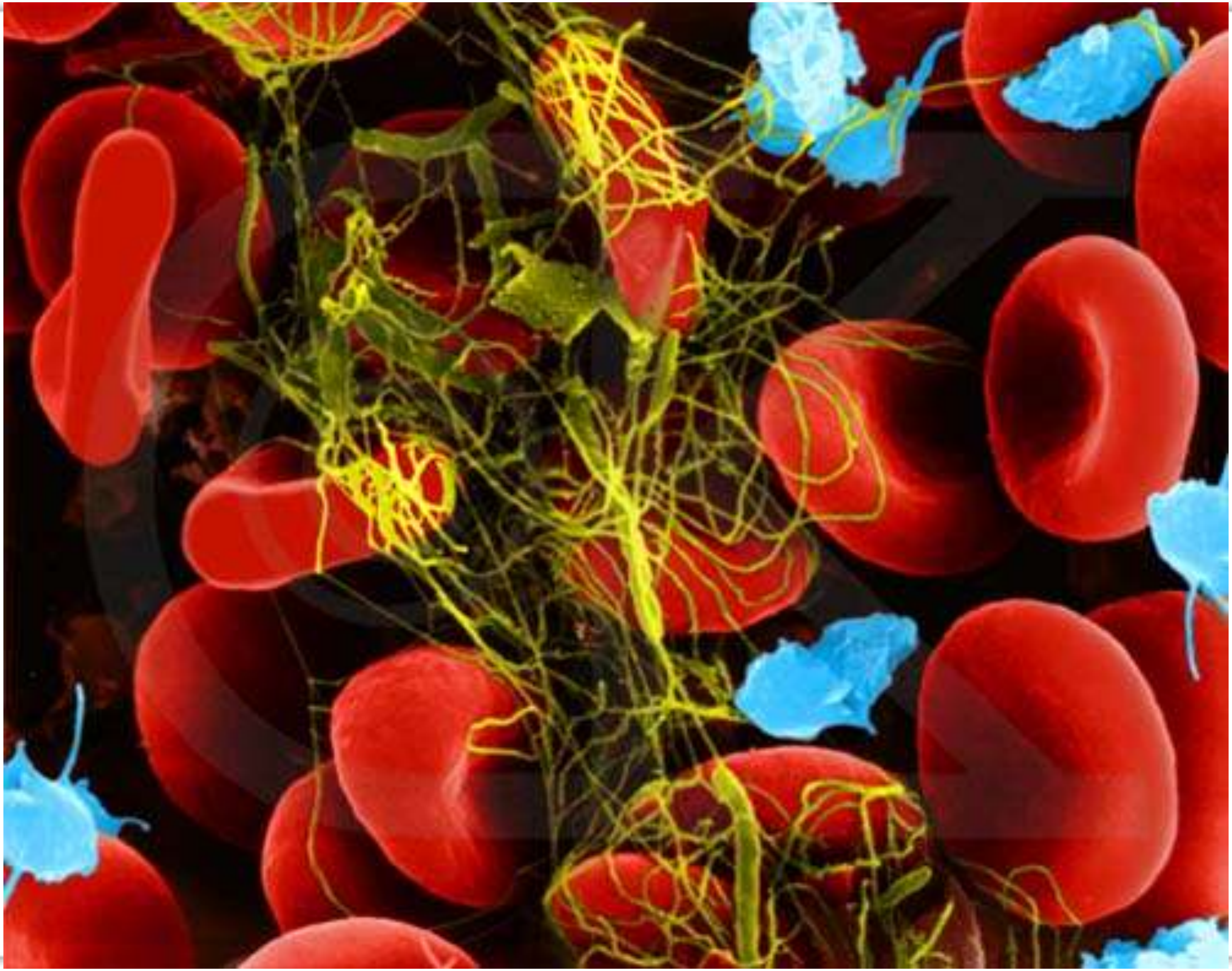
- are larger than erythrocytes,
- have a nucleus, and lack hemoglobin.
- They function in the cellular immune response.
- White blood cells (leukocytes) are less than 1% of the blood's volume.

Type of WBCs

- There are five types of leukocytes:
  - Neutrophils enter the tissue fluid by squeezing through capillary walls and phagocytosis foreign substances.
  - Macrophages release white blood cell growth factors, causing a population increase for white blood cells.
  - Lymphocytes fight infection.
  - T-cells attack cells containing viruses.
  - B-cells produce antibodies. Antigen-antibody complexes are phagocytized by a macrophage. White blood cells can squeeze through pores in the capillaries and fight infectious diseases in interstitial areas

Platelets

- **Platelets** are blood cells that help stop bleeding.
  - When we cut ourselves we have broken a blood vessel and the blood leaks out.
  - In order to plug up the holes where the blood is leaking from the platelets start to stick to the opening of the damaged blood vessels.
  - As the platelets stick to the opening of the damaged vessel they attract more platelets, fibers and other blood cells to help form a plug to seal the broken blood vessel.
  - When the platelet plug is completely formed the wound stops bleeding.
  - Platelets survive for 10 days before being removed by the liver and spleen.
  - Hemophilia – inability to clot – bleeders disease



Where are the blood cells made?

- In bone marrow.
- The Red Blood Cells are made in the red marrow and White Blood Cells and Platelets are made in the yellow marrow.
- Bone marrow is a soft tissue inside of bones that produces blood cells.

The Blood Vessels

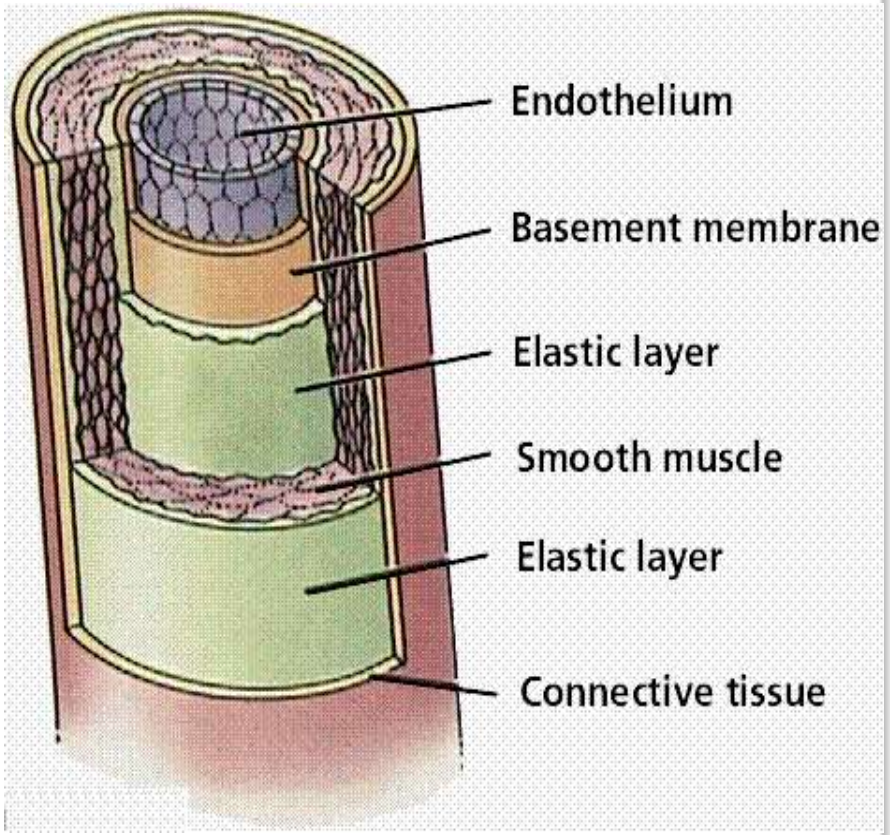
- In class we talked about three types of **blood vessels**:
- **Arteries** – carry blood AWAY from heart
- **Capillaries** – Place were gas exchange takes place
- **Veins** – Carry blood BACK to the heart

Arteries

- **Arteries** are blood vessels that carry oxygen rich blood AWAY from the heart. Remember, Arteries Away,
- The aorta, the largest artery in the body, is almost the diameter of a garden hose..
- Arterial walls are able to expand and contract with the heart as it pushes blood through the body

Arteries

- Arterial walls are able to expand and contract.
- Arteries have three layers of thick walls.
- Smooth muscle fibers contract, another layer of connective tissue is quite elastic, allowing the arteries to carry blood under high pressure.

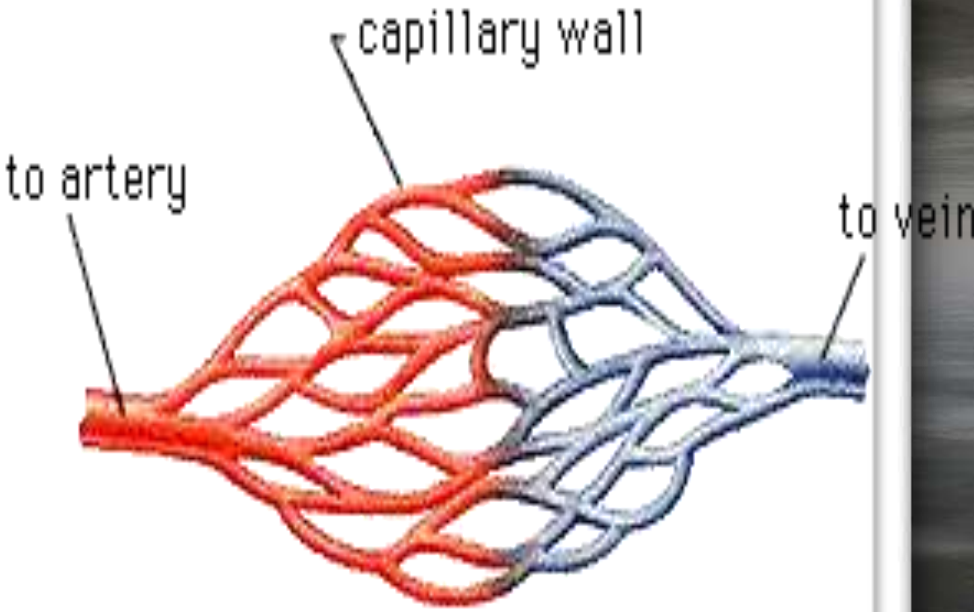


Artery Continued

- The aorta is the main artery leaving the heart.
- The pulmonary artery is the only artery that carries oxygen-poor blood. The pulmonary artery carries deoxygenated blood to the lungs.
- Arterioles are small arteries that connect larger arteries with capillaries.
  - Small arterioles branch into collections of capillaries known as capillary beds.

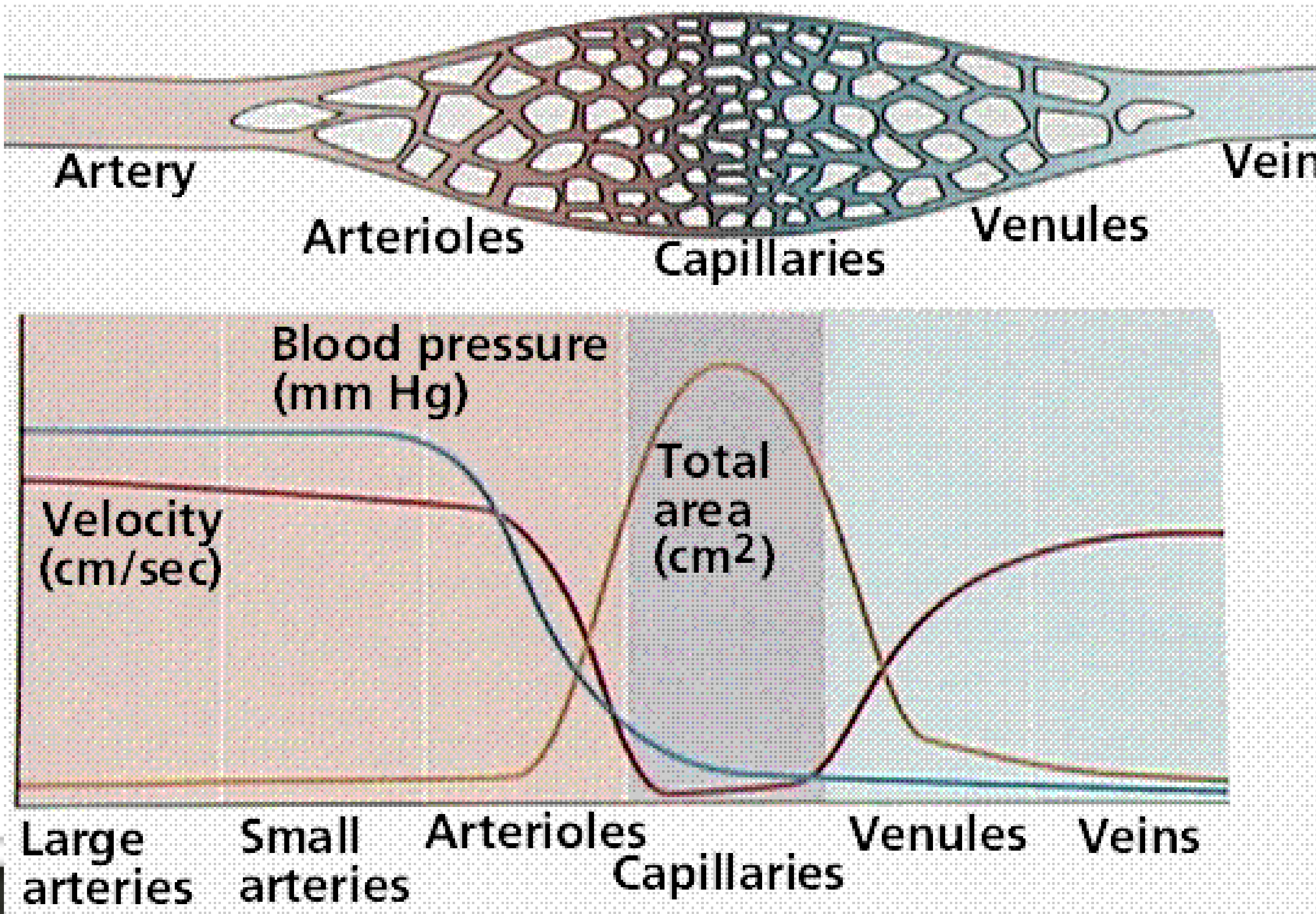
Capillaries

- **Capillaries** are tiny blood vessels. Only 1 RBC fits though at a time
- Capillaries are only 1 cell thick
- Capillaries connect arteries to veins.



Capillaries 2

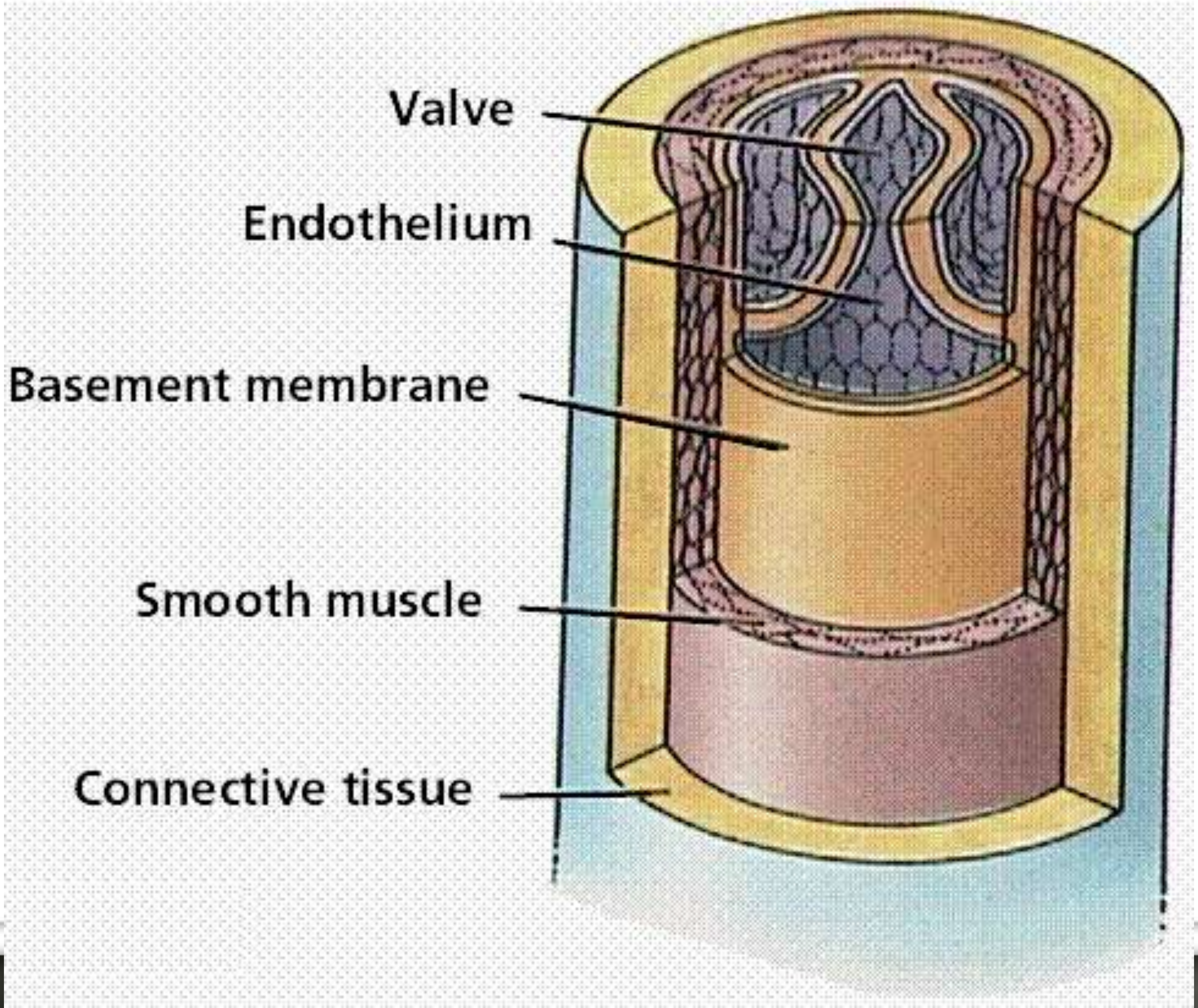
- Food substances (nutrients), oxygen and wastes pass in and out of your blood through the capillary walls.
- Capillaries, on the other hand, are so small that it takes ten of them to equal the thickness of a human hair
- Capillaries are thin-walled blood vessels in which gas exchange occurs. In the capillary, the wall is only one cell layer thick. Capillaries are concentrated into capillary beds.
- Nutrients, wastes, and hormones are exchanged across the thin walls of capillaries.


Artery
Arterioles
Capillaries
Venules
Vein
Blood pressure (mm Hg)
Velocity (cm/sec)
Total area (cm2)
Large arteries
Small arteries
Arterioles
Capillaries
Venules
Veins

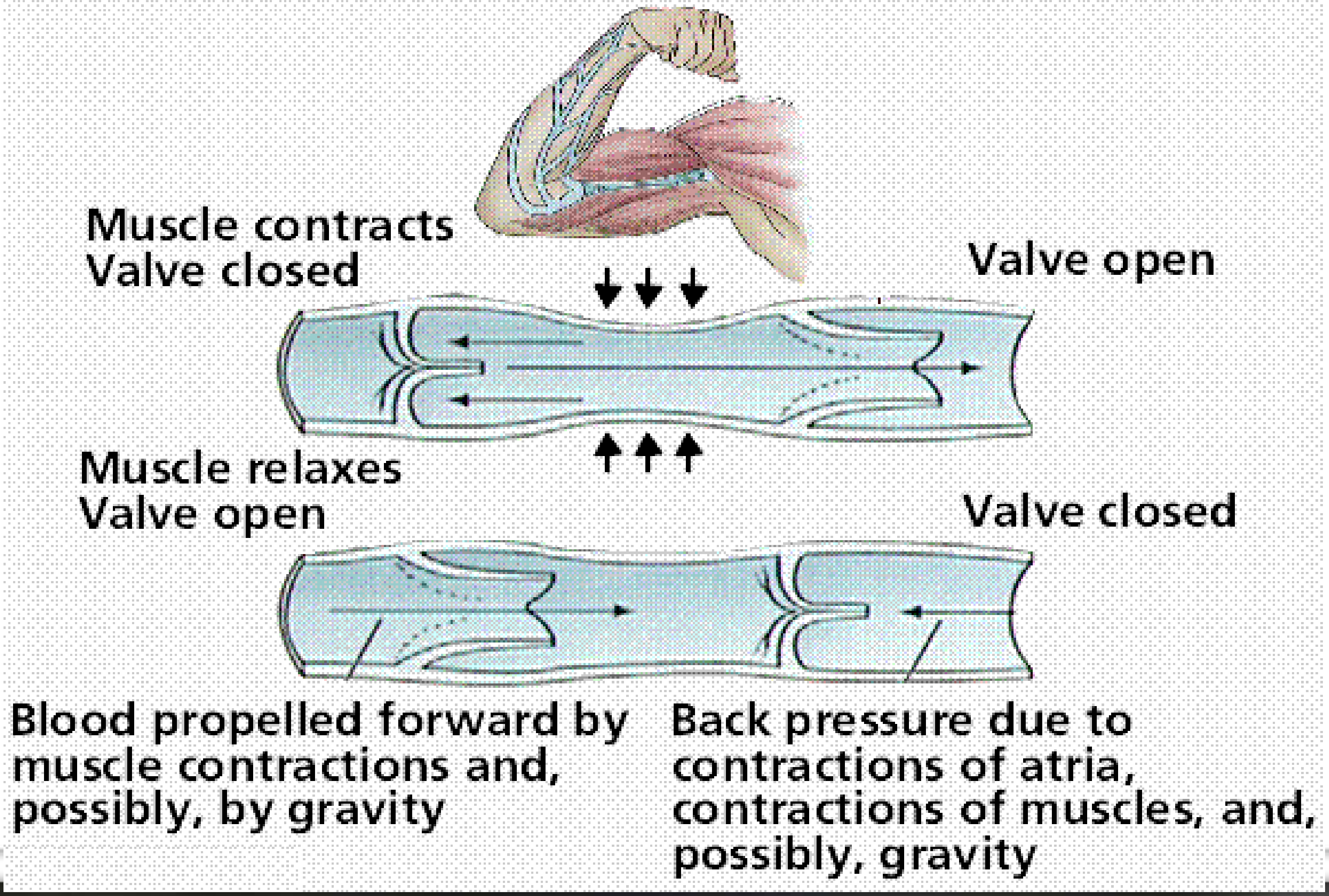
Veins

- **Veins** carry blood back toward heart.
- Veins carry blood from capillaries to the heart. With the exception of the pulmonary veins, blood in veins is oxygen-poor. The pulmonary veins carry oxygenated blood from lungs back to the heart.
- Venules are smaller veins that gather blood from capillary beds into veins.
- The veins have valves that prevent back-flow of blood.

Structure of a vein

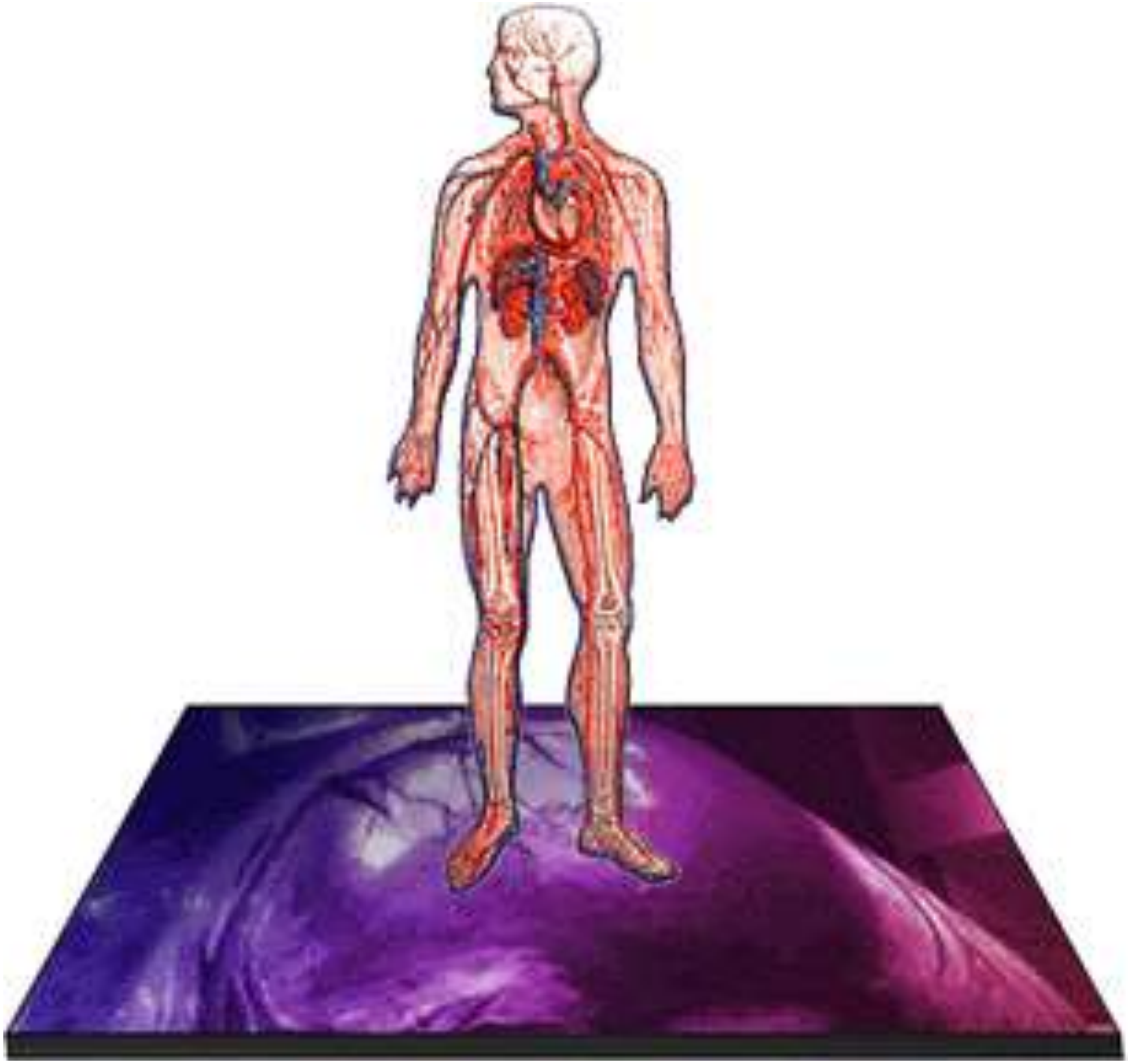


The actions of muscles to propel blood through the veins



AMAZING FACTS

- One drop of blood contains a half a drop of plasma, **5 MILLION** Red Blood Cells, **10 Thousand** White Blood Cells and **250 Thousand** Platelets.
- You have thousands of miles of blood vessels in your body. Anywhere between 75,000 -100,000 miles. The earths diameter is 25,000 miles. **So your blood vessels around the equator 3 to 4 times!**
- Keep your heart healthy...it's going to have to beat about **3 BILLION times during your lifetime!**



Central Nerve System   CNS

Essam Mohammed AL Fahadawy

The nervous system has two major divisions . The **central nervous system (CNS)** consists of the brain and spinal cord. The brain is completely surrounded and protected by the skull. It connects directly to the spinal cord, similarly protected by the vertebral column.

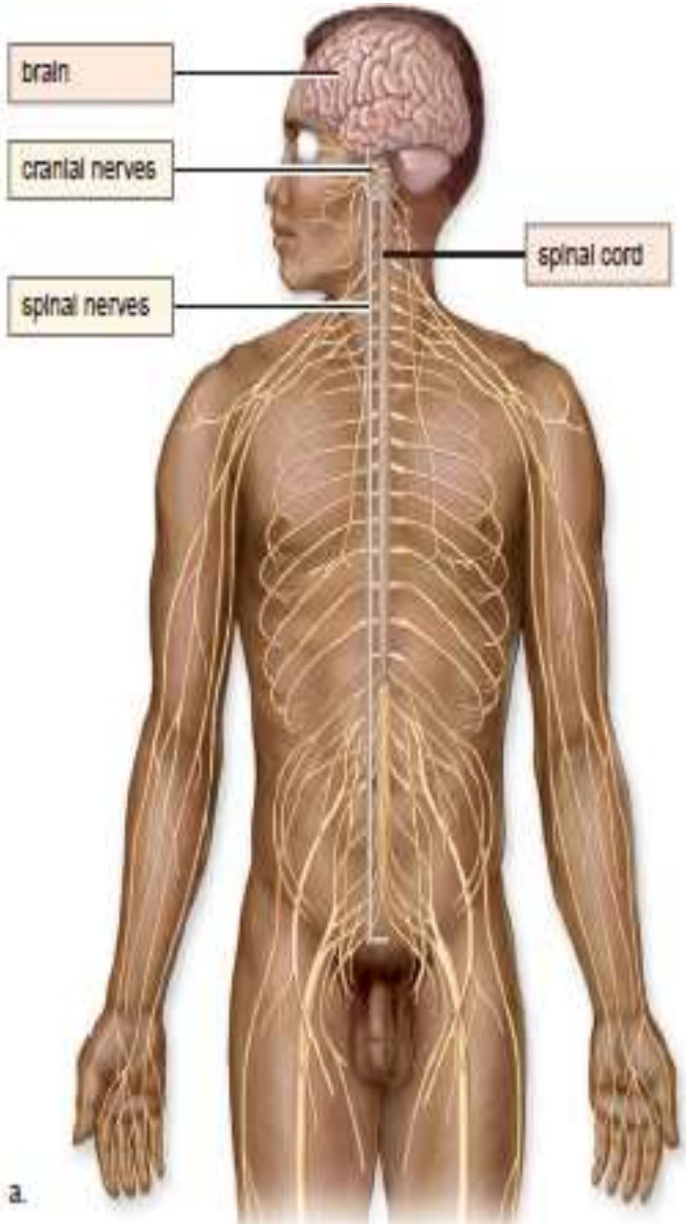
The **peripheral nervous system (PNS)** consists of nerves. Nerves lie outside the CNS.

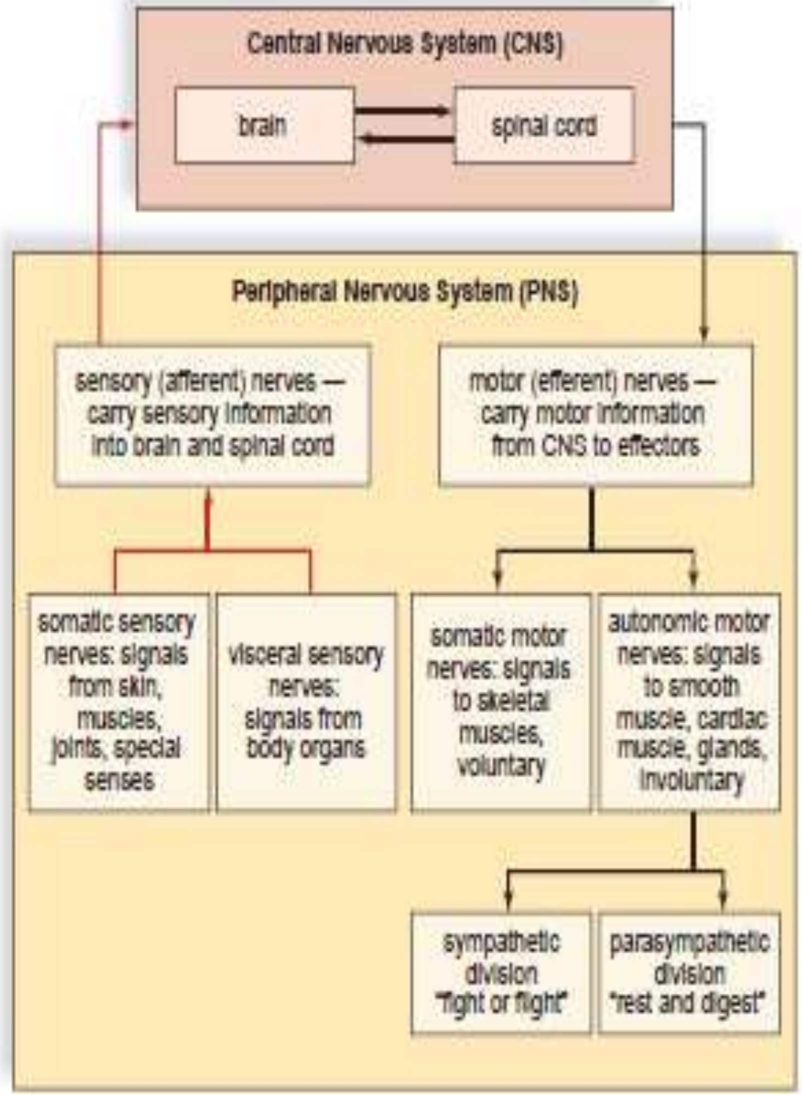
The nervous system has three specific functions:

1. The nervous system receives sensory input. Sensory receptors in skin and other organs respond to external and internal stimuli by generating nerve signals that travel by way of the PNS to the CNS. For example, if you smell baking cookies, olfactory (smell) receptors in the nose uses the PNS to transmit that information to the CNS.

2. The CNS performs information processing and integration, summing up the input it receives from all over the body. The CNS reviews the information, stores the information as memories, and creates the appropriate motor responses. The smell of those baking cookies evokes pleasant memories of their taste

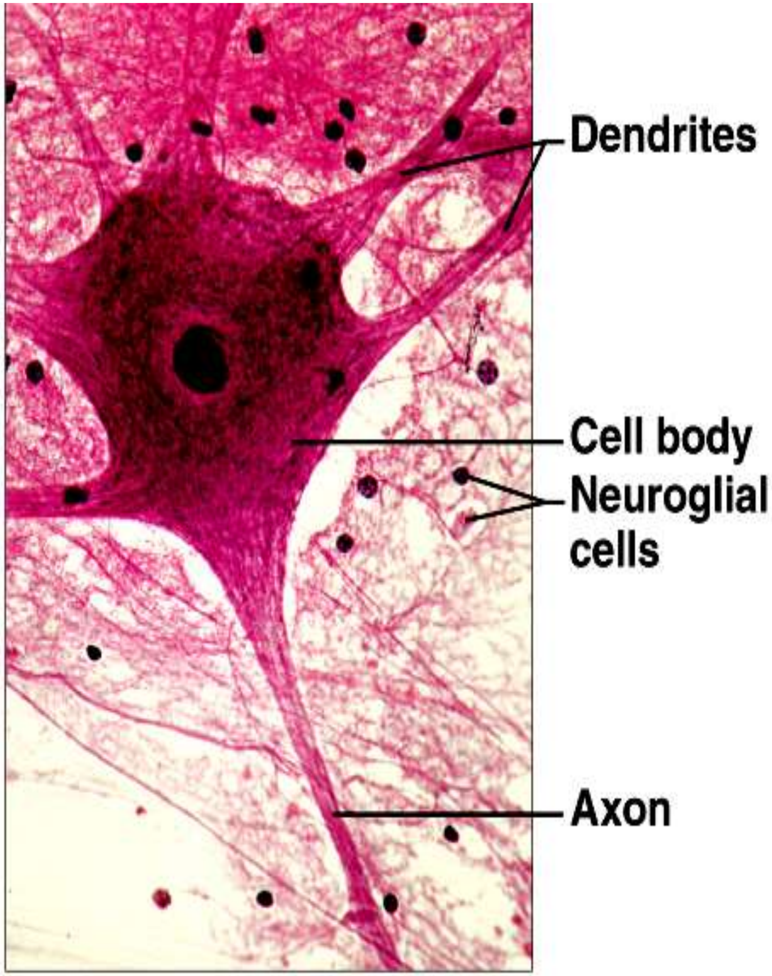
3. The CNS generates motor output. Nerve signals from the CNS go by way of the PNS to the muscles, glands, and organs, all in response to the cookies. Signals to the salivary glands make you salivate. Your stomach generates the acid and enzymes needed to digest.


brain
cranial nerves
spinal cord
spinal nerves
a.


Central Nervous System (CNS)
brain
spinal cord
Peripheral Nervous System (PNS)
sensory (afferent) nerves — carry sensory information into brain and spinal cord
motor (efferent) nerves — carry motor information from CNS to effectors
somatic sensory nerves: signals from skin, muscles, joints, special senses
visceral sensory nerves: signals from body organs
somatic motor nerves: signals to skeletal muscles, voluntary
autonomic motor nerves: signals to smooth muscle, cardiac muscle, glands, involuntary
sympathetic division "fight or flight"
parasympathetic division "rest and digest"
b.

Nervous Tissue is composed of two major cell types: **neurons** and **neuroglial cells**.

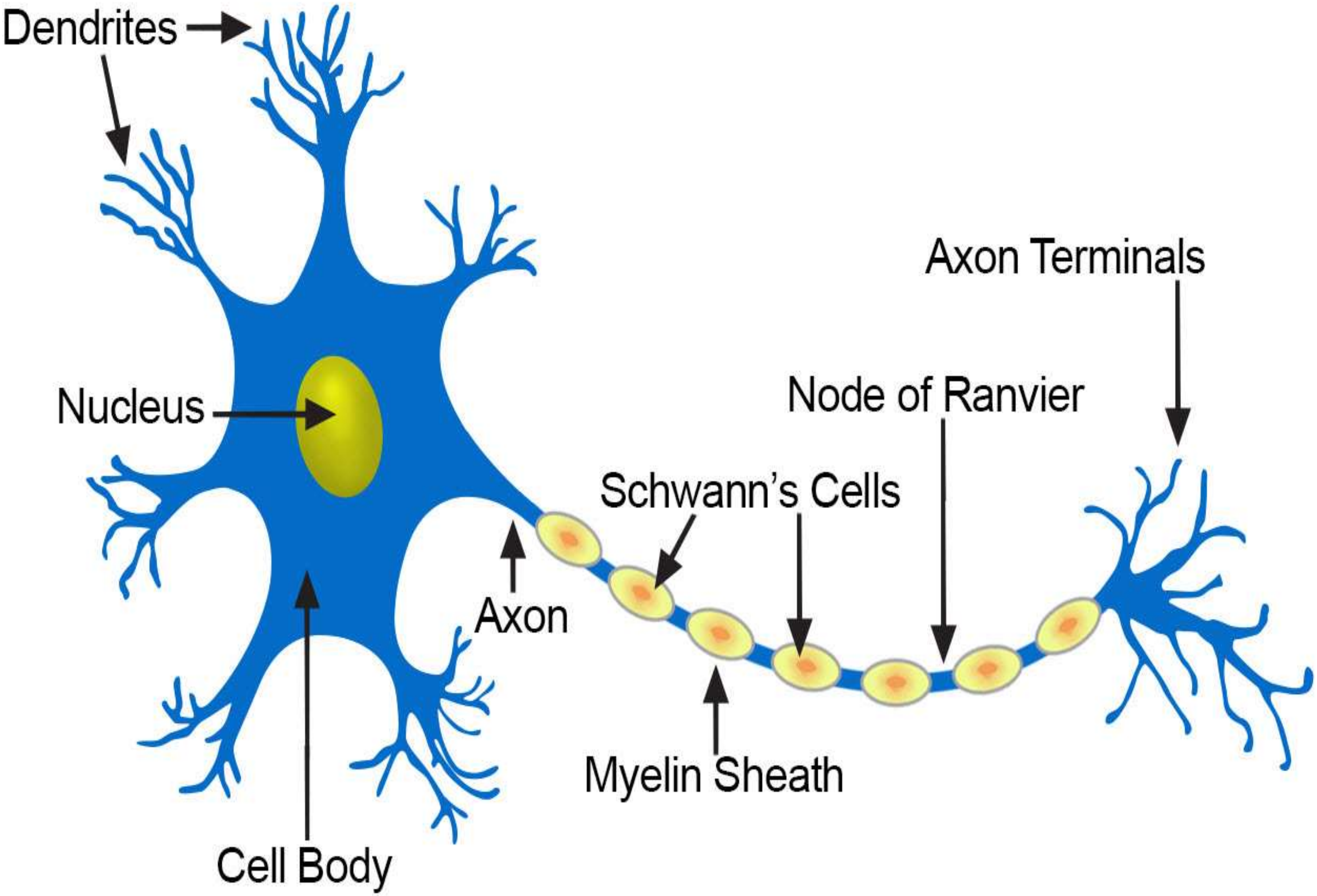
Neurons are the cells that transmit nerve impulses between parts of the nervous system; **neuroglia** support and nourish neurons.



Neuron Structure

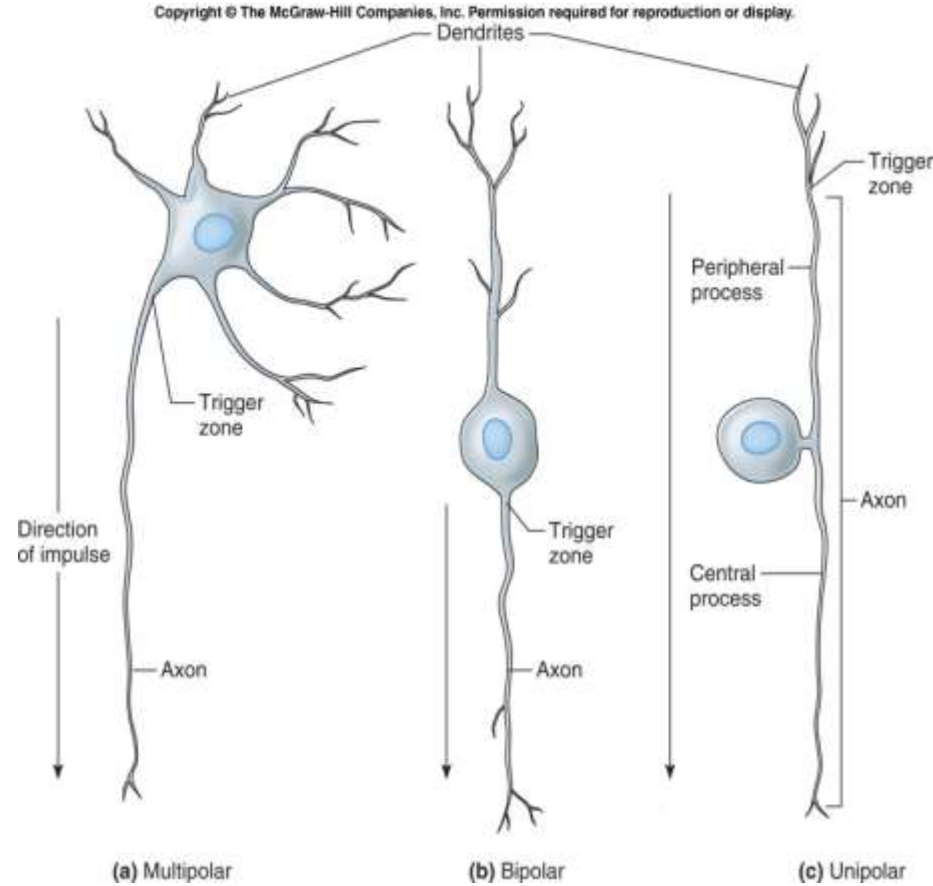
Neurons vary in appearance, but all of them have just three parts: a cell body, dendrites, and an axon. The **cell body** contains the nucleus, as well as other organelles. **Dendrites** are short extensions that receive signals from sensory receptors or other neurons. Incoming signals from dendrites can result in nerve signals that are then conducted by an axon. The **axon** is the portion of a neuron that conducts nerve impulses.

Structure of a Typical Neuron



Classification of Neurons

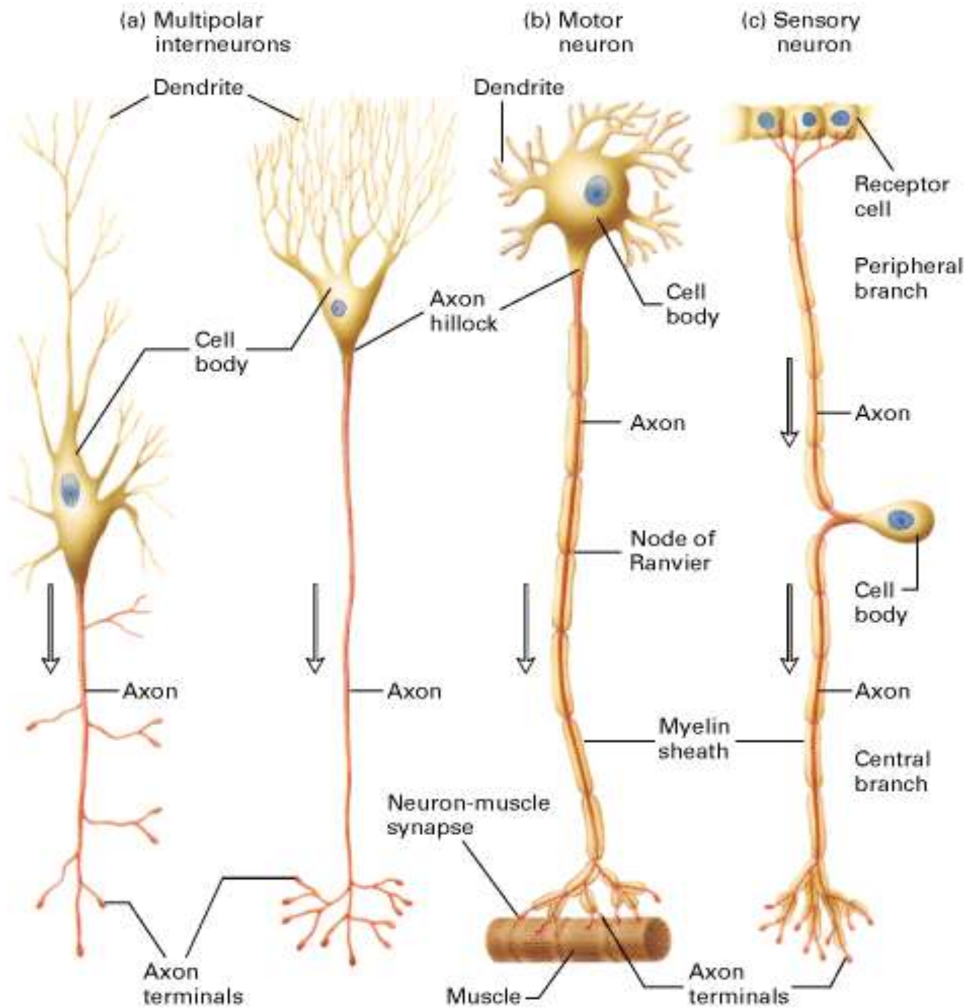
- Neurons can be classified based on function or by structure.
- Structure:
- (1) Multipolar
- Many processes arising from cell body
- Brain or spinal cord
- (2) Bipolar
- 2 processes (1 from each end of cell body)
- Ear, eyes, nose
- (3) Unipolar
- Single process extends from cell body
- Outside of brain & spinal cord



Classification of Neurons (by function)

Sensory Neurons – (afferent) have specialized receptor ends that sense stimuli and then carry impulses from peripheral body parts to brain or spinal cord.

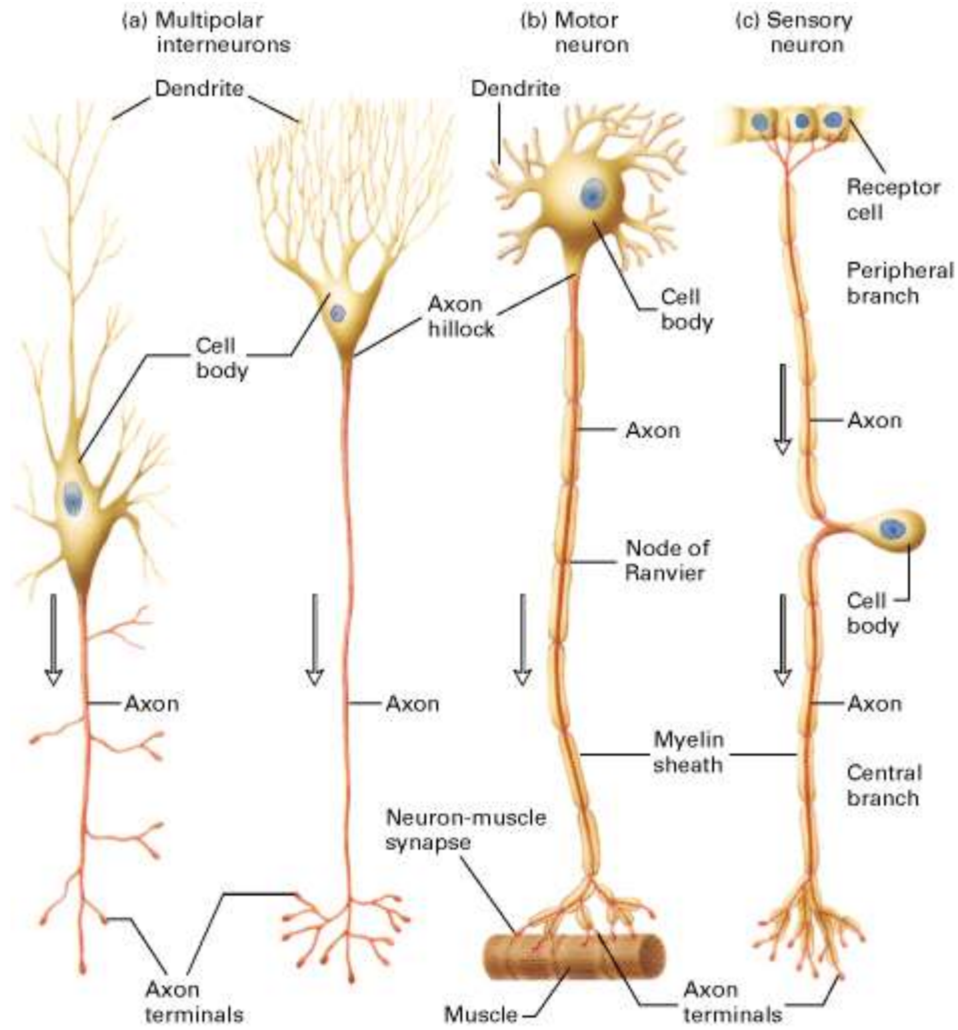
Can be **unipolar** or **bipolar**.

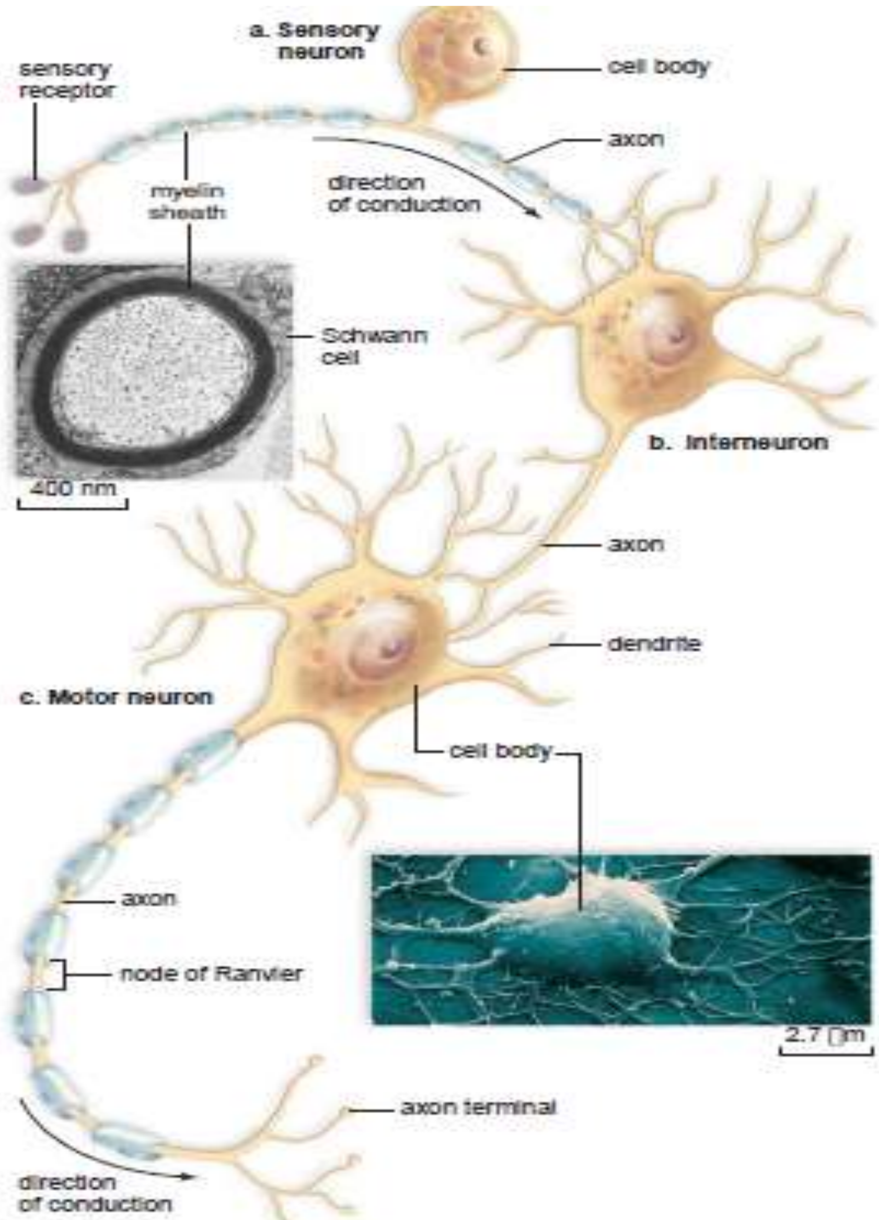


Interneurons – lie entirely within the brain or spinal cord; direct incoming sensory impulses to appropriate parts for processing and interpreting.

Motor Neurons – (efferent) carry impulses out of the brain or spinal cord to effectors (muscles, glands).

Interneurons and motor neurons are **multipolar**.

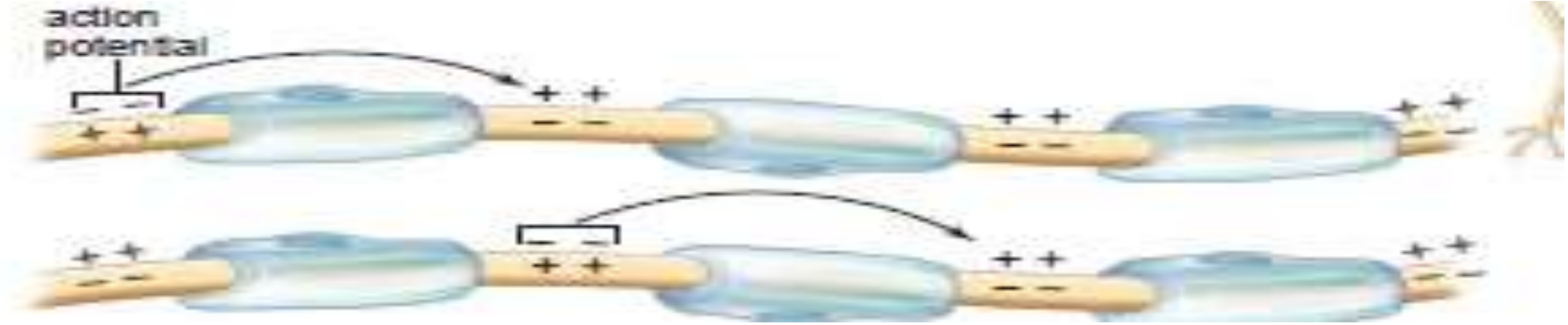



a. Sensory neuron
cell body
sensory receptor
axon
myelin sheath
direction of conduction
Schwann cell
400 nm
b. Interneuron
axon
dendrite
c. Motor neuron
cell body
axon
node of Ranvier
2.7 µm
axon terminal
direction of conduction

Myelin Sheath

Myelin is an insulating layer, or **sheath** that forms around nerves, including those in the brain and spinal cord. It is made up of protein and fatty substances. This **myelin sheath** allows electrical impulses to transmit quickly and efficiently along the nerve cells. If **myelin** is damaged, these impulses slow down.

In the PNS, this covering is formed by a type of neuroglia called **Schwann cells.** Each neuroglia cell covers only a portion of an axon, so the myelin sheath is interrupted. The gaps where there is no myelin sheath are called **nodes of Ranvier.** Long axons tend to have a myelin sheath, but short axons do not. The gray matter of the CNS is gray because it contains no myelinated axons; the white matter of the CNS is white because it does.

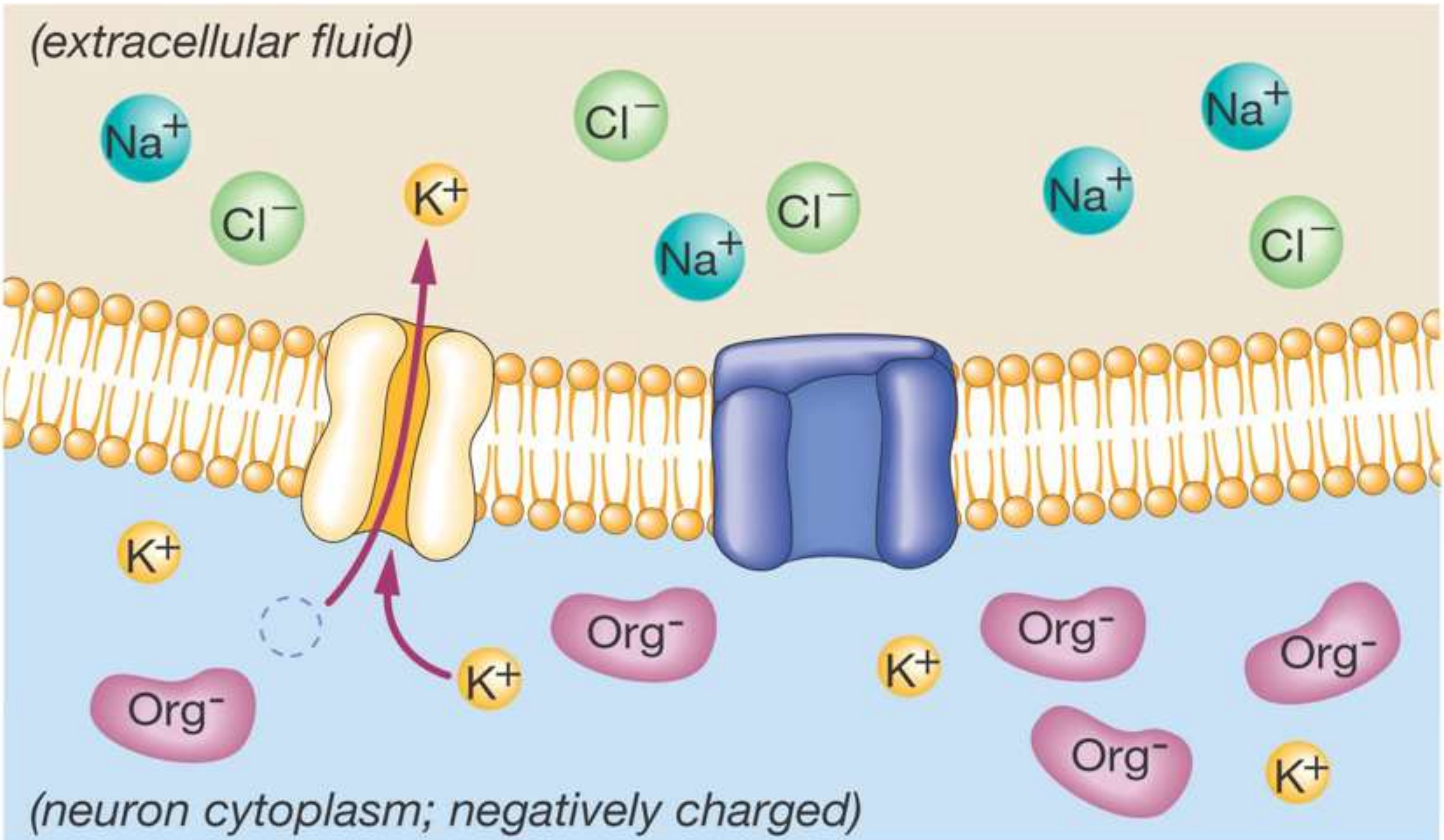


Resting Potential

The **resting potential,** exists because the cell membrane is *polarized:* positively charged ions are outside the cell, with negatively charged ions inside. the outside of the cell is positive because positively charged sodium ions (Na+) gather around the outside of the cell membrane. At rest, the neuron's cell membrane is permeable to potassium, but not to sodium. Thus, positively charged potassium ions (K+) contribute to the positive charge by diffusing out of the cell to join the sodium ions. The inside of the cell is negative because of the presence of large, negatively charged proteins and other molecules that are stuck inside the cell because of their size.

Neurons actively transport sodium ions out of the cell and return potassium ions to the cytoplasm. A protein carrier in the membrane, called the **sodium–potassium pump,** pumps sodium ions (Na+) out of the neuron and potassium ions (K+) into the neuron.

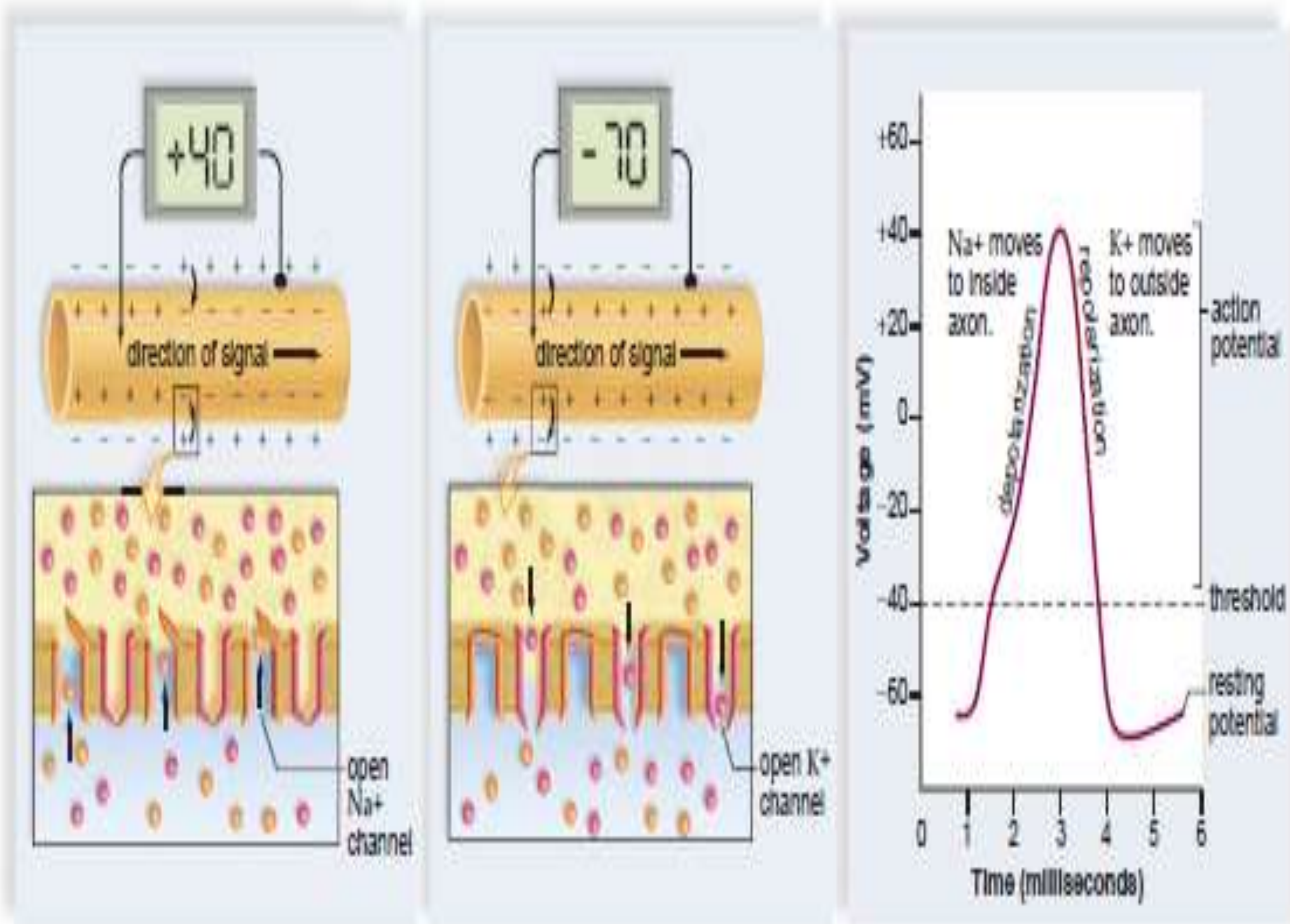
resting potential



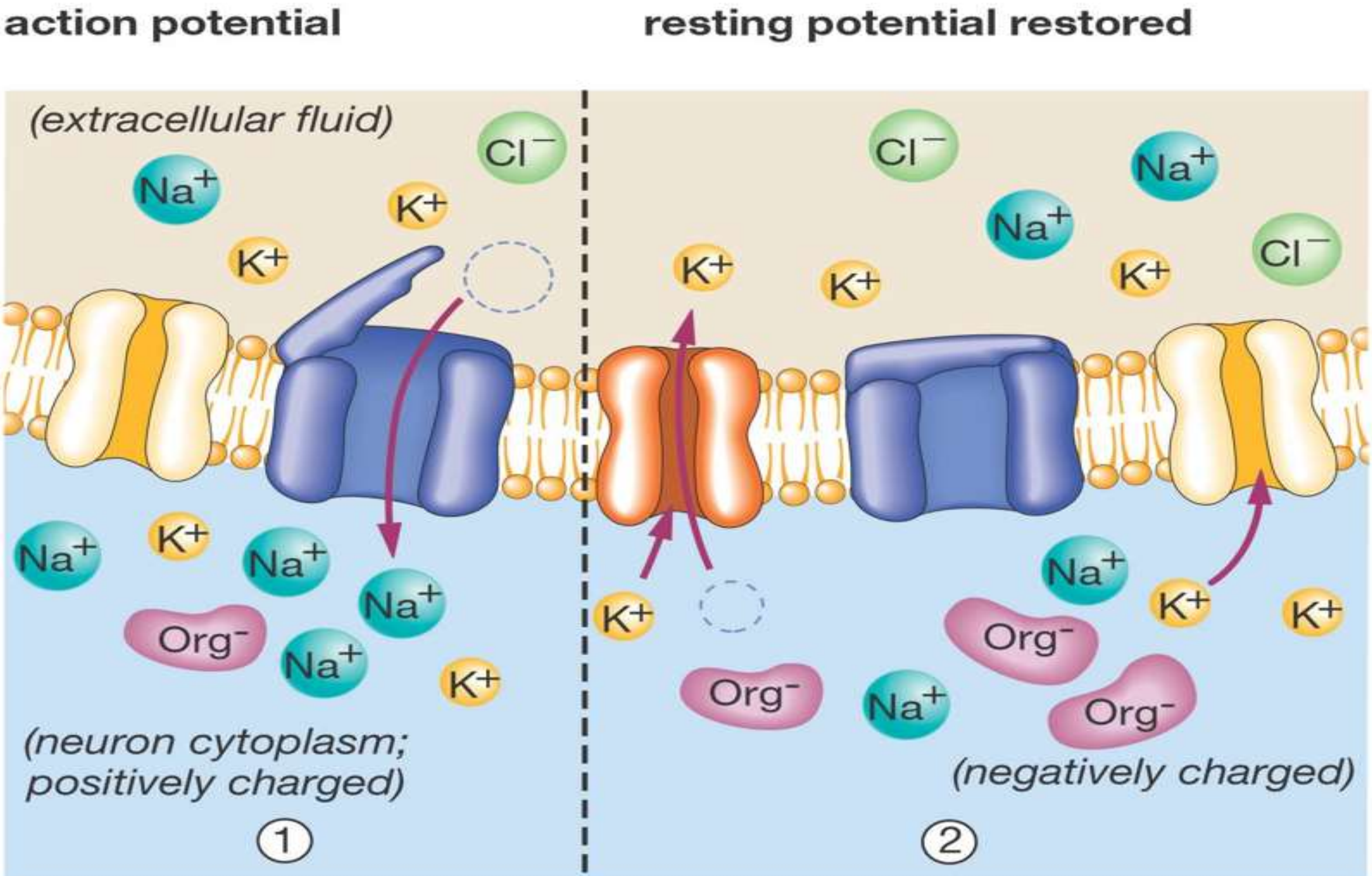
Action Potential

The process of conduction is termed an **action potential,** and it occurs in the axons of neurons. A **stimulus** activates the neuron and begins the action potential.

For example, a stimulus for pain neurons in the skin would be the prick of a sharp pin. However, the stimulus must be strong enough to cause the cell to reach **threshold,** the voltage that will result in an action potential. The threshold voltage is −40 mV. An action potential is an all-or-nothing event. Once threshold is reached, the action potential happens automatically and completely. On the other hand, if the threshold voltage is never reached, the action potential does not occur.



+40
direction of signal
open Na+ channel
-70
direction of signal
open K+ channel
+60
+40
+20
0
-20
-40
-60
Voltage (mV)
Na+ moves to inside axon.
depolarization
repolarization
K+ moves to outside axon.
action potential
threshold
resting potential
0
1
2
3
4
5
6
Time (milliseconds)



action potential
resting potential restored
(extracellular fluid)
Cl⁻
Na+
K+
K+
Cl⁻
Na+
Na+
K+
K+
K+
Cl⁻
Na+
K+
Na+
Na+
Org⁻
Na+
Na+
K+
(neuron cytoplasm; positively charged)
1
K+
Org⁻
Na+
Na+
Org⁻
K+
K+
Org⁻
(negatively charged)
2

Sodium Gates Open Protein channels specific for sodium ions are located in the cell membrane of the axon. When an action potential begins in response to a threshold stimulus, these protein channels open, and sodium ions rush into the cell. Adding positively charged sodium ions causes the inside of the axon to become positive compared to the outside This change is called **depolarization** because the charge inside the axon (its polarity) changes from negative to positive.

Potassium Gates Open Almost immediately after depolarization, the channels for sodium close and a separate set of potassium protein channels opens. Potassium flows rapidly from the cell. As positively charged potassium ions exit the cell, the inside of the cell becomes negative again because of the presence of large, negatively charged ions trapped inside the cell. This change in polarity is called **repolarization,** because the inside of the axon resumes a negative charge as potassium exits the axon. Finally, the sodium– potassium pump completes the action potential. Potassium ions are returned to the inside of the cell and sodium ions to the outside, and resting potential is restored.

Propagation of an Action Potential

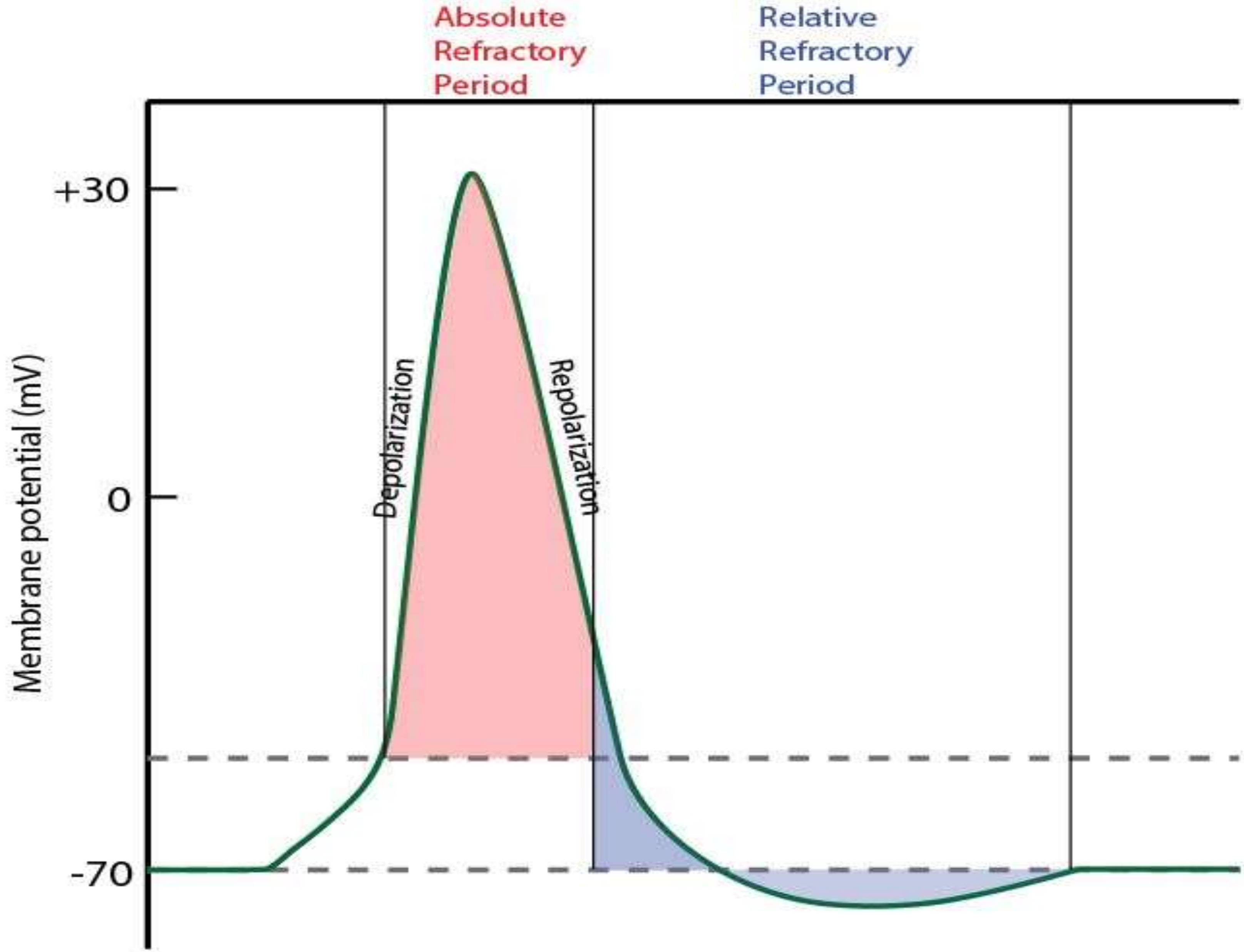
If an axon is unmyelinated, an action potential at one local stimulates an adjacent part of the axon membrane to produce an action potential. Conduction along the entire axon in this fashion can be rather slow (approximately 1 meter/second in thin axons) because each section of the axon must be stimulated. In myelinated fibers, an action potential at one node of Ranvier causes an action potential at the next node, jumping over the entire myelin-coated portion of the axon. This type of conduction is called **saltatory conduction** and is much faster. In thick, myelinated fibers, the rate of transmission is more than 100 m/s.

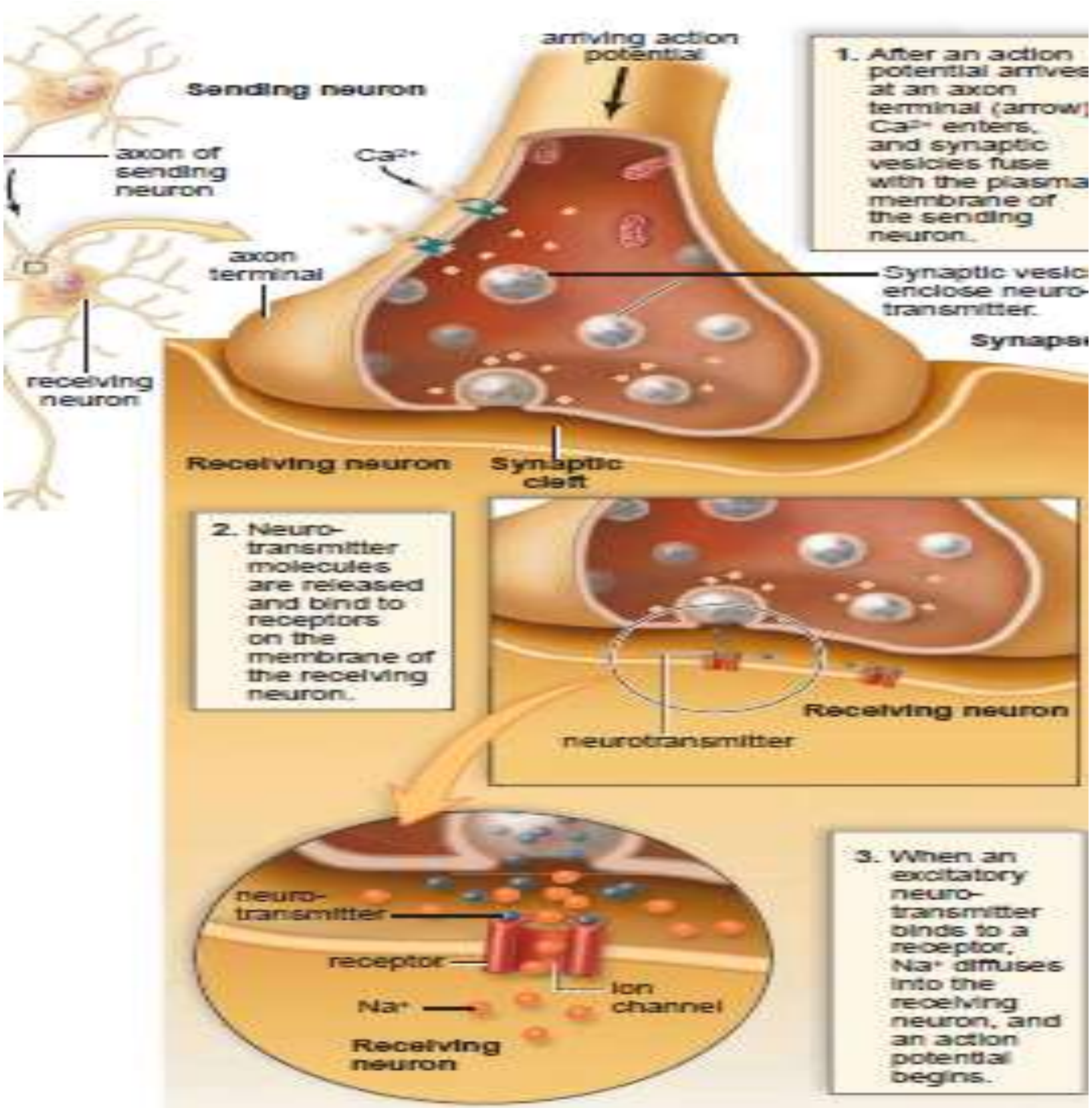
As soon as the action potential has passed by each successive portion of an axon, **refractory period** is a **period** of time during which an organ or cell is incapable of repeating a particular action.

The Synapse

Every axon branches into many fine endings, each tipped by a small swelling called an **axon terminal.** Each terminal lies very close to either the dendrite or the cell body of another neuron. This region of close proximity is called a **synapse** At a synapse, a small gap called the **synaptic cleft** separates the sending neuron from the receiving neuron.

Transmission across a synapse is carried out by molecules called **neurotransmitters,** stored in synaptic vesicles in the axon terminals. The events at a synapse are (1) nerve signals traveling along an axon to reach an axon terminal; (2) calcium ions entering the terminal and stimulating synaptic vesicles to merge with the sending membrane; and (3) neurotransmitter molecules releasing into the synaptic cleft and diffusing across the cleft to the receiving membrane.


Absolute Refractory Period
Relative Refractory Period
+30
0
-70
Membrane potential (mV)
Depolarization
Repolarization



arriving action potential
Sending neuron
axon of sending neuron
Ca2+
axon terminal
receiving neuron
1. After an action potential arrives at an axon terminal (arrow), Ca2+ enters, and synaptic vesicles fuse with the plasma membrane of the sending neuron.
Synaptic vesic enclose neuro-transmitter.
Synapse
Receiving neuron
Synaptic cleft
2. Neuro-transmitter molecules are released and bind to receptors on the membrane of the receiving neuron.
Receiving neuron
neurotransmitter
neuro-transmitter
receptor
ion channel
Na+
Receiving neuron
3. When an excitatory neuro-transmitter binds to a receptor, Na+ diffuses into the receiving neuron, and an action potential begins.

neurotransmitter molecules bind with specific receptor proteins. Depending on the type of neurotransmitter, the response of the receiving neuron can be toward excitation or toward inhibition. excitation occurs because the neurotransmitter, such as acetylcholine (ACh), has caused the sodium gate to open. Sodium ions diffuse into the receiving neuron. Inhibition would occur if a neurotransmitter caused potassium ions to exit the receiving neuron.

Once a neurotransmitter has been released into a synaptic cleft and has initiated a response, it is removed from the cleft. In some synapses, the receiving membrane contains enzymes that rapidly inactivate the neurotransmitter. For example, the enzyme **acetylcholinesterase (AChE)** breaks down acetylcholine.

In other synapses, the sending membrane rapidly reabsorbs the neurotransmitter, possibly for repackaging in synaptic vesicles or for molecular breakdown.

Neurotransmitter Molecules

Among the more than 100 substances known or suspected to be neurotransmitters are **acetylcholine (ACh), norepinephrine (NE), dopamine, serotonin, glutamate,** and **GABA (gamma aminobutyric acid).** Neurotransmitters transmit signals between nerves. Nerve–muscle, nerve–organ, and nerve– gland synapses also communicate using neurotransmitters. Acetylcholine and norepinephrine are active in both the CNS and PNS. In the PNS, these neurotransmitters act at synapses called neuromuscular junctions. In the PNS, ACh excites skeletal muscle but inhibits cardiac muscle.

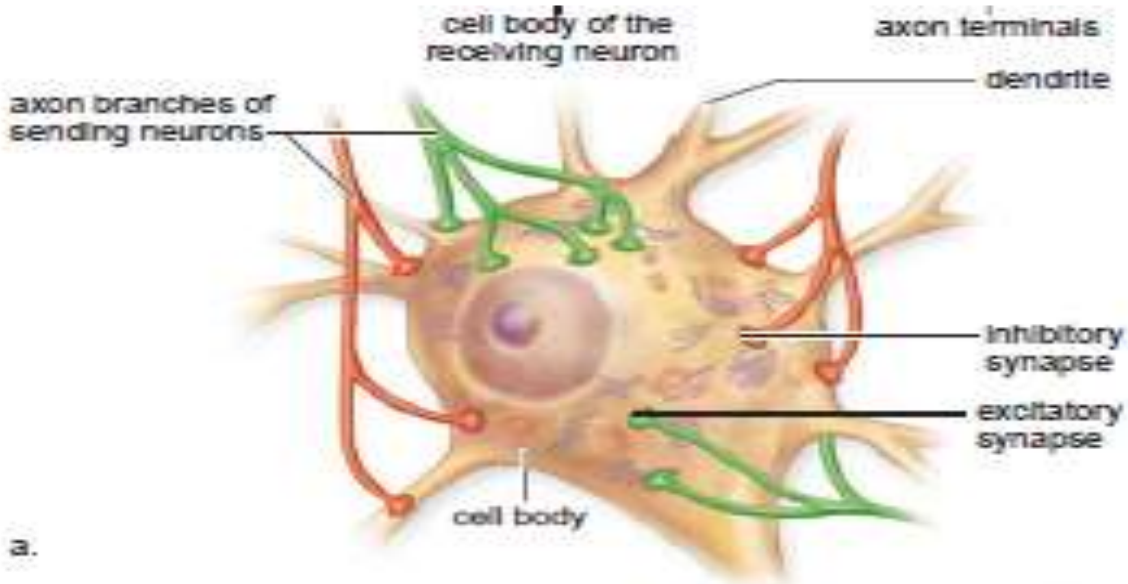
It has either an excitatory or inhibitory effect on smooth muscle or glands, depending on their location.

Norepinephrine generally excites smooth muscle. In the CNS, norepinephrine is important to dreaming, waking, and mood. Serotonin is involved in thermoregulation, sleeping, emotions, and perception. Many drugs that affect the nervous system act at the synapse. Some interfere with the actions of neurotransmitters, and other drugs prolong the effects of neurotransmitters .

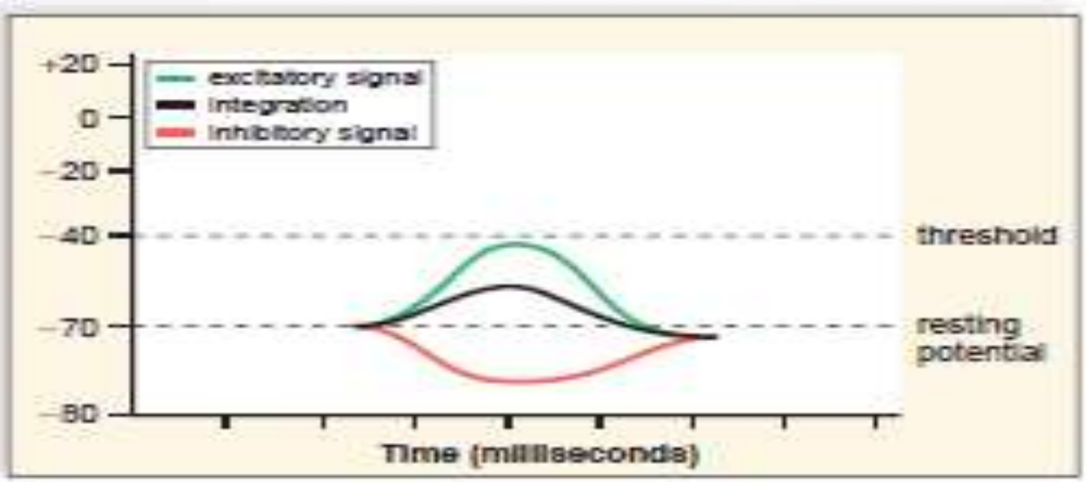
Synaptic Integration

A single neuron has a cell body and may have many dendrites. All can have synapses with many other neurons. Therefore, a neuron is on the receiving end of many signals, which can either be excitatory or inhibitory. Recall that an excitatory neurotransmitter produces an excitatory signal by opening sodium gates at a synapse. This drives the neuron closer to its threshold . If threshold is reached, an action potential is inevitable. On the other hand, an inhibitory neurotransmitter drives the neuron farther from an action potential by opening the gates for potassium. Neurons integrate these incoming signals.

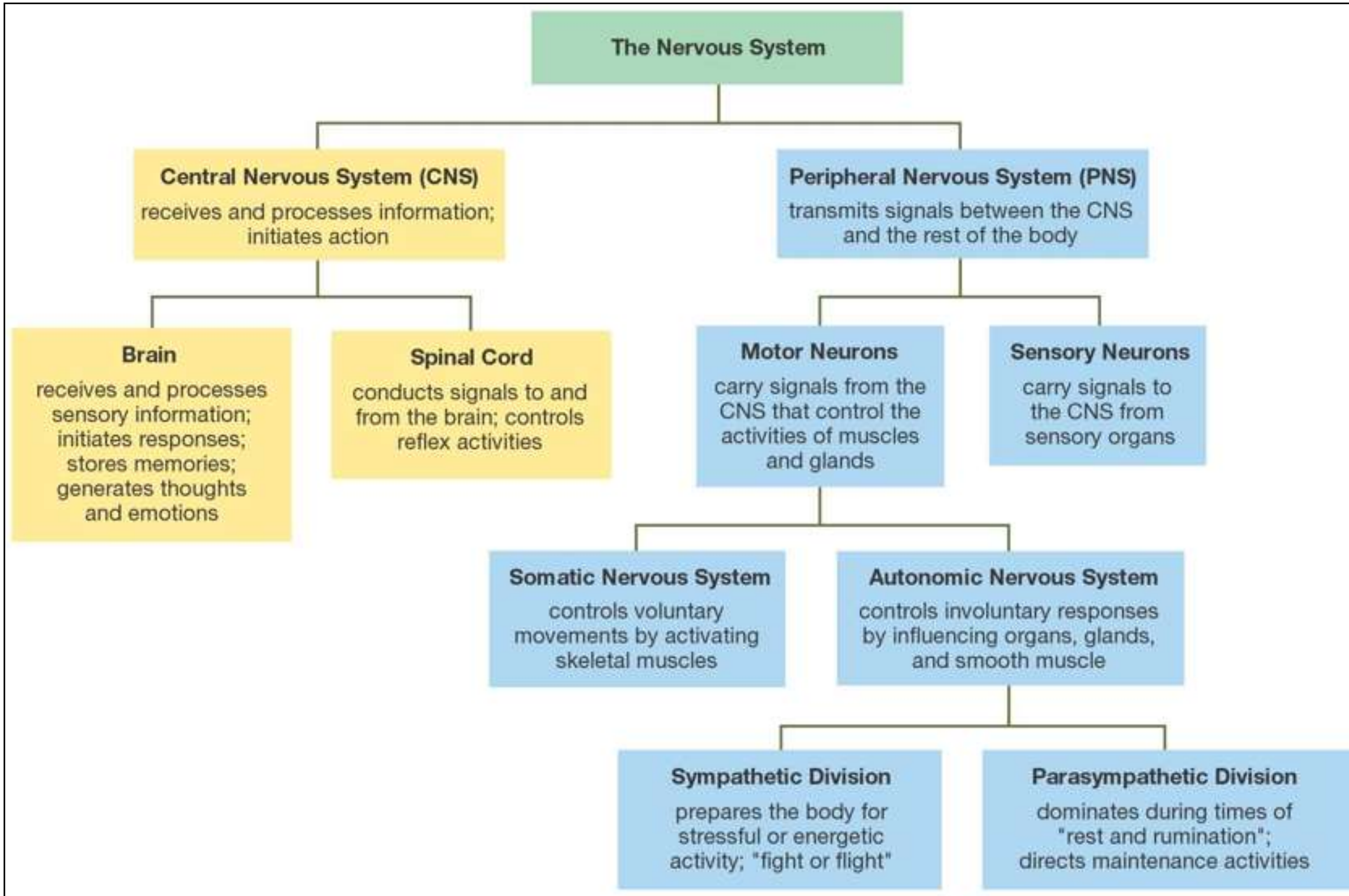
Integration is the summing up of excitatory and inhibitory signals. If a neuron receives enough excitatory signals (either from different synapses or at a rapid rate from a single synapse) to outweigh the inhibitory ones, chances are the axon will transmit a signal. On the other hand, if a neuron receives more inhibitory than excitatory signals, summing these signals may prohibit the axon from reaching threshold and then depolarizing.


cell body of the receiving neuron
axon terminals
dendrite
axon branches of sending neurons
inhibitory synapse
excitatory synapse
cell body

a.


+20
0
-20
-40
-70
-80
excitatory signal
integration
inhibitory signal
threshold
resting potential
Time (milliseconds)

b.


The Nervous System
Central Nervous System (CNS)
receives and processes information; initiates action
Peripheral Nervous System (PNS)
transmits signals between the CNS and the rest of the body
Brain
receives and processes sensory information; initiates responses; stores memories; generates thoughts and emotions
Spinal Cord
conducts signals to and from the brain; controls reflex activities
Motor Neurons
carry signals from the CNS that control the activities of muscles and glands
Sensory Neurons
carry signals to the CNS from sensory organs
Somatic Nervous System
controls voluntary movements by activating skeletal muscles
Autonomic Nervous System
controls involuntary responses by influencing organs, glands, and smooth muscle
Sympathetic Division
prepares the body for stressful or energetic activity; "fight or flight"
Parasympathetic Division
dominates during times of "rest and rumination"; directs maintenance activities

The Central Nervous System

The spinal cord and the brain make up the CNS, where sensory information is received and motor control is initiated. As mentioned previously, both the spinal cord and the brain are protected by bone. The spinal cord is surrounded by vertebrae, and the brain is enclosed by the skull. Also, both the spinal cord and the brain are wrapped in protective membranes known as **meninges**. The spaces between the meninges are filled with **cerebrospinal fluid,** which cushions and protects the CNS. The CNS is composed of two types of nervous tissue— gray matter and white matter. **Gray matter** contains cell bodies and short, nonmyelinated fibers. **White matter** contains myelinated axons that run together in bundles called **tracts.**

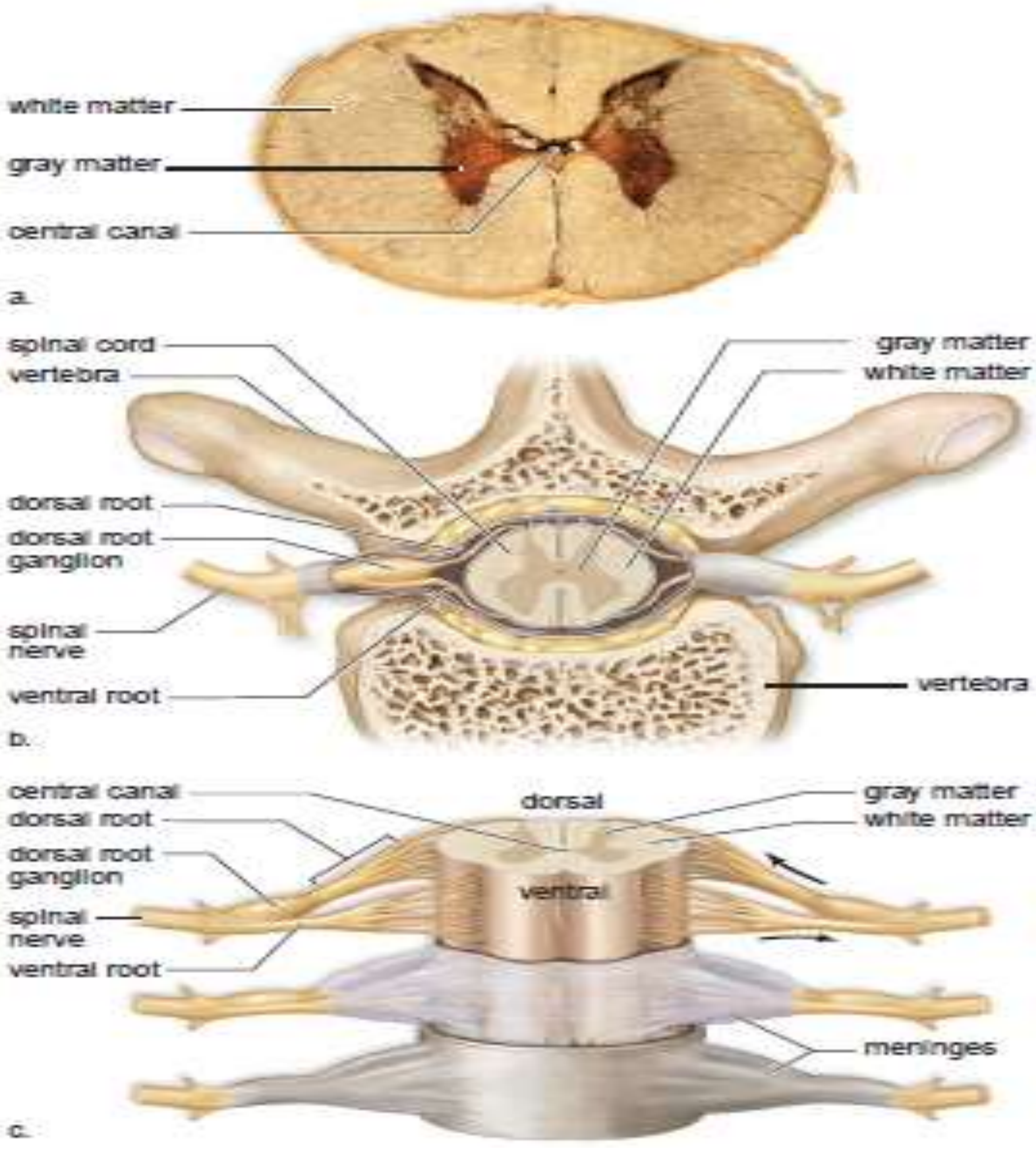
The Spinal Cord

The **spinal cord** extends from the base of the brain through a large opening in the skull called the foramen magnum . From the foramen magnum, the spinal cord proceeds inferiorly in the vertebral canal.

Structure of the Spinal Cord

A cross section of the spinal cord shows a central canal, gray matter, and white matter. The spinal nerves project from the cord through intervertebral foramina . Fibrocartilage intervertebral disks separate the vertebrae. If the disk ruptures or herniates, the vertebrae compress a spinal nerve. Pain and loss of mobility result. The central canal of the spinal cord contains cerebrospinal fluid, as do the meninges that protect the spinal cord. The gray matter is centrally located and shaped like the letter H. Portions of sensory neurons and motor neurons are found in gray matter, as are interneurons that communicate with these two types of neurons. The dorsal root of a spinal nerve contains sensory fibers entering the gray matter. The ventral root of a spinal nerve contains motor fibers exiting the gray matter. The dorsal and ventral roots join before the spinal nerve leaves the vertebral canal, forming a mixed nerve. Spinal nerves are a part of the PNS.

The white matter of the spinal cord occurs in areas around the gray matter. The white matter contains ascending tracts taking information to the brain (primarily located posteriorly) and descending tracts taking information from the brain (primarily located anteriorly). Many tracts cross just after they enter and exit the brain, so the left side of the brain controls the right side of the body. Likewise, the right side of the brain controls the left side of the body.



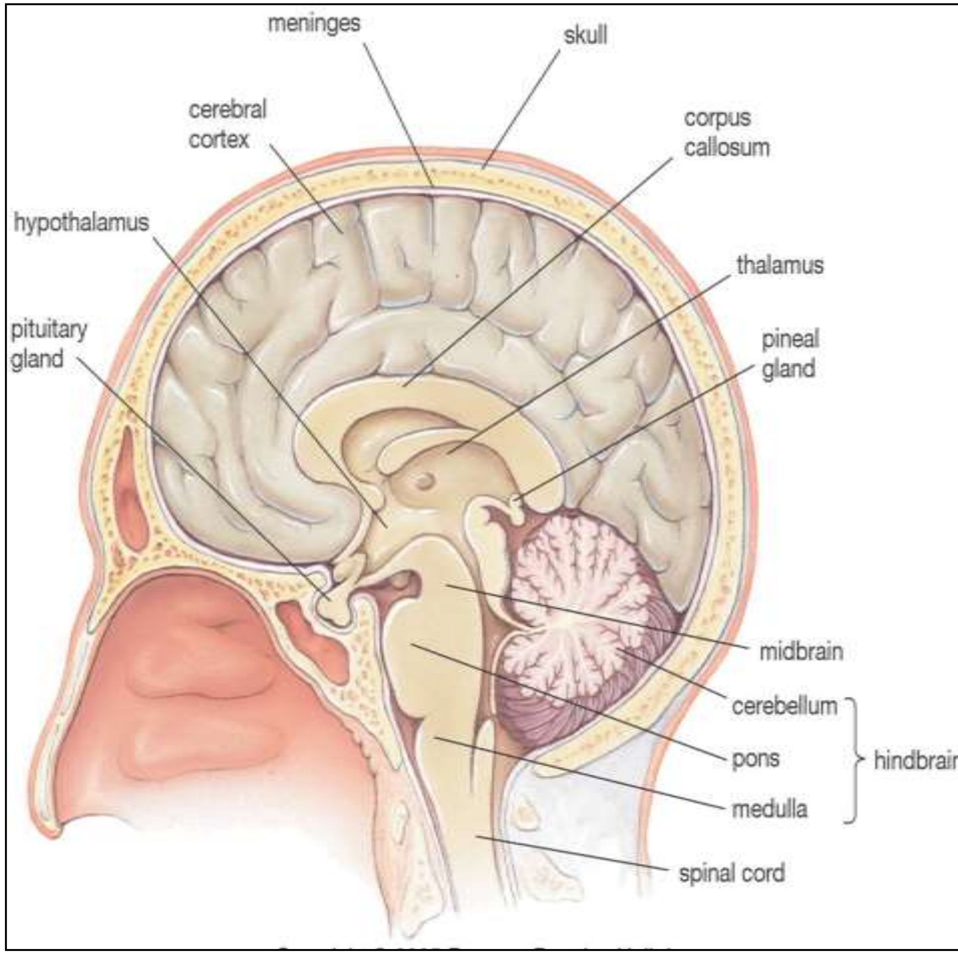
white matter
gray matter
central canal
a.
spinal cord
vertebra
gray matter
white matter
dorsal root
dorsal root ganglion
spinal nerve
ventral root
vertebra
b.
central canal
dorsal root
dorsal root ganglion
spinal nerve
ventral root
dorsal
ventral
gray matter
white matter
meninges
c.

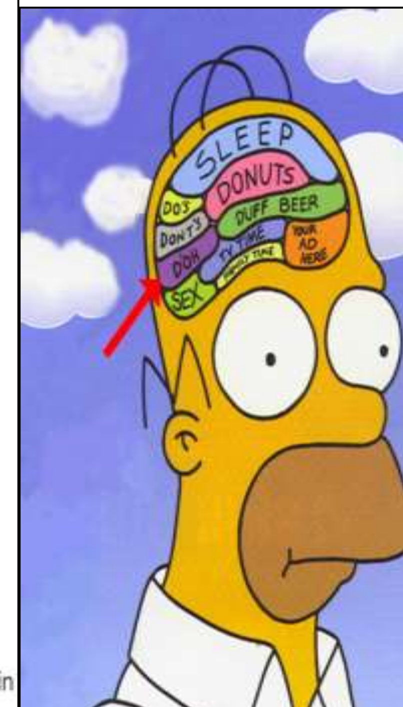
Reflex Actions The spinal cord is the center for thousands of reflex arcs. A stimulus causes sensory receptors to generate signals that travel in sensory axons to the spinal cord. Interneurons integrate the incoming data and relay signals to motor neurons. A response to the stimulus occurs when motor axons cause skeletal muscles to contract. Motor neurons in a reflex arc may also affect smooth muscle, organs, or glands. Each interneuron in the spinal cord has synapses with many other neurons. Therefore, interneurons send signals to other interneurons and motor neurons.

Similarly, the spinal cord creates reflex arcs for the internal organs. For example, when blood pressure falls, internal receptors in the carotid arteries and aorta generate nerve signals that pass through sensory fibers to the cord and then up an ascending tract to a cardiovascular center in the brain. Thereafter, nerve signals pass down a descending tract to the spinal cord. Motor signals then cause blood vessels to constrict so that the blood pressure rises.

Brain: Structure

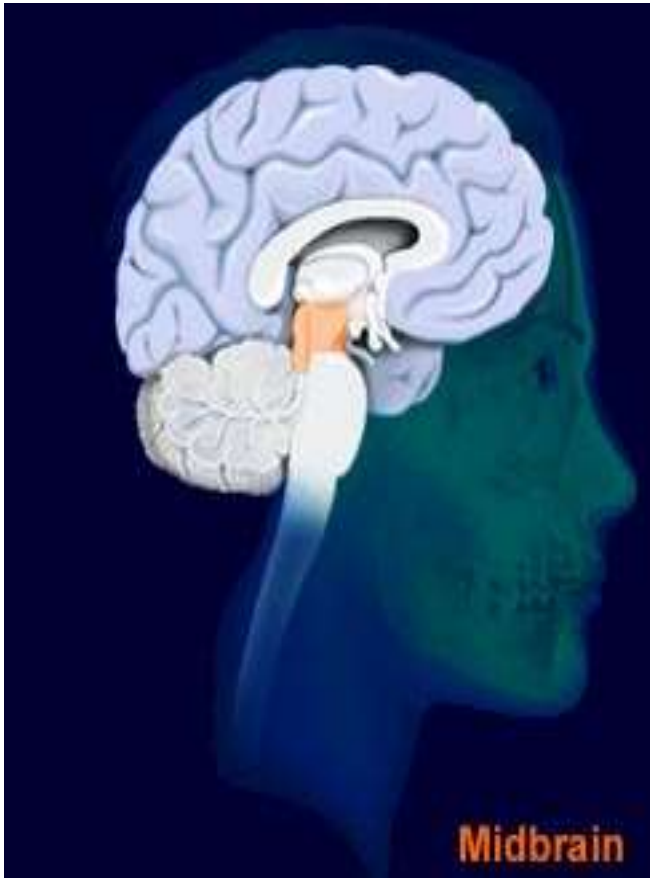
- Hindbrain carries out the most basic functions.
- Midbrain coordinates signals.
- Forebrain processes signals, stores memories, creates thought.





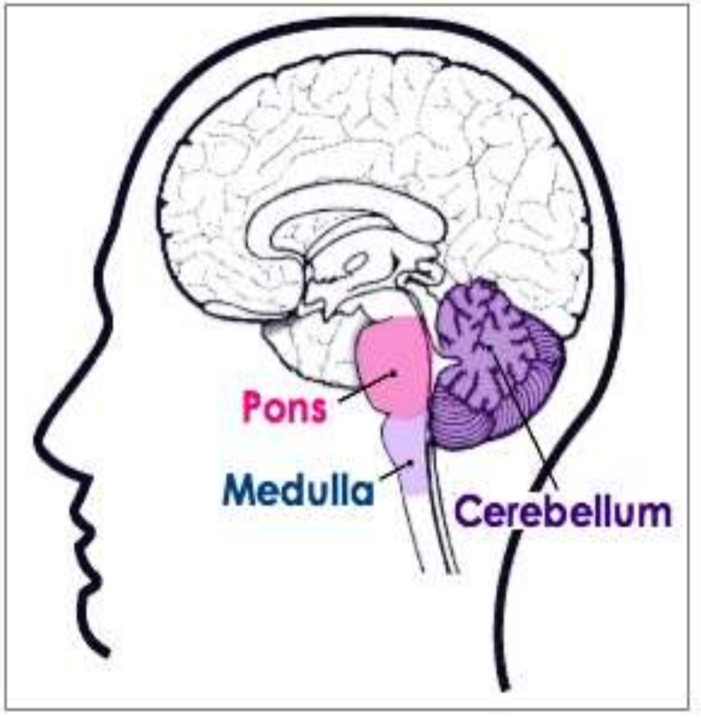
Midbrain

- Reticular formation: the “traffic cops” of the brain.
- Filters sensory input, which allows us to concentrate.
- Filtering can be affected by higher thoughts.



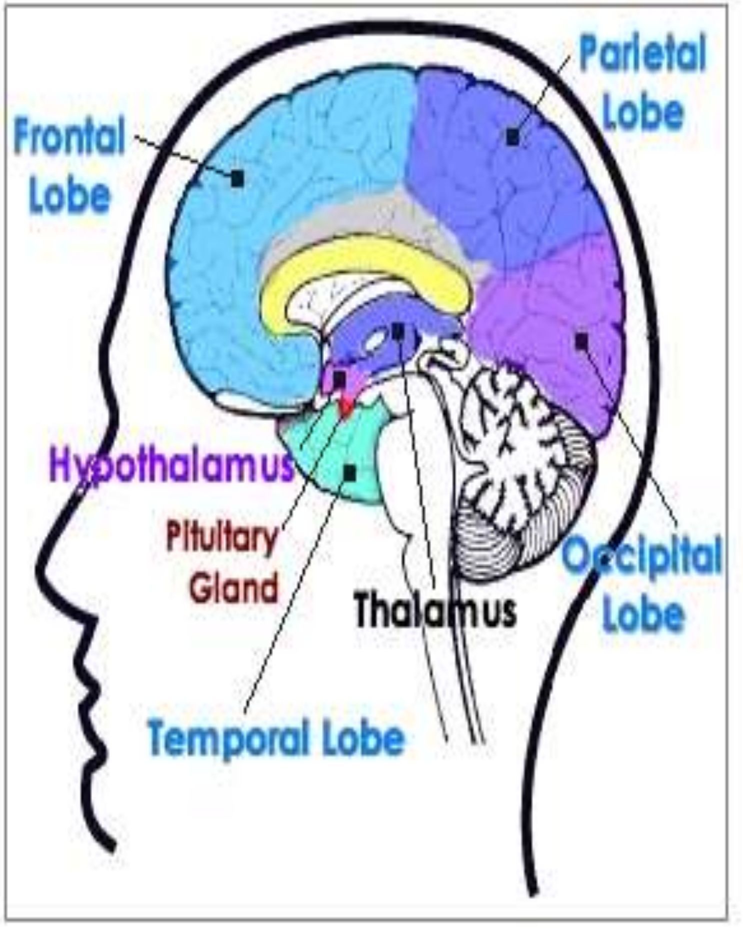
Hindbrain

- Medulla: controls autonomic functions.
- Pons: controls sleep stages.
- Cerebellum: coordinates movement, stores some motor memory.



Forebrain

- Thalamus: relay station channeling sensory information.
- Limbic system: basic emotions, drives, and behaviors.
- Cortex: higher thought



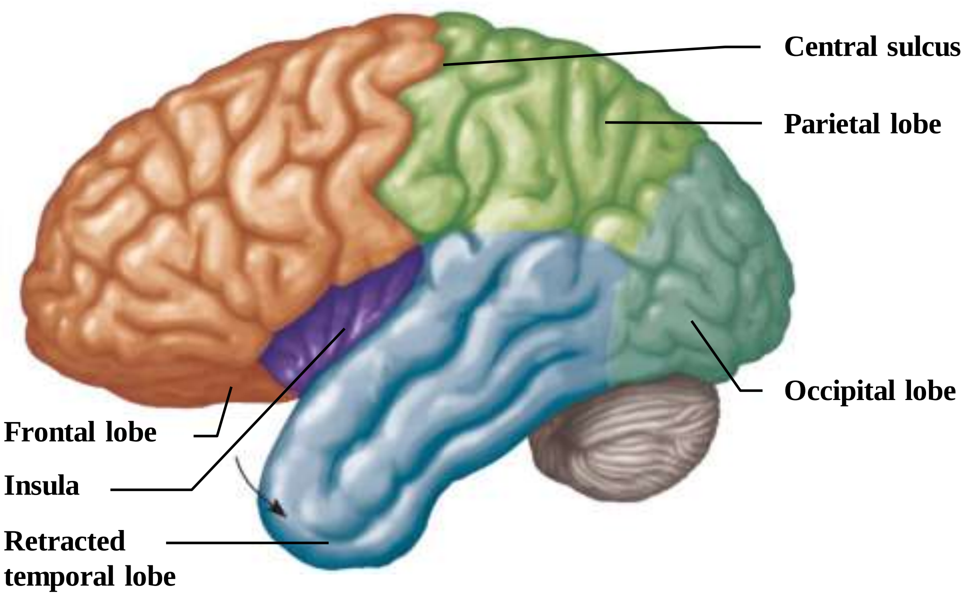
Brain

- Functions of the brain:
  - Interprets sensations
  - Determines perception
  - Stores memory
  - Reasoning
  - Makes decisions
  - Coordinates muscular movements
  - Regulates visceral activities
  - Determines personality

- Major parts of the brain:
  - Cerebrum
    - Frontal lobes
    - Parietal lobes
    - Occipital lobes
    - Temporal lobes
    - Diencephalon
  - Cerebellum
  - Brainstem
    - Midbrain
    - Pons
    - Medulla oblongata

Lobes of the Cerebrum

- Four (4) lobes bilaterally:
  - Frontal lobe
  - Parietal lobe
  - Temporal lobe
  - Occipital lobe



(c)

Functions of the Cerebral Lobes

TABLE 11.5 | Functions of the Cerebral Lobes

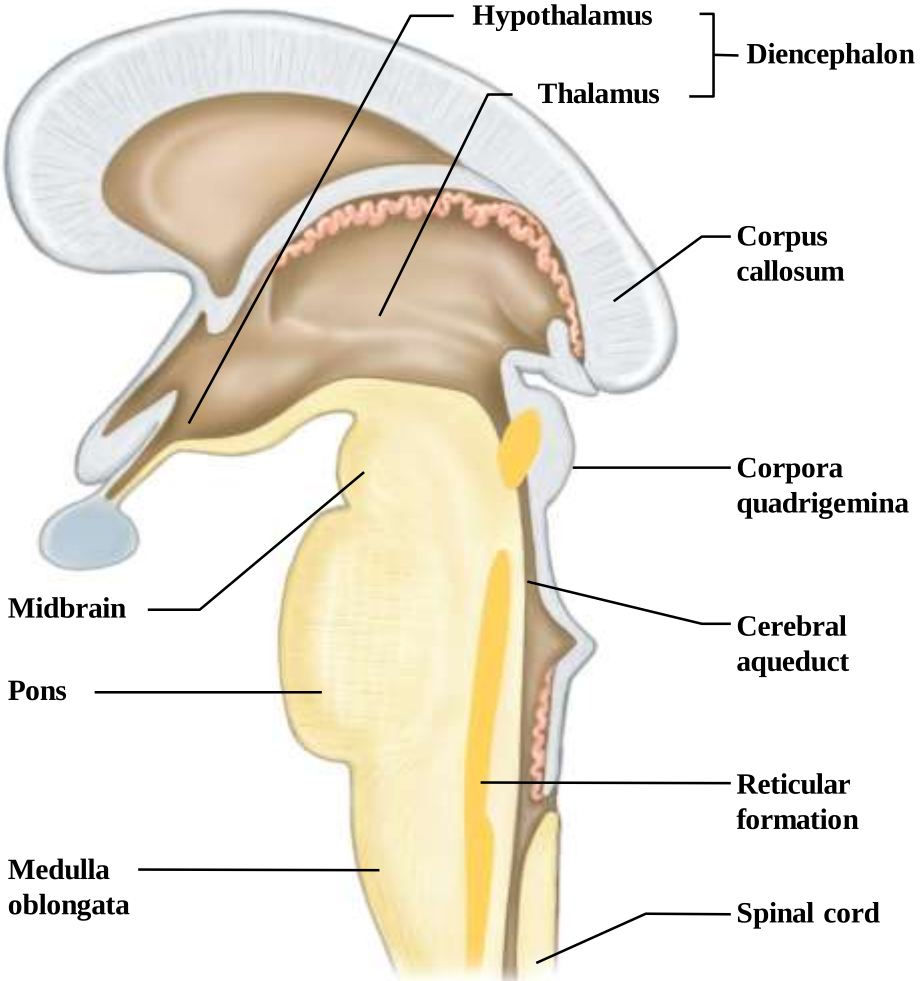
Lobe	Functions
Frontal lobes	Association areas carry on higher intellectual processes for concentrating, planning, complex problem solving, and judging the consequences of behavior. Motor areas control movements of voluntary skeletal muscles.
Parietal lobes	Sensory areas provide sensations of temperature, touch, pressure, and pain involving the skin. Association areas function in understanding speech and in using words to express thoughts and feelings.
Temporal lobes	Sensory areas are responsible for hearing. Association areas interpret sensory experiences and remember visual scenes, music, and other complex sensory patterns.
Occipital lobes	Sensory areas are responsible for vision. Association areas combine visual images with other sensory experiences.

Brain compone	
Cerebral cortex	1. Sensory perception 2. Voluntary control of movement 3. Language 4. Personality traits 5. Sophisticated mental events, such as thinking memory, decision making, creativity, and self-consciousness
Basal nuclei	1. Inhibition of muscle tone 2. Coordination of slow, sustained movements 3. Suppression of useless patterns of movements
Thalamus	1. Relay station for all synaptic input 2. Crude awareness of sensation 3. Some degree of consciousness 4. Role in motor control
Hypothalamu	1. Regulation of many homeostatic functions, such as temperature control, thirst, urine output, and food intake 2. Important link between nervous and endocrine systems 3. Extensive involvement with emotion and basic behavioral patterns
Cerebellum	1. Maintenance of balance 2. Enhancement of muscle tone 3. Coordination and planning of skilled voluntary muscle activity
Brain stem (midbrain, pons, and medulla)	1. Origin of majority of peripheral cranial nerves 2. Cardiovascular, respiratory, and digestive control centers 3. Regulation of muscle reflexes involved with equilibrium and posture 4. Reception and integration of all synaptic input from spinal cord; arousal and activation of cerebral cortex 5. Role in sleep-wake cycle

Brainstem

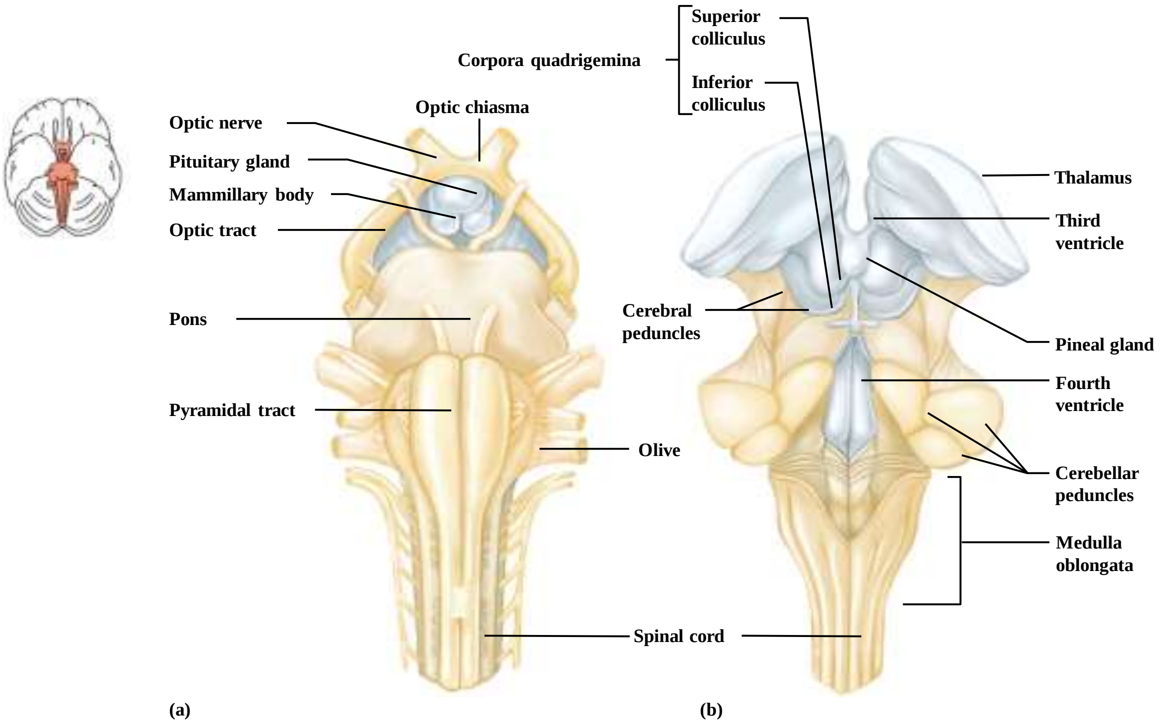
Three parts:

1. Midbrain
2. Pons
3. Medulla Oblongata



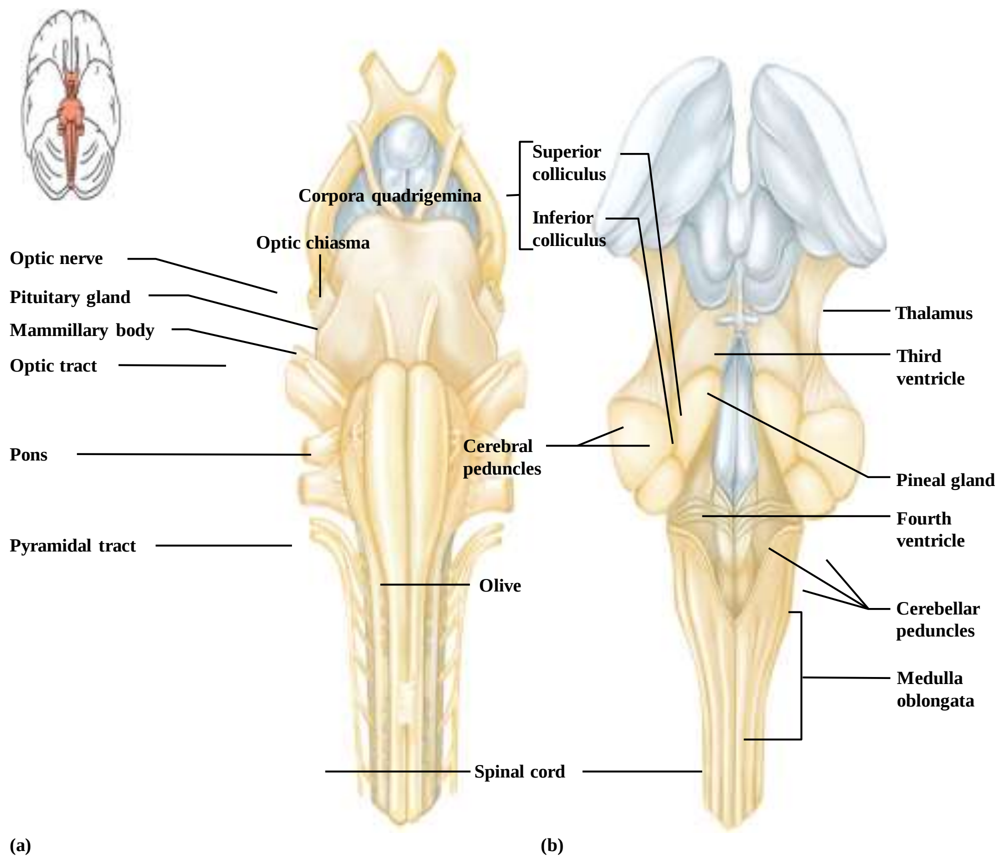
Midbrain

- Between diencephalon and pons
- Contains bundles of fibers that join lower parts of brainstem and spinal cord with higher parts of the brain
- Corpora quadrigemina (centers for visual and auditory reflexes)



Pons

- Rounded bulge on underside of brainstem
- Between medulla oblongata and midbrain
- Helps regulate rate and depth of breathing
- Relays nerve impulses to and from medulla oblongata and cerebellum (bridge)



Medulla Oblongata

- Enlarged continuation of spinal cord
- Conducts ascending and descending impulses between brain and spinal cord
- Contains cardiac, vasomotor, and respiratory control centers
- Contains various nonvital reflex control centers (coughing, sneezing, swallowing, and vomiting)

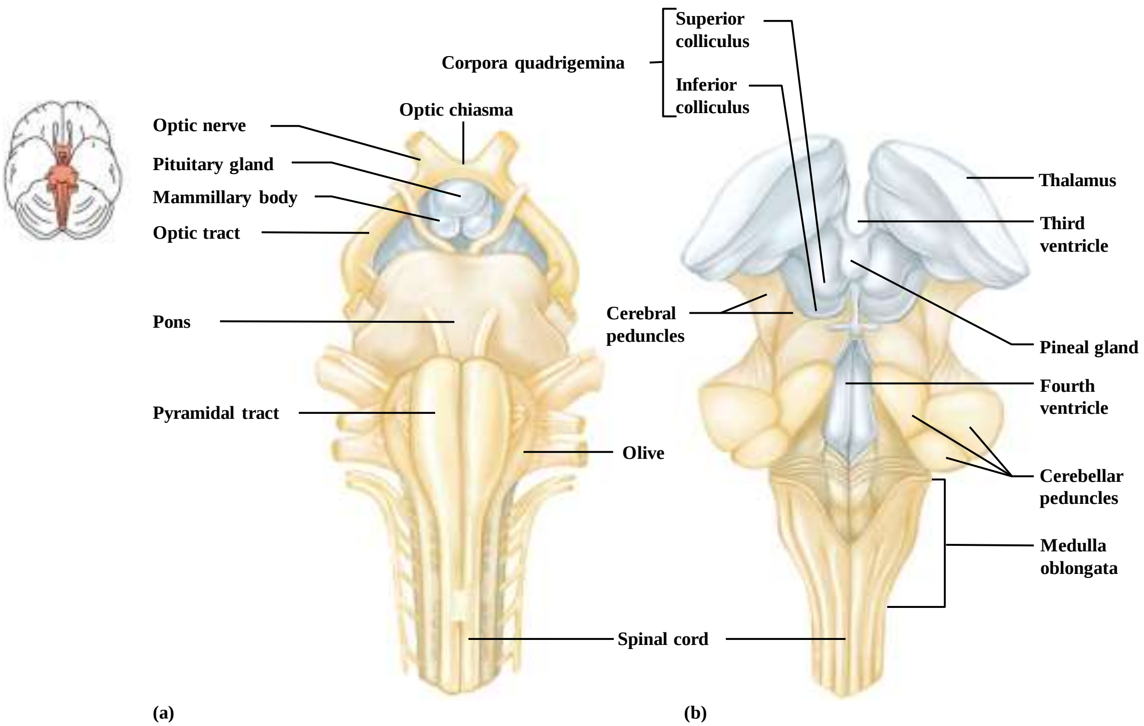
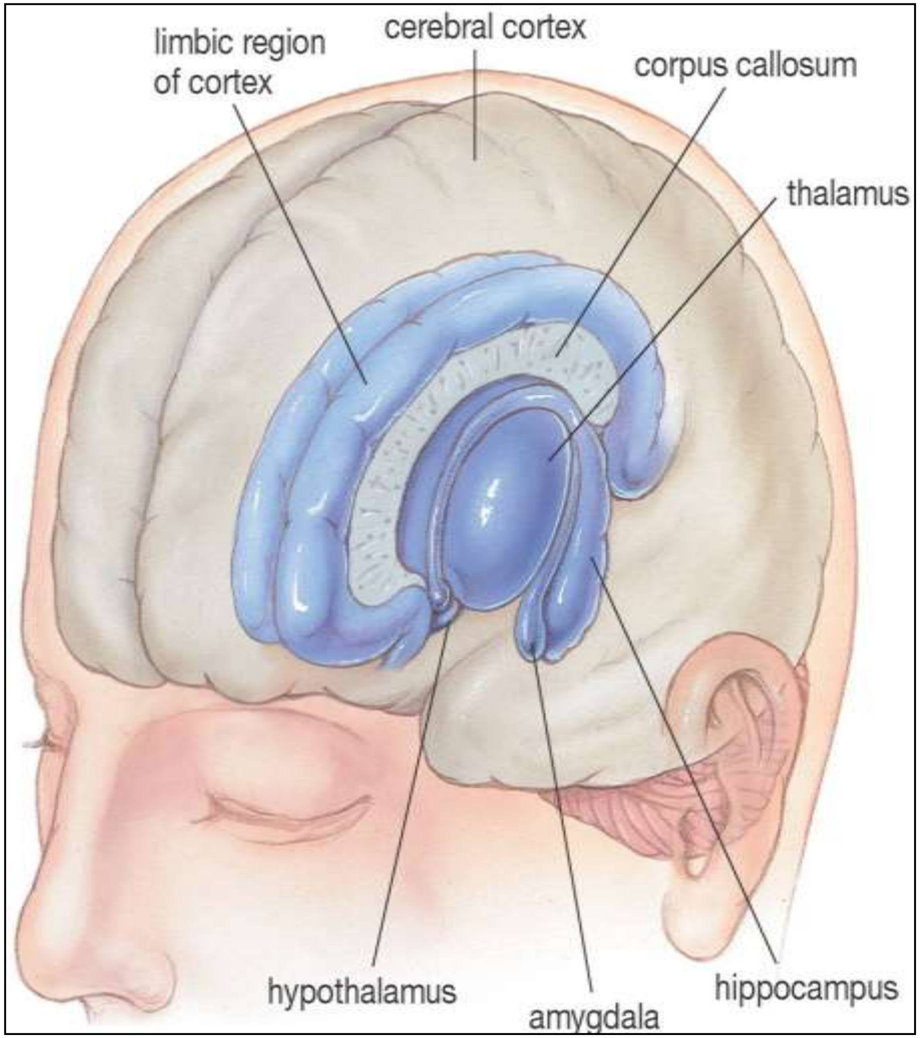


TABLE 11.7 | Major Parts of the Brain

Part	Characteristics	Functions
1. Cerebrum	Largest part of the brain; two hemispheres connected by the corpus callosum	Controls higher brain functions, including interpreting sensory impulses, initiating muscular movements, storing memory, reasoning, and determining intelligence
2. Basal nuclei (ganglia)	Masses of gray matter deep within the cerebral hemispheres	Relay stations for motor impulses originating in the cerebral cortex and passing into the brainstem and spinal cord
3. Diencephalon	Includes masses of gray matter (thalamus and hypothalamus)	The thalamus is a relay station for sensory impulses ascending from other parts of the nervous system to the cerebral cortex; the hypothalamus helps maintain homeostasis by regulating visceral activities and by linking the nervous and endocrine systems
4. Brainstem	Connects the cerebrum to the spinal cord	
a. Midbrain	Contains masses of gray matter and bundles of nerve fibers that join the spinal cord to higher regions of the brain	Contains reflex centers that move the eyes and head, and maintains posture
b. Pons	A bulge on the underside of the brainstem that contains masses of gray matter and nerve fibers	Relays nerve impulses to and from the medulla oblongata and cerebrum; helps regulate rate and depth of breathing
c. Medulla oblongata	An enlarged continuation of the spinal cord that extends from the foramen magnum to the pons and contains masses of gray matter and nerve fibers	Conducts ascending and descending impulses between the brain and spinal cord; contains cardiac, vasomotor, and respiratory control centers and various nonvital reflex control centers
5. Cerebellum	A large mass of tissue inferior to the cerebrum and posterior to the brainstem; includes two lateral hemispheres connected by the vermis	Communicates with other parts of the CNS by nerve tracts; integrates sensory information concerning the position of body parts; and coordinates muscle activities and maintains posture

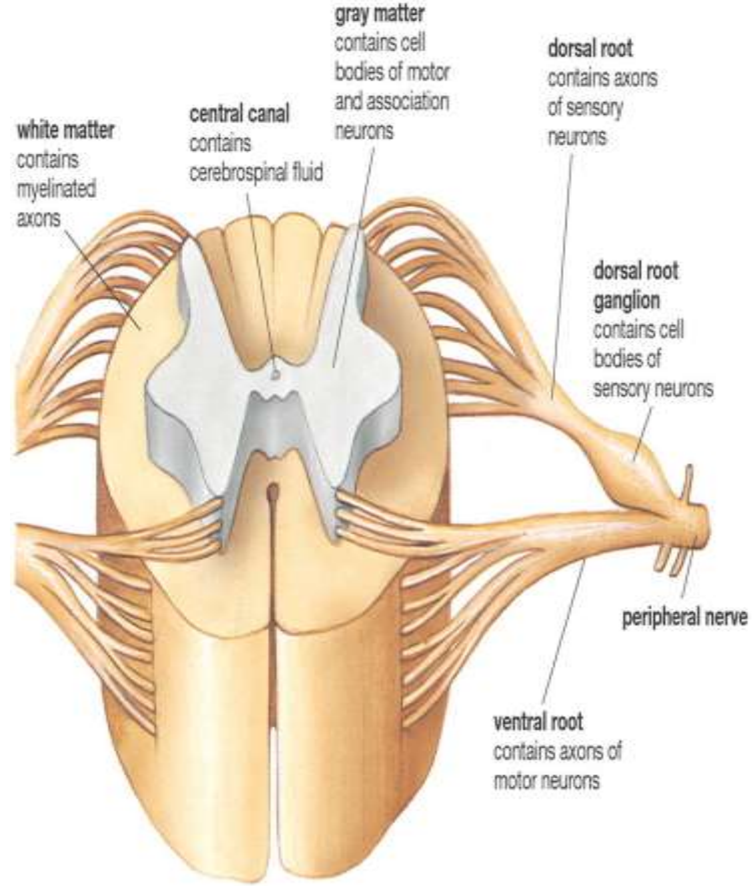
Limbic system

- Hypothalamus: master controller of the endocrine system.
- Amygdala: sensations of pleasure or fear, recognition of fear in others.
- Hippocampus: formation of memories.



Spine: structure

- The spinal cord is protected by the vertebrae.
- Gray matter contains cell bodies; white matter contains myelinated fibers.
- PNS nerves extend outside of the vertebrae.



The Peripheral Nervous System

The peripheral nervous system (PNS), which lies outside the central nervous system, contains the nerves. Nerves are designated as cranial nerves when they arise from the brain and spinal nerves when they arise from the spinal cord. In any case, all nerves carry signals to and from the CNS. So right now, your eyes are sending messages by way of a cranial nerve to the brain, allowing you to read a page. When you're finished, your brain will direct the muscles in your fingers to turn the page by way of the spinal cord and a spinal nerve. The cell body and the dendrites of neurons are in either the CNS or ganglia. **Ganglia** (sing., **ganglion**) are collections of nerve cell bodies outside the CNS. The axons of neurons project from the CNS and form the spinal cord. In other words, nerves, whether cranial or spinal, are composed of axons, the long part of neurons. Humans have 12 pairs of **cranial nerves** attached to the brain. By convention, the pairs of cranial nerves are referred to by roman numerals. Some cranial nerves are sensory nerves—they contain only sensory fibers; some are motor nerves that contain only motor fibers; and others are mixed nerves that contain both sensory and motor fibers.

Cranial nerves are largely concerned with the head, neck, and facial regions of the body. However, the vagus nerve (X) has branches not only to the pharynx and larynx but also to most of the internal organs. From which part of the brain do you think the vagus arises? It arises from the brain stem, specifically, the medulla oblongata that communicates so well with the hypothalamus. These two parts of the brain control the internal organs. The **spinal nerves** of humans emerge from either side of the spinal cord. There are 31 pairs of spinal nerves. The roots of a spinal nerve physically separate the axons of sensory neurons from the axons of motor neurons, forming an arrangement resembling a letter Y . The posterior root of a spinal nerve contains sensory fibers that direct sensory receptor information inward (toward the spinal cord). The cell body of a sensory neuron is in a posterior-root ganglion (also termed a **dorsal-root ganglion).** The anterior (also termed ventral) root of a spinal nerve contains motor fibers that conduct impulses outward (away from the cord) to the effectors. The anterior and posterior roots rejoin to form a spinal nerve. All spinal nerves are called mixed nerves because they contain both sensory and motor fibers.

Each spinal nerve serves the particular region of the body in which it is located. For example, the intercostal muscles of the rib cage are innervated by thoracic nerves.

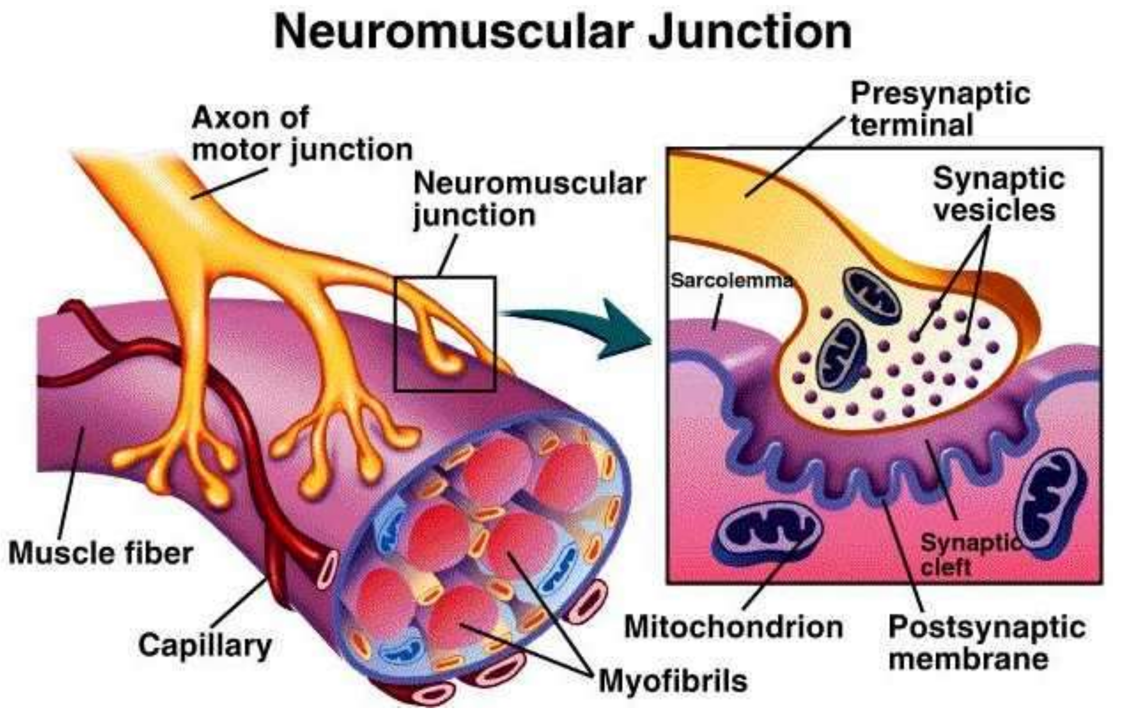
Somatic System

The nerves in the **somatic system** serve the skin, skeletal muscles, and tendons. The somatic system sensory nerves take sensory information from external sensory receptors to the CNS. Motor commands leaving the CNS travel to skeletal muscles via somatic motor nerves.

Not all somatic motor actions are voluntary. Some actions are automatic. Automatic responses to a stimulus in the somatic system are called **reflexes.** A reflex occurs quickly, without your even having to think about it. For example, a reflex may cause you to blink your eyes in response to a flash of light, without your willing it. A reflex because it allows us to study in detail the path of nerve signals to and from the CNS.

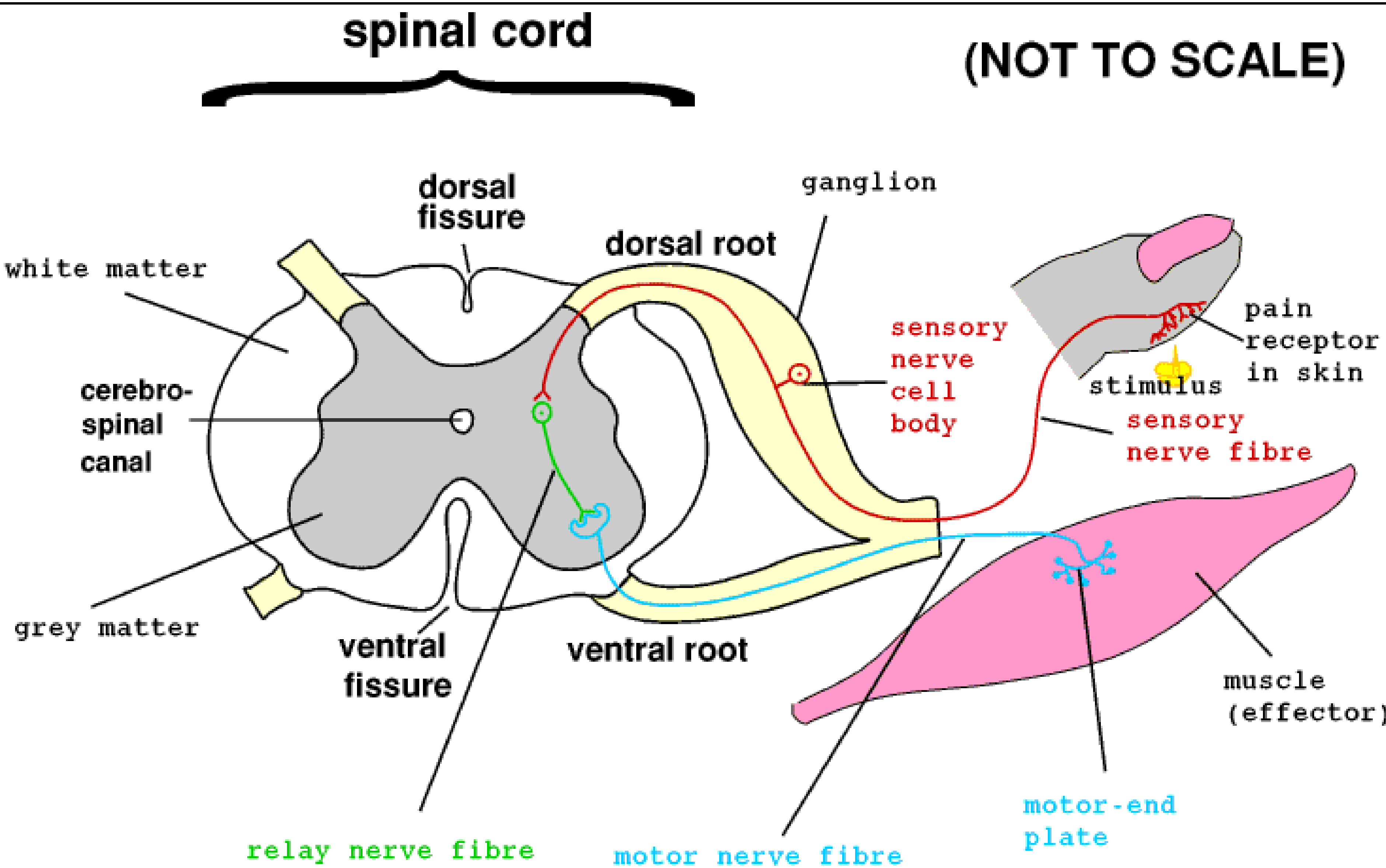
Peripheral Nervous System

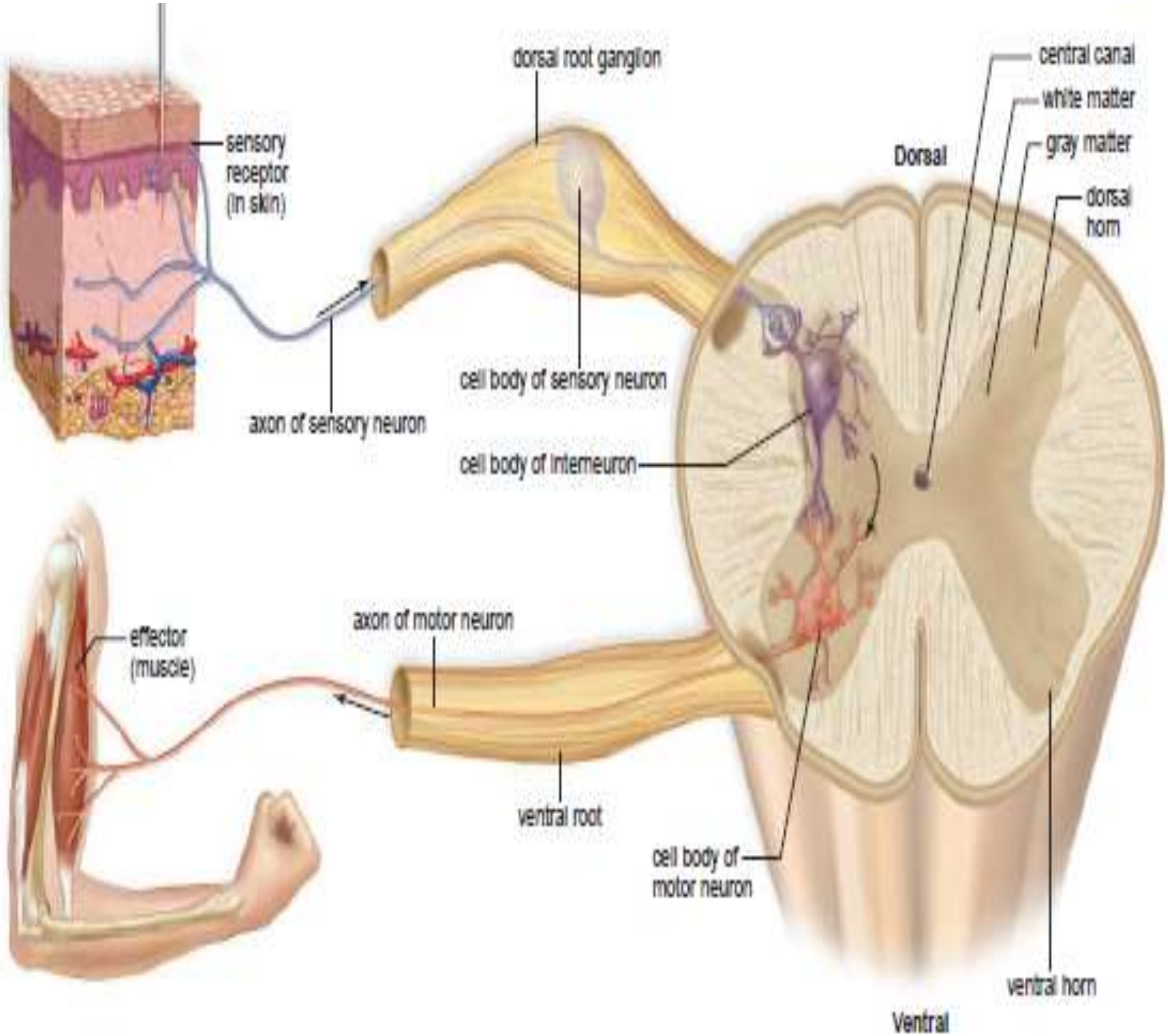
- (2) Somatic
  - Cranial & spinal nerves connecting CNS to skin & skeletal muscles
  - Oversees conscious activities



The Reflex Arc

A reflex that involves only the spinal cord. If your hand touches a sharp pin, sensory receptors in the skin generate nerve signals that move along sensory fibers through the dorsal-root ganglia toward the spinal cord. Sensory neurons that enter the cord dorsally (posteriorly) pass signals on to many interneurons. Some of these interneurons synapse with motor neurons whose short dendrites and cell bodies are in the spinal cord. Nerve signals travel along these motor fibers to an effector, which brings about a response to the stimulus. In this case, the effector is a muscle, which contracts so that you withdraw your hand from the pin. Various other reactions are also possible— you will most likely look at the pin, wince, and cry out in pain. This whole series of responses occur because some of the interneurons involved carry nerve signals to the brain. The brain makes you aware of the stimulus and directs these other reactions to it. You don’t feel pain until the brain receives the information and interprets it!


spinal cord
(NOT TO SCALE)
dorsal fissure
dorsal root
ganglion
white matter
cerebro-spinal canal
sensory nerve cell body
pain receptor in skin
stimulus
sensory nerve fibre
grey matter
ventral fissure
ventral root
muscle (effector)
motor-end plate
relay nerve fibre
motor nerve fibre


sensory
receptor
(in skin)
dorsal root ganglion
axon of sensory neuron
cell body of sensory neuron
cell body of interneuron
central canal
white matter
gray matter
Dorsal
dorsal
horn
effector
(muscle)
axon of motor neuron
ventral root
cell body of
motor neuron
ventral horn
Ventral

Autonomic System

The **autonomic system** is also in the PNS . The autonomic system regulates the activity of cardiac and smooth muscles, organs, and glands. The system is divided into the sympathetic and parasympathetic divisions

Activation of these two systems generally causes opposite responses.

Although their functions are different, the two divisions share some features: (1) They function automatically and usually in an involuntary manner; (2) they innervate all internal organs; and (3) they use two neurons and one ganglion for each impulse. The first neuron has a cell body within the CNS and a preganglionic fiber that enters the ganglion. The second neuron has a cell body within a ganglion and a postganglionic fiber that leaves the ganglion. Reflex actions, such as those that regulate blood pressure and breathing rate, are especially important to the maintenance of homeostasis. These reflexes begin when the sensory neurons in contact with internal organs send messages to the CNS. They are completed by motor neurons within the autonomic system.

Sympathetic Division

Most preganglionic fibers of the **sympathetic division** arise from the middle, or thoracolumbar, portion of the spinal cord. They terminate almost immediately in ganglia that lie near the cord. Therefore, in this division, the preganglionic fiber is short, but the postganglionic fiber that contacts an organ is long.

The sympathetic division is especially important during emergency situations when you might be required to fight or take flight. It accelerates the heartbeat and dilates the bronchi—active muscles, after all, require a ready supply of glucose and oxygen. Sympathetic neurons inhibit the digestive organs, as well as the kidneys and urinary bladder. The neurotransmitter released by the postganglionic axon is primarily norepinephrine (NE). The structure of NE is like that of epinephrine (adrenaline), an adrenal medulla hormone that usually increases heart rate and contractility.

Parasympathetic Division

The **parasympathetic division** includes a few cranial nerves (e.g., the vagus nerve) as well as fibers that arise from the sacral (bottom) portion of the spinal cord. Therefore, this division is often referred to as the craniosacral portion of the autonomic system.

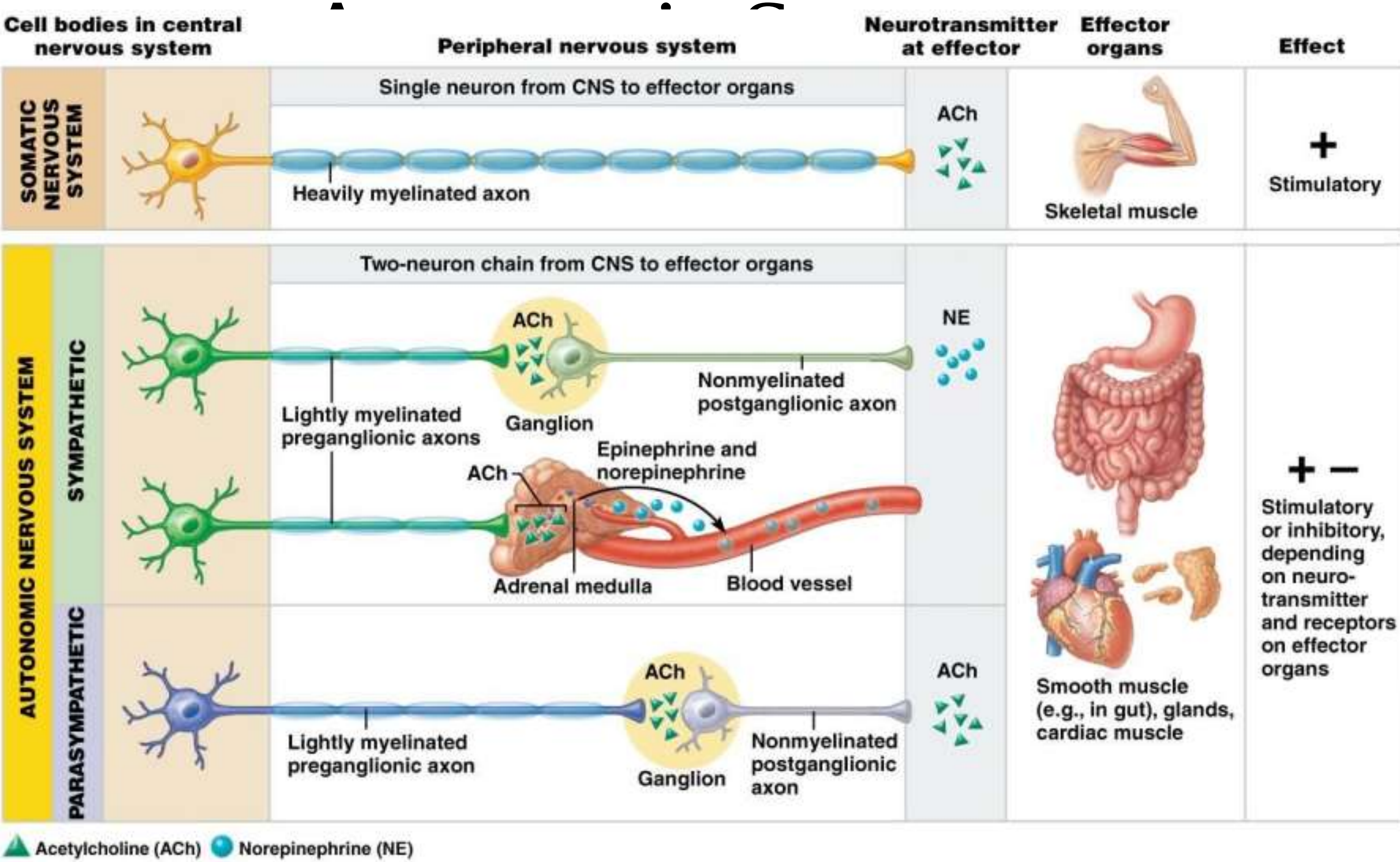
In the parasympathetic division, the preganglionic fiber is long, and the postganglionic fiber is short because the ganglia lie near or within the organ.

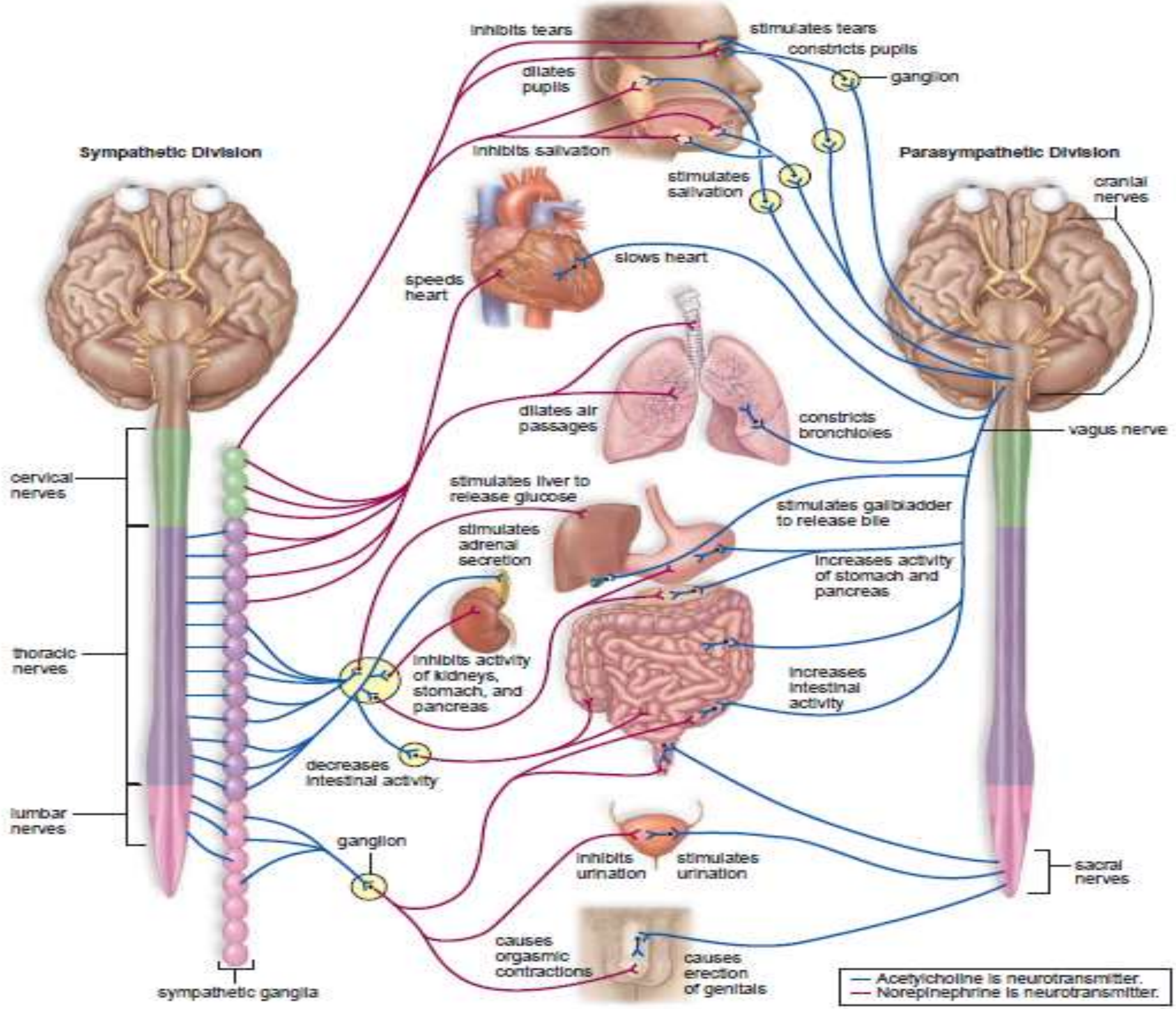
The parasympathetic division, sometimes called the housekeeper division, promotes all the internal responses we associate with a relaxed state. For example, it causes the pupil of the eye to contract, promotes digestion of food, and slows heart rate. It has been suggested that the parasympathetic system could be called the *rest-and-digest* system.

The neurotransmitter used by the parasympathetic division is acetylcholine (ACh).

	Somatic Motor Pathway	Autonomic Motor Pathways	
		Sympathetic	Parasympathetic
Type of control	Voluntary/involuntary	Involuntary	Involuntary
Number of neurons per message	One	Two (preganglionic shorter than postganglionic)	Two (preganglionic longer than postganglionic)
Location of motor fiber	Most cranial nerves and all spinal nerves	Thoracolumbar spinal nerves	Cranial (e.g., vagus) and sacral spinal nerves
Neurotransmitter	Acetylcholine	Norepinephrine	Acetylcholine
Effectors	Skeletal muscles	Smooth and cardiac muscle, glands and organs	Smooth and cardiac muscle, glands and organs

Comparison of Somatic and Autonomic Systems




Sympathetic Division
Parasympathetic Division
inhibits tears
stimulates tears
constricts pupils
ganglion
dilates pupils
inhibits salivation
stimulates salivation
cranial nerves
speeds heart
slows heart
dilates air passages
constricts bronchioles
vagus nerve
cervical nerves
stimulates liver to release glucose
stimulates gallbladder to release bile
stimulates adrenal secretion
increases activity of stomach and pancreas
thoracic nerves
inhibits activity of kidneys, stomach, and pancreas
increases intestinal activity
decreases intestinal activity
lumbar nerves
ganglion
inhibits urination
stimulates urination
sacral nerves
causes orgasmic contractions
causes erection of genitals
sympathetic ganglia
Acetylcholine is neurotransmitter.
Norepinephrine is neurotransmitter.

Digestive system

Essam Mohammed Al-Fhadawy

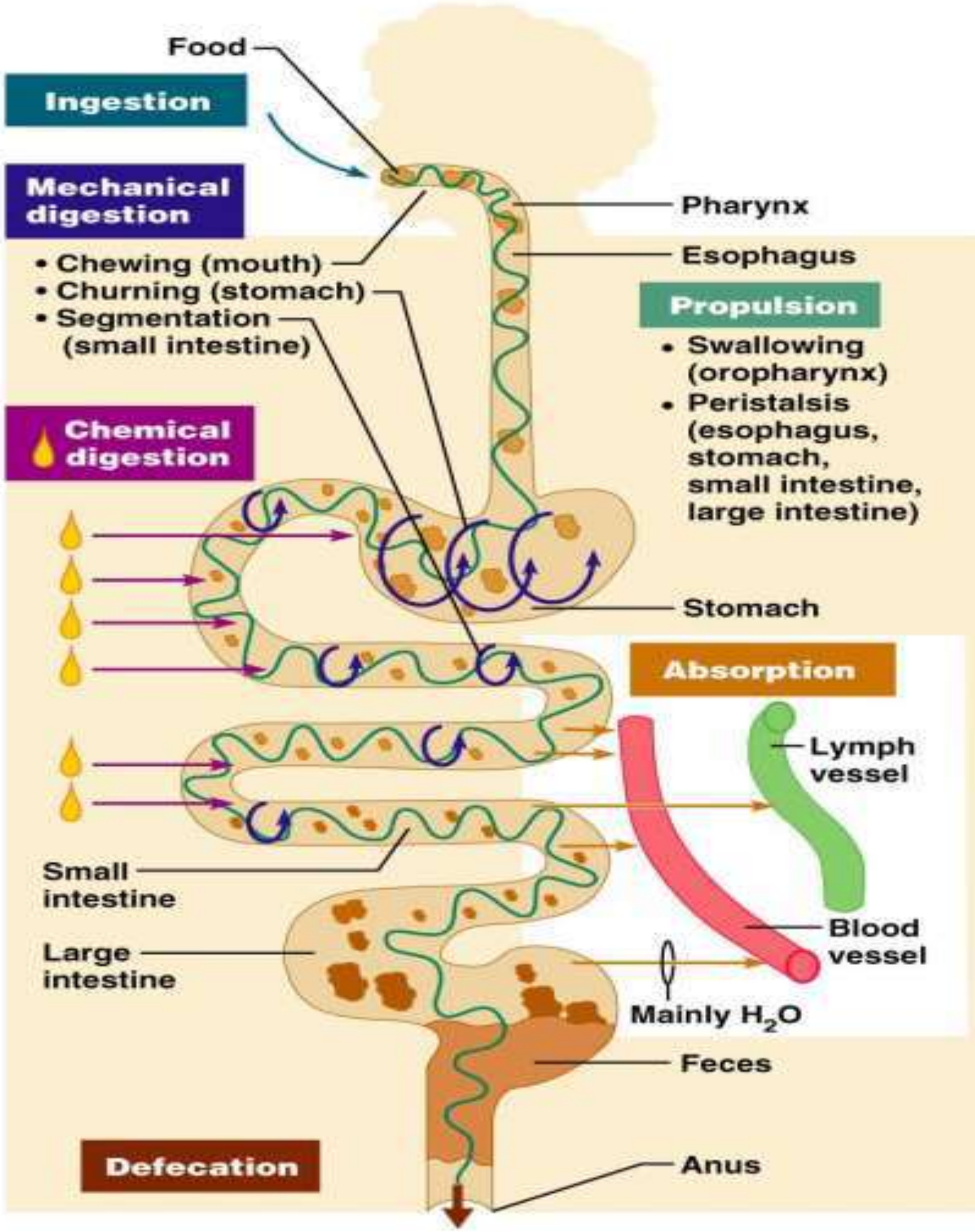
The organs of the digestive system are located within a tube called the gastrointestinal tract (GIT) .
The purpose of digestion is to **hydrolyze**—or break down using water—these macromolecules to their subunit molecules (micromolecules).

The following processes are necessary to the digestive process.

- **Ingestion** occurs when the mouth takes in food.
- **Digestion** can be mechanical or chemical processes.

A- Mechanical digestion occurs when large pieces of food are divided into smaller pieces. Mechanical digestion occurs primarily in the mouth by chewing and by wavelike contractions of the smooth muscles in the stomach called **peristalsis.**

B-Chemical digestion digestive enzymes hydrolyze our food's macromolecules into absorbable subunits. Chemical digestion begins in the mouth, continues in the stomach, and is completed in the small intestine.


Food
Ingestion
Mechanical digestion
• Chewing (mouth)
• Churning (stomach)
• Segmentation (small intestine)
Chemical digestion
Pharynx
Esophagus
Propulsion
• Swallowing (oropharynx)
• Peristalsis (esophagus, stomach, small intestine, large intestine)
Stomach
Absorption
Lymph vessel
Small intestine
Blood vessel
Large intestine
Mainly H_2O
Feces
Defecation
Anus

• **Movement** of GI tract contents along the digestive tract is very important for the tract. For example, food must be passed along from one organ to the next, normally by peristalsis, and indigestible remains must be expelled.

• **Absorption** occurs as subunit molecules produced by chemical digestion (i.e., nutrients) cross the wall of the GI tract and enter the cells lining the tract. From there, the nutrients enter the blood for delivery to the cells.

• **Elimination:** Molecules that cannot be digested need to be eliminated from the body. The removal of indigestible wastes through the anus is termed *defecation*.

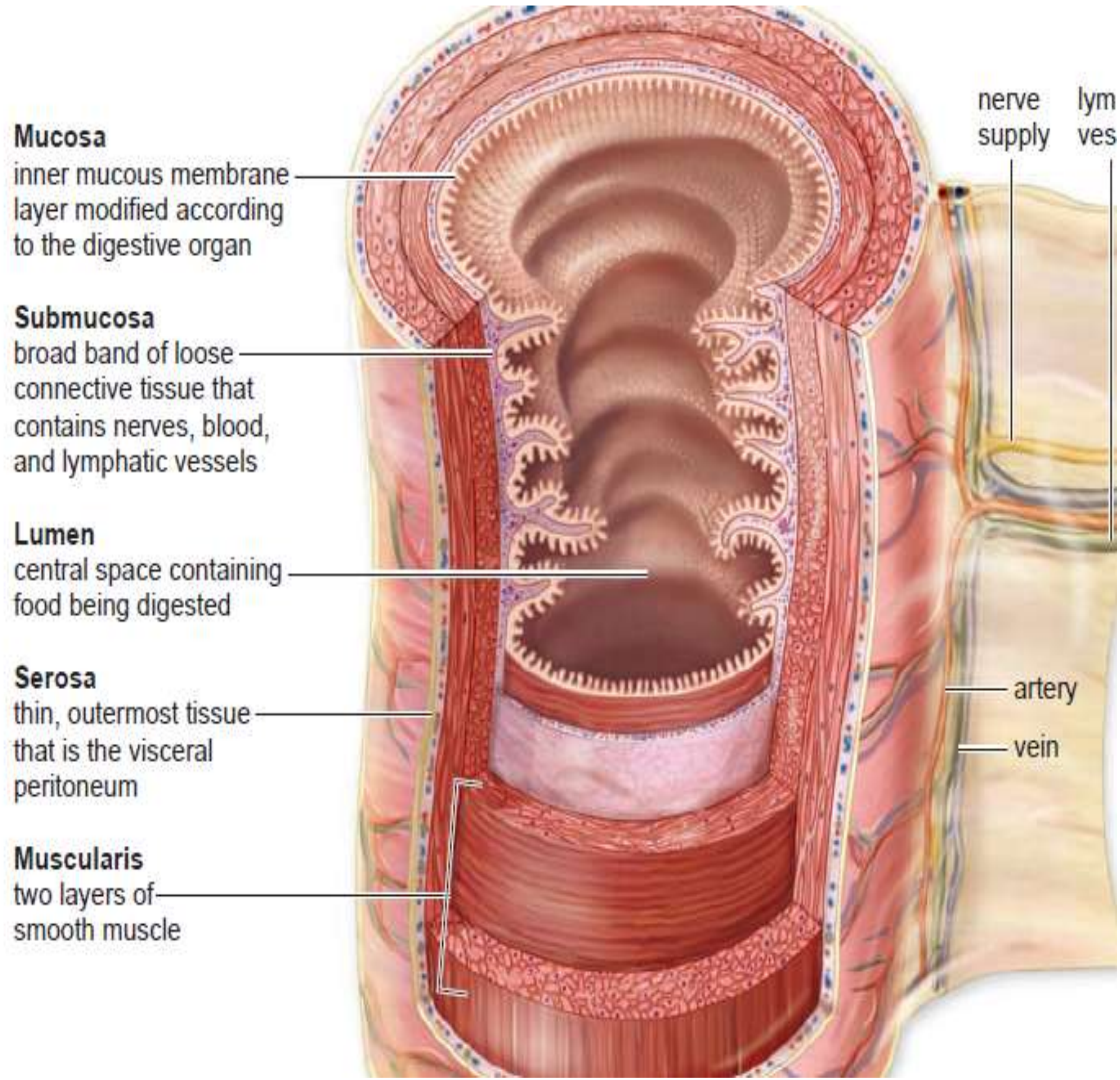
Wall of the Digestive Tract: The inner layer of the wall next to the lumen is called the

mucosa. The mucosal layer contains cells that produce and secrete mucus used to protect all the layers of the tract from the digestive enzymes inside the lumen. Glands in the mucosa of the mouth, stomach, and small intestine also release digestive enzymes. Hydrochloric acid, an important digestive enzyme, is produced by glands in the mucosa of the stomach.

The second layer in the GI wall is called the **submucosa.** The submucosal layer is a broad band of loose connective tissue that contains blood vessels, lymphatic vessels, and nerves. These are the vessels that will carry the nutrients absorbed by the mucosa. Lymph nodules, called Peyer's patches, are also in the submucosa. Like the tonsils, they help protect from disease.

The third layer is termed the **muscularis**, and it contains two layers of smooth muscle. The inner, circular layer encircles the tract. The outer, longitudinal layer lies in the same direction as the tract. The contraction of these muscles, under nervous and hormonal control, accounts for peristalsis and subsequent movement of digested food from the esophagus to the anus.

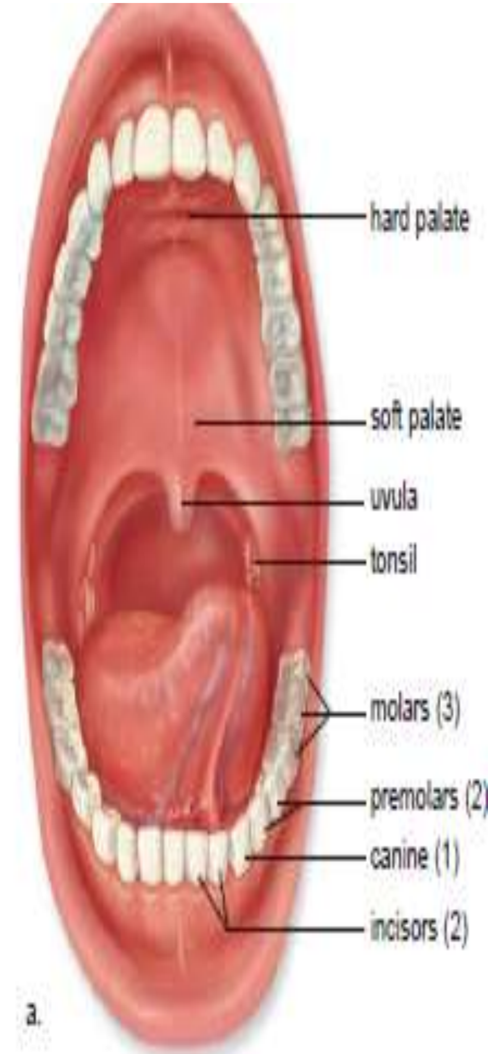
The fourth and outermost layer of the tract is the **serosa** (serous membrane layer), which secretes a lubricating fluid. The serosa is a part of the peritoneum, the internal lining of the abdominal cavity.


Mucosa
inner mucous membrane layer modified according to the digestive organ
Submucosa
broad band of loose connective tissue that contains nerves, blood, and lymphatic vessels
Lumen
central space containing food being digested
Serosa
thin, outermost tissue that is the visceral peritoneum
Muscularis
two layers of smooth muscle
nerve supply
lym ves
artery
vein

The Mouth : The mouth (also called the **oral cavity**) receives food and begins the process of mechanical and chemical digestion. The mouth is bounded externally by the lips and cheeks. The lips extend from the base of the nose to the start of the chin. The red portion of the lips is poorly keratinized, and this allows blood to show through.

The roof of the mouth separates the nasal cavities from the oral cavity. The roof has two parts: an anterior (toward the front) **hard palate** and a posterior (toward the back) **soft palate** . The hard palate contains several bones, but the soft palate is composed entirely of muscle. The soft palate ends in a finger-shaped projection called the uvula.

The tonsils are also in the back of the mouth on either side of the tongue. Tonsils are lymphatic tissue and help protect us from disease.

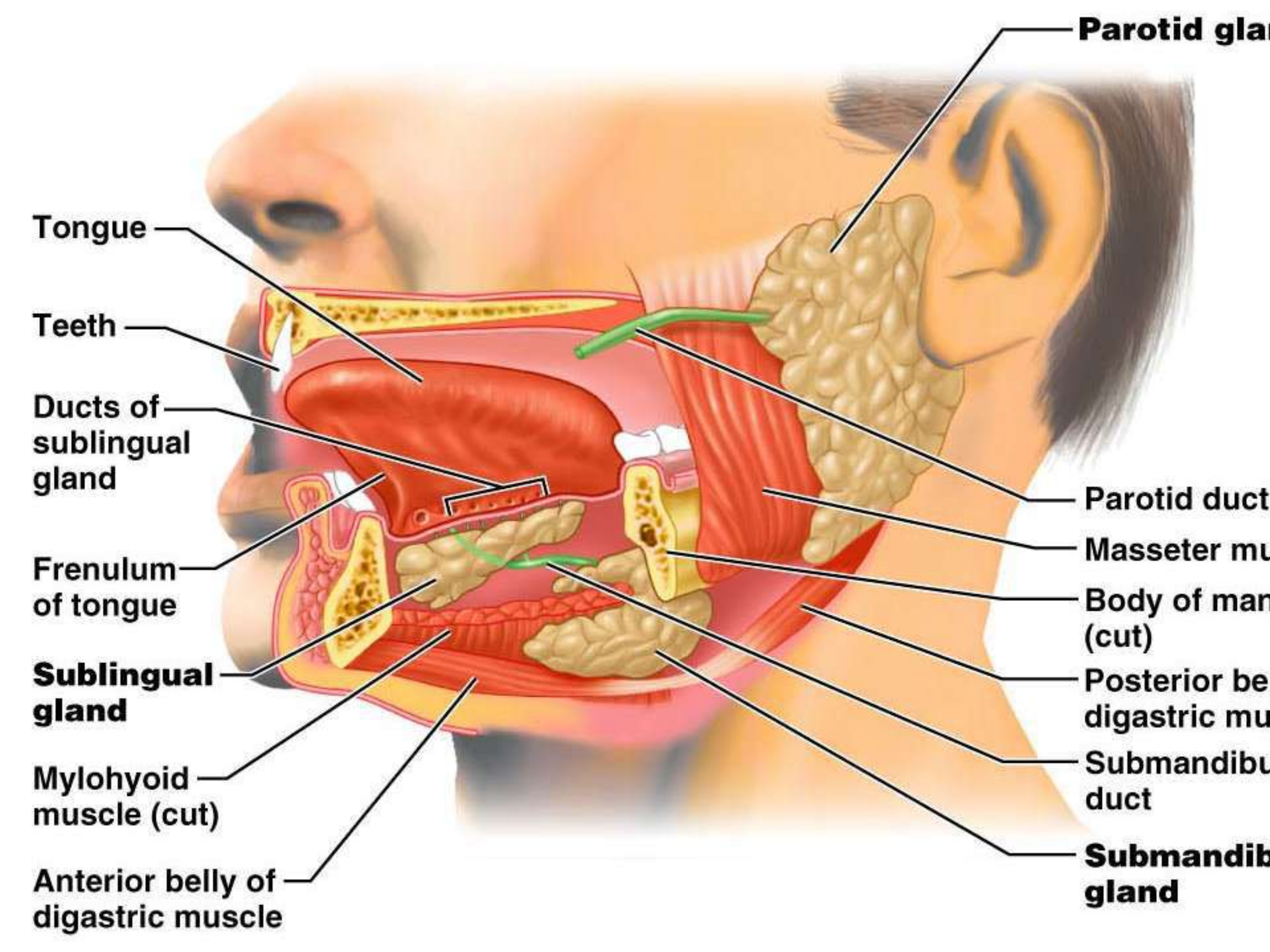


Salivary Glands

1. Three pairs of salivary glands called **parotid ,** **submandibular** , and **sublingual** gland secrete most of the saliva in the oral cavity , using salivary ducts .

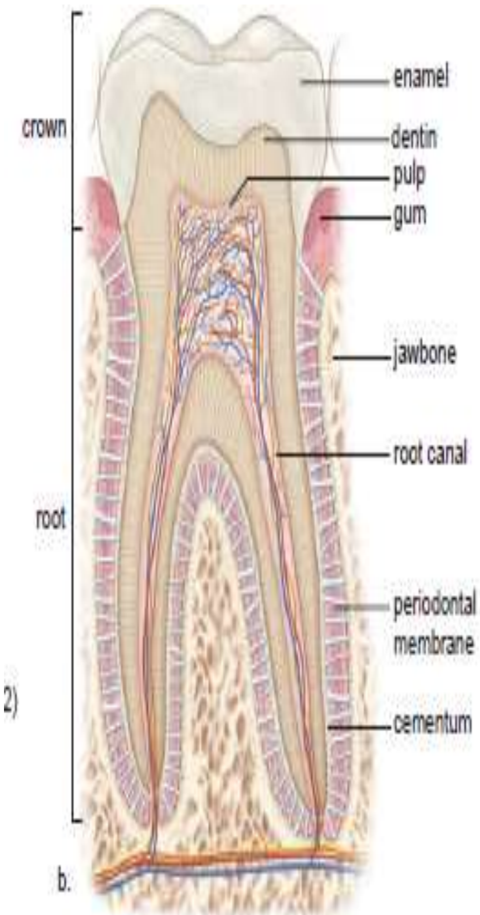
2. Saliva helps moisten the food during mastication , dissolve the food in forming the bolus , and help cleanse the teeth.

3. Saliva consists of 99.5% water , the remaining 0.5% is dissolved substances including **amylase** enzyme (for chemically digesting carbohydrate), bicarbonate ion (HCO3 **-**; maintains pH of saliva at 6.5-7.5) , and many electrolytes.


Parotid gla
Tongue
Teeth
Ducts of sublingual gland
Frenulum of tongue
Sublingual gland
Mylohyoid muscle (cut)
Anterior belly of digastric muscle
Parotid duct
Masseter mu
Body of man (cut)
Posterior be digastric mu
Submandibu duct
Submandib gland

The Teeth and Tongue

Mechanical digestion occurs when our teeth chew food into pieces convenient for swallowing. Each tooth has two main divisions: a crown, the portion of the tooth above the gumline, and a root, the portion below the gumline . The crown has a layer of enamel, an extremely hard outer covering of calcium compounds; dentin, a thick layer of bonelike material; and an inner pulp, which contains the nerves and the blood vessels. Dentin and pulp also make up a portion of the root, which includes periodontal membranes to anchor the tooth into the jawbone.



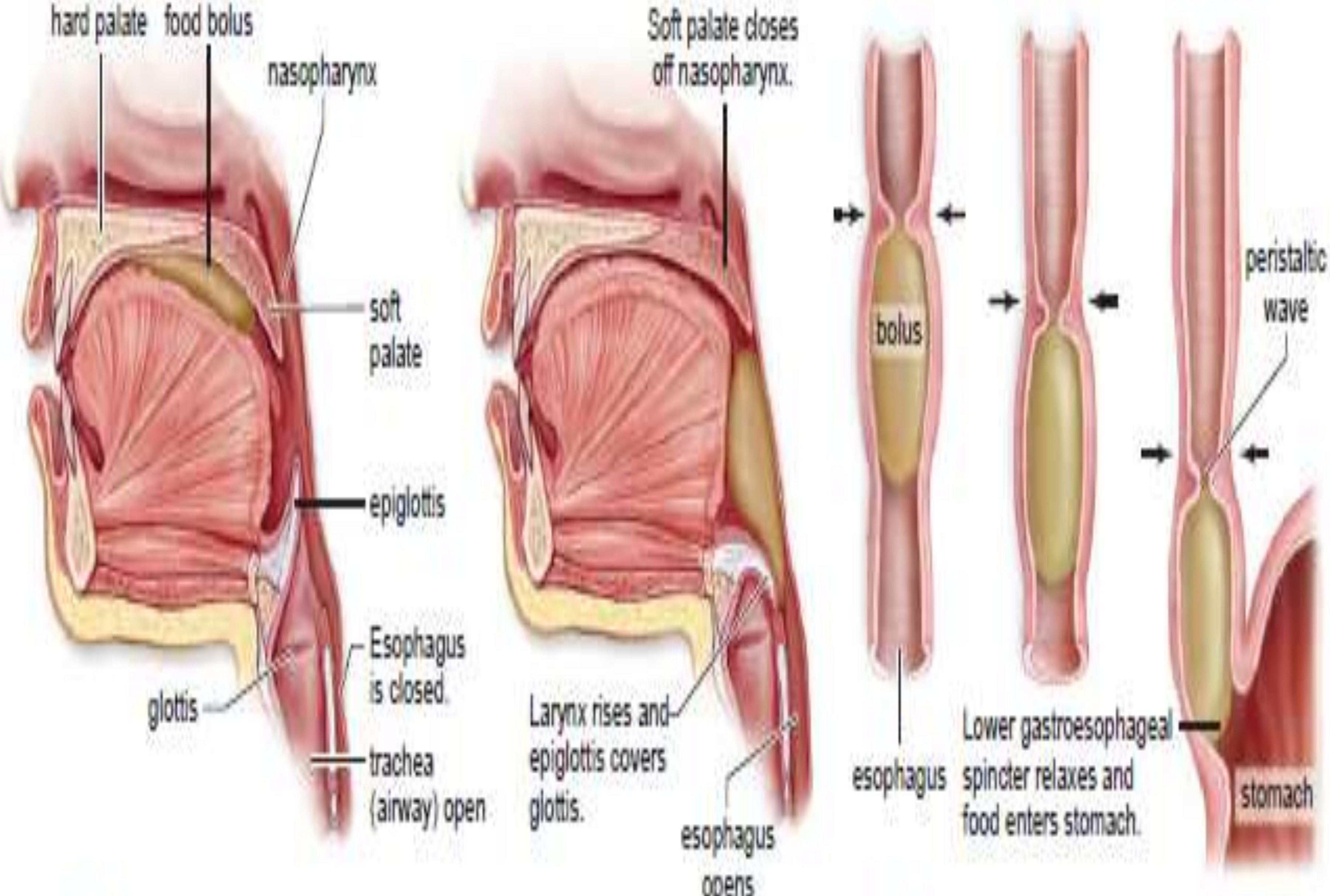
The tongue is covered by a mucous membrane, which contains the sensory receptors called taste buds . When taste buds are activated by the presence of food, nerve impulses travel by way of nerves to the brain. The tongue is composed of skeletal muscle, and it assists the teeth in carrying out mechanical digestion by moving food around in the mouth. In preparation for swallowing, the tongue forms chewed food into a mass called a **bolus,** which it pushes toward the pharynx.

The Pharynx and Esophagus

Both the mouth and the nasal passages lead to the **pharynx,** a hollow space at the back of the throat . In turn, the pharynx opens into both the food passage (**esophagus**) and air passage (**trachea**, or **windpipe**).

Swallowing

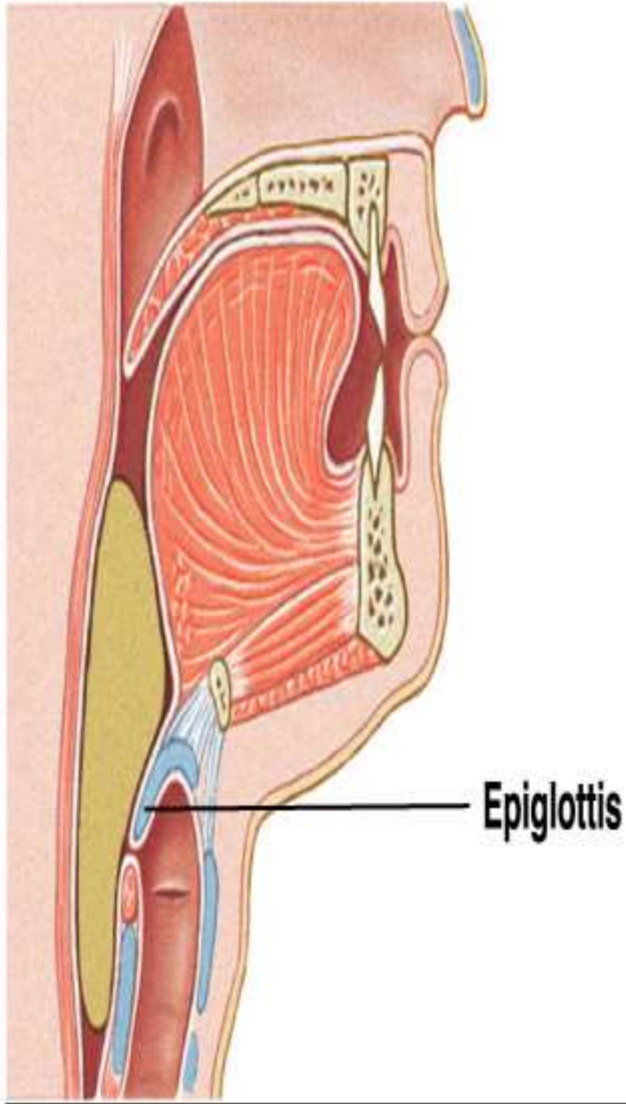
During swallowing, food normally enters the esophagus, a muscular tube that moves food into the stomach, because other possible avenues are blocked. The soft palate moves back to close off the nasal passages, and the trachea moves up under the **epiglottis** to cover the glottis.



a. Swallowing

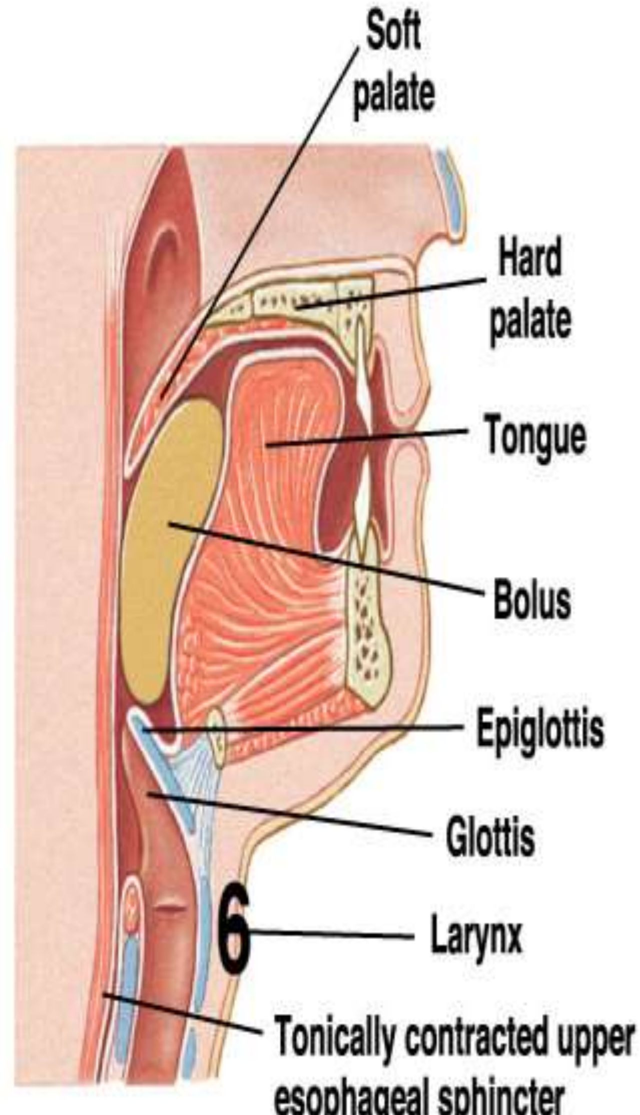
b. Peristalsis

Step 2



2. Upper esophageal sphincter relaxes while epiglottis closes to keep swallowed material out of the airways.

Step 1



1. Tongue pushes bolus against soft palate and back of mouth, triggering swallowing reflex.

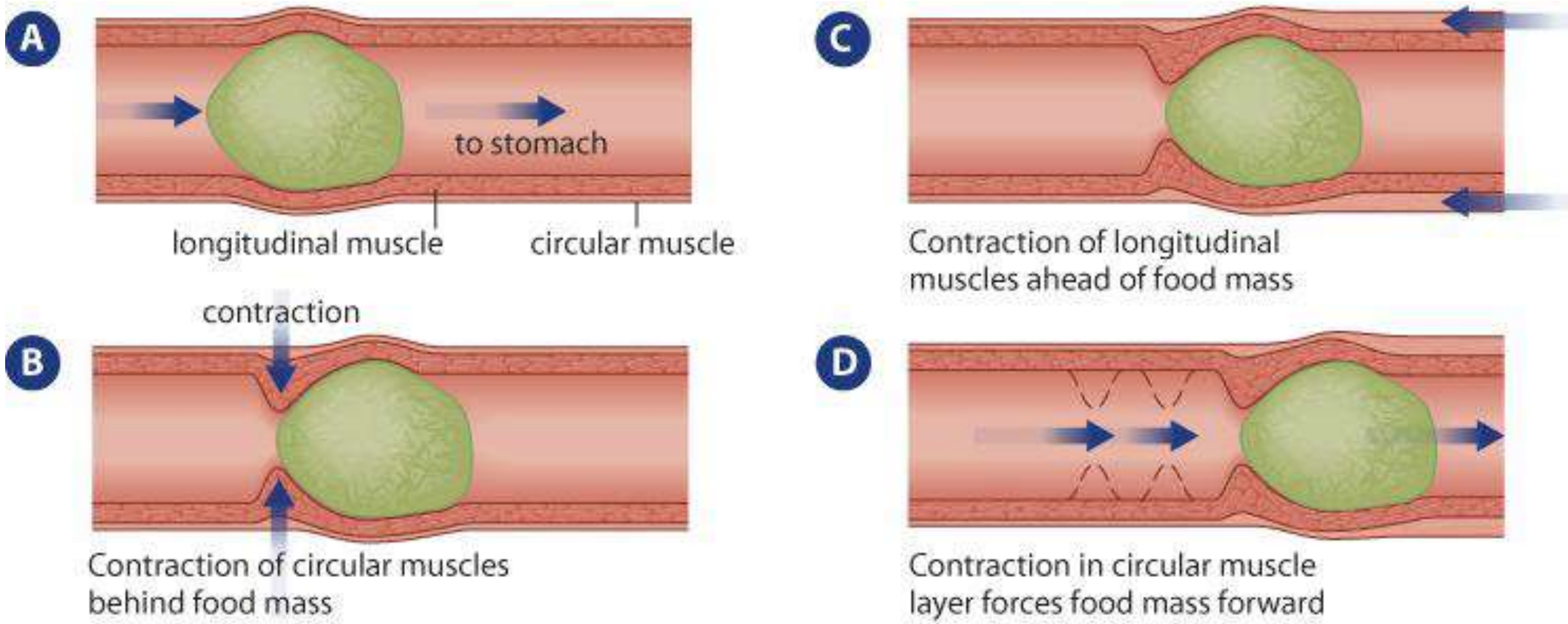
Peristalsis

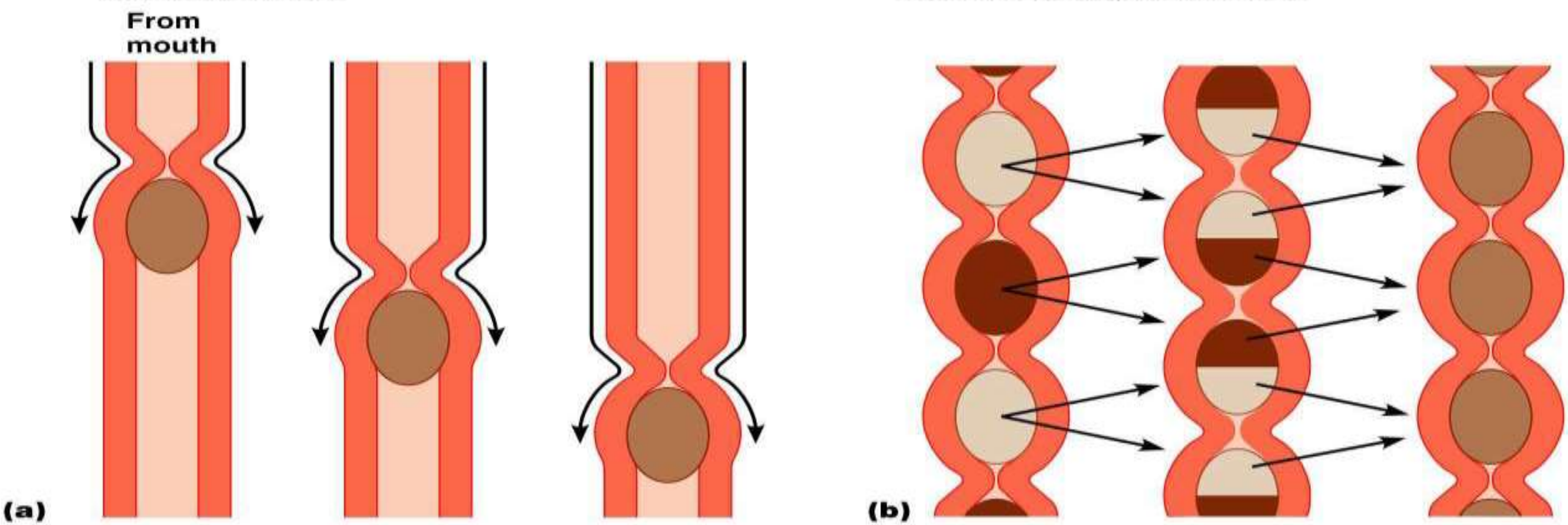
Peristalsis pushes food through the esophagus. The peristaltic contractions continue in the stomach and intestines.

The esophagus plays no role in the chemical digestion of food. Its sole purpose is to move the food bolus from the mouth to the stomach.

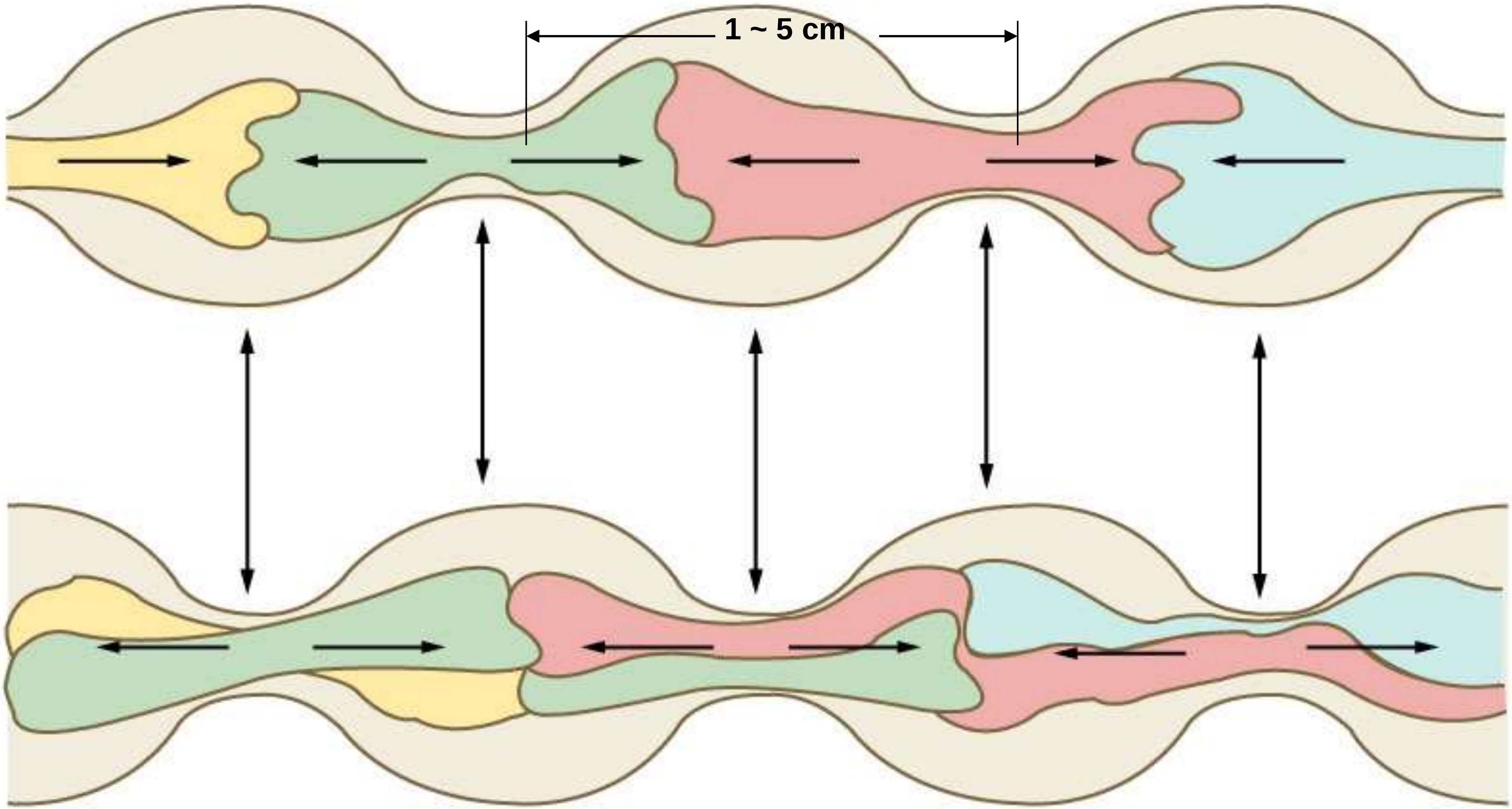
A constriction called the *lower gastroesophageal sphincter* marks the entrance of the esophagus to the stomach.

Sphincters are muscles that encircle tubes and act as valves. The tubes close when the sphincters contract and they open when the sphincters relax. When food or saliva is swallowed, the sphincter relaxes for a moment to allow the food or saliva to enter the stomach . The sphincter then contracts, preventing the acidic stomach contents from backing up into the esophagus.


A
to stomach
longitudinal muscle
circular muscle
B
contraction
Contraction of circular muscles
behind food mass
C
Contraction of longitudinal
muscles ahead of food mass
D
Contraction in circular muscle
layer forces food mass forward


From
mouth
(a)
(b)

Segmental contractions are responsible for mixing



No net forward movement

The Stomach

The **stomach** is a thick-walled, J-shaped organ that lies on the left side of the body beneath the diaphragm. The stomach is continuous with the esophagus above and the duodenum of the small intestine below. The stomach stores food, initiates the digestion of protein, and controls the movement of food into the small intestine. Nutrients are not absorbed by the stomach. However, it does absorb alcohol, because alcohol is fat soluble and can pass through membranes easily.

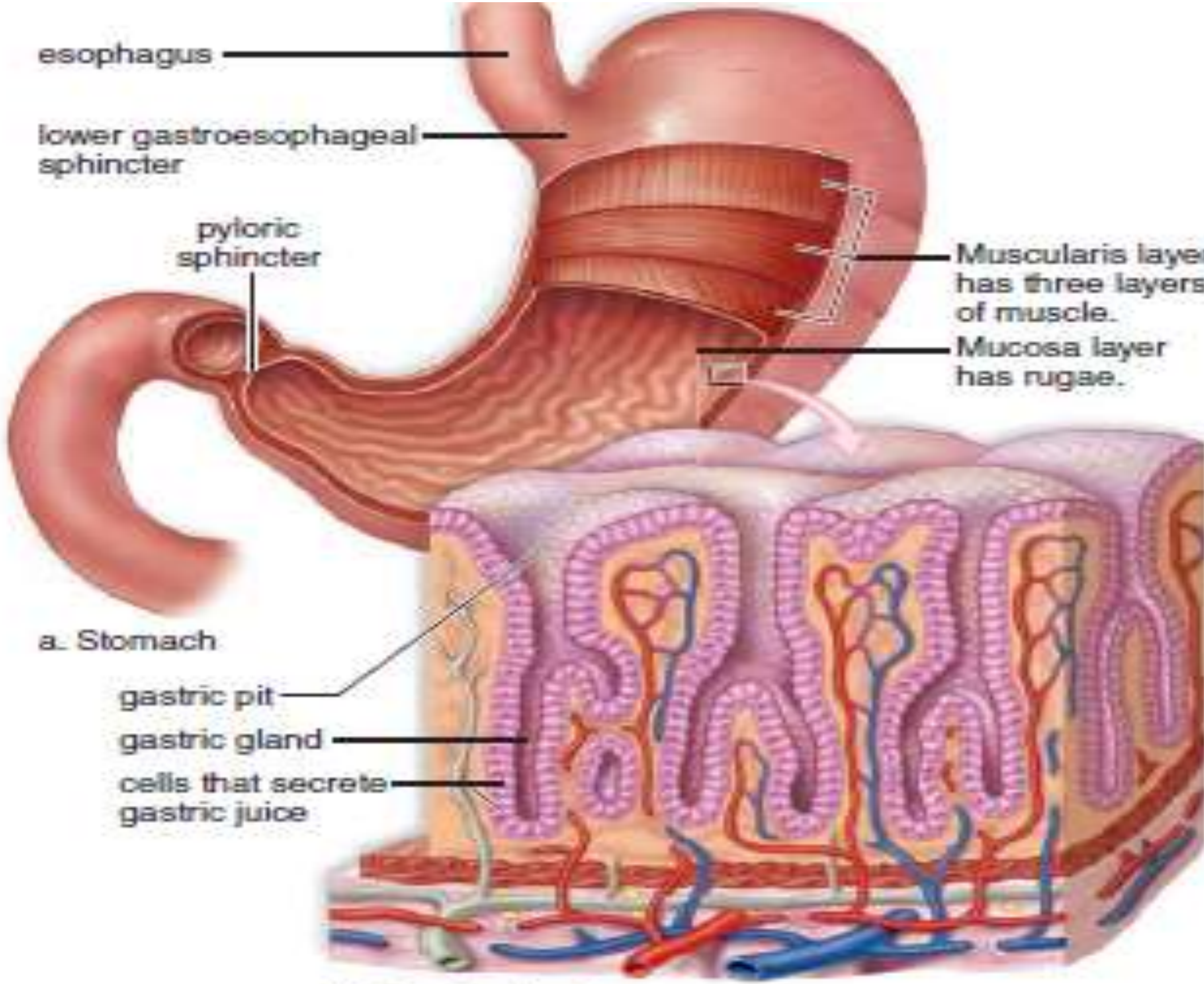
The stomach wall has the usual four layers, but two of them are modified for particular functions. The muscular is contains three layers of smooth muscle . In addition to the circular and longitudinal layers, the stomach also contains a layer of smooth muscle that runs obliquely to the other two. The **oblique** layer also allows the stomach to stretch and to mechanically break down food into smaller fragments that are mixed with gastric juice.

The mucosa of the stomach has deep folds called **rugae.** These disappear as the stomach fills to an approximate capacity of 1 liter. The mucosa of the stomach has millions of gastric pits, which lead into **gastric glands.**

Gastric juice

The gastric glands produce gastric juice. Gastric juice contains an enzyme called **pepsin,** which digests protein, plus hydrochloric acid (HCl) and mucus. HCl causes the stomach to be very acidic with a pH of about 2. This acidity is beneficial because it kills most bacteria present in food. Although HCl does not digest food, it does break down the connective tissue of meat and activates pepsin. When food leaves the stomach, it is a thick, soupy liquid of partially digested food called **chyme.**

Chyme's entry into the small intestine is regulated into small amounts entering at intervals. Peristaltic waves move the chyme toward the pyloric sphincter.



a. Stomach
b. Gastric glands

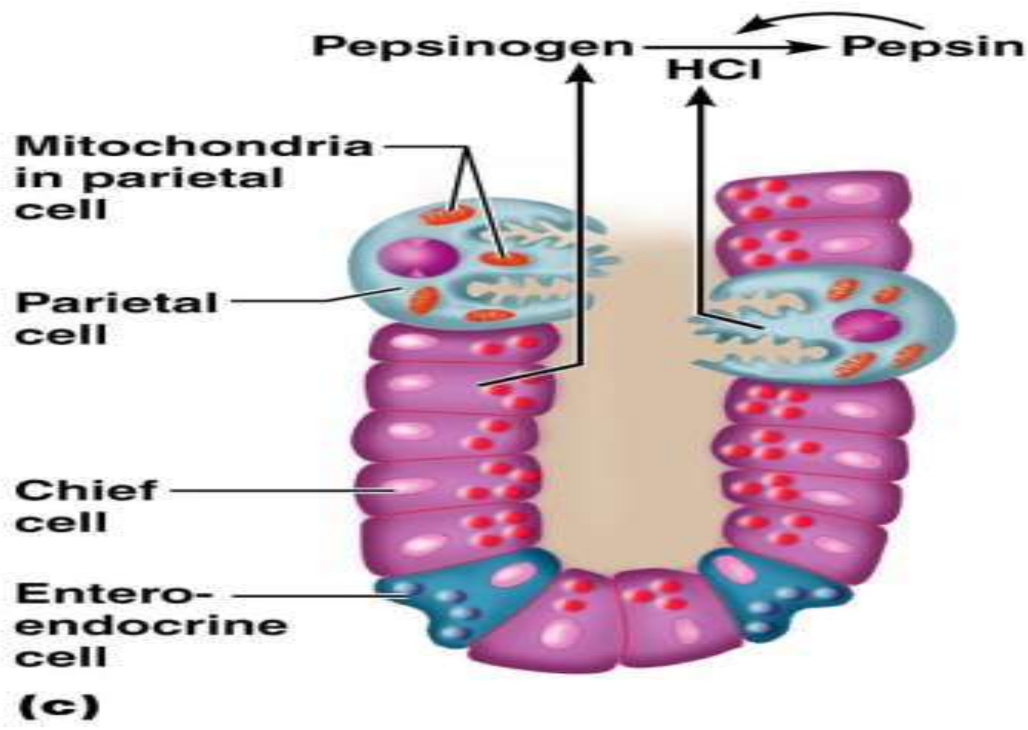
Gastric Secretory Cells

1 - Chief cells: secrete pepsinogen (an inactive enzyme).

2 - Parietal cells: secrete hydrochloric acid (HCl) and "intrinsic factor" (which helps absorption of vitamin B12 in the intestines).

3 - Mucous cells: secrete mucus and alkaline substances to help neutralize HCl in the gastric juice .

4 - G cells: secrete a hormone called gastrin , which stimulates the parietal cells and overall gastric secretion .



Regulation of Gastric Secretion

1. Regulation of gastric secretion and activities is by both nervous and hormonal mechanisms – food moving along the oral cavity and esophagus stimulates the **parasympathetic nerves** to activate the secretion in gastric glands , the **gastric hormone** from G cells in turn stimulates the gastric glands for more activities ("positive feedback").

2. When food is emptying from the stomach , **sympathetic nerves** inhibit the gastric glands and a hormone called **intestinal gastrin** (released by small intestine) inhibits other gastric activities.

3. The above regulations occur in 3 overlapping phases:

Cephalic Phase, **Gastric Phase, & Intestinal Phase.**

1. Cephalic phase: involves special senses detect food and uses parasympathetic nerves in the vagus nerve to stimulate gastric activities.

A. Sight, Smell , and Taste of food cause stimulation of vagus nuclei in brain.

B. Vagus stimulates acid secretion.

a. Direct stimulation of parietal cells (major effect).

b. Stimulation of Gastrin secretion (lesser effect).

2. Gastric phase involves the distention of stomach and stimulates its own activities by the vagus nerve. Distension of stomach (stretch - receptors) stimulates vagus nerve.

a-vagus stimulates acid secretion .

b. Amino acids and peptides in stomach lumen stimulates acid secretion (chemo - receptors)

c. Direct stimulation of parietal cells (lesser effect)

d. Stimulation of gastrin secretion ; gastrin stimulates acid secretion (major effect)

f. Gastrin secretion inhibited when pH of gastric juice falls below 2.5.

3. intestinal phase involves acidic chyme passing into the small intestine which secretes intestinal gastrin hormone to inhibit gastric activates.

A. Neural inhibition of gastric emptying and acid secretion. Arrival of chyme in duodenum causes distension & an increase in osmotic pressure. These stimuli activate a neural reflex that inhibits gastric activity.

B. In response to fat in chyme , duodenum secretes the hormone, **secretin** that inhibits gastric acid secretion.

C. The enterogastric reflex: This reflex begins in the small intestine (entero) and ends in the stomach (gastro).

D. Duodenum fills with chyme. Sensory stretch receptors are stimulated. Sensory nerve impulses travel to CNS. Nerve impulses from CNS (vagus) inhibit peristalsis in stomach wall.

The Small Intestine

The **small intestine** is named for its small diameter compared with that of the large intestine.

Digestion Is Completed in the Small Intestine

The small intestine contains enzymes to digest all types of foods, primarily carbohydrates, proteins, and fats. Most of these enzymes are secreted by the pancreas and enter via a duct at the **duodenum** . Another duct brings bile from the liver and gallbladder into the duodenum.

Bile emulsifies fat. Emulsification causes fat droplets to disperse in water. After fat is mechanically broken down to fat droplets by bile, it is hydrolyzed to monoglycerides and fatty acids by the enzyme **lipase** present in pancreatic juice. Pancreatic amylase begins the digestion of carbohydrates. An intestinal enzyme completes the digestion of carbohydrates to glucose.

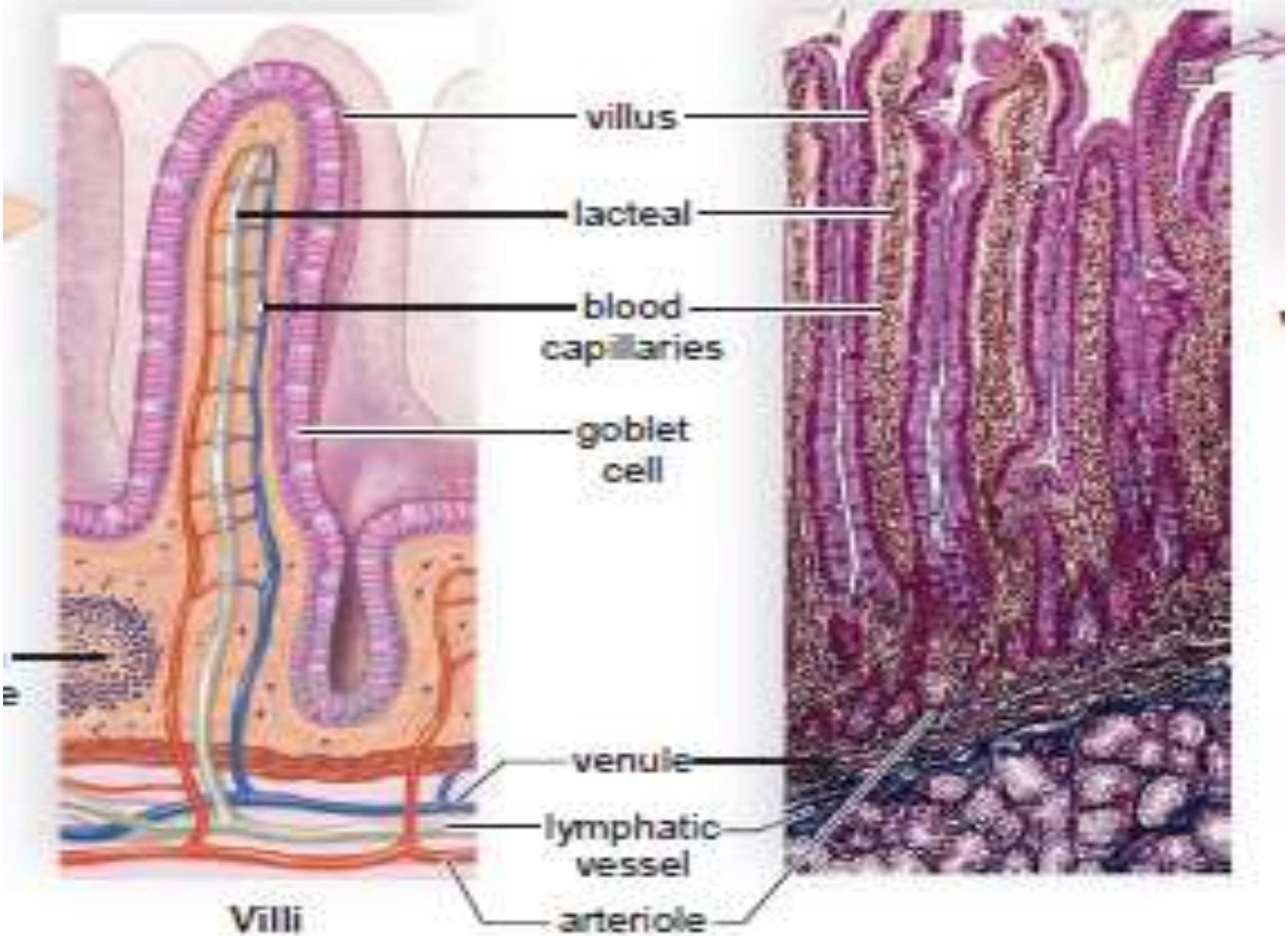
Similarly, pancreatic trypsin begins and intestinal enzymes finish the digestion of proteins to amino acids. The intestine has a slightly basic pH because pancreatic juice contains sodium bicarbonate (NaHCO3), which neutralizes chyme.

Nutrients Are Absorbed in the Small Intestine

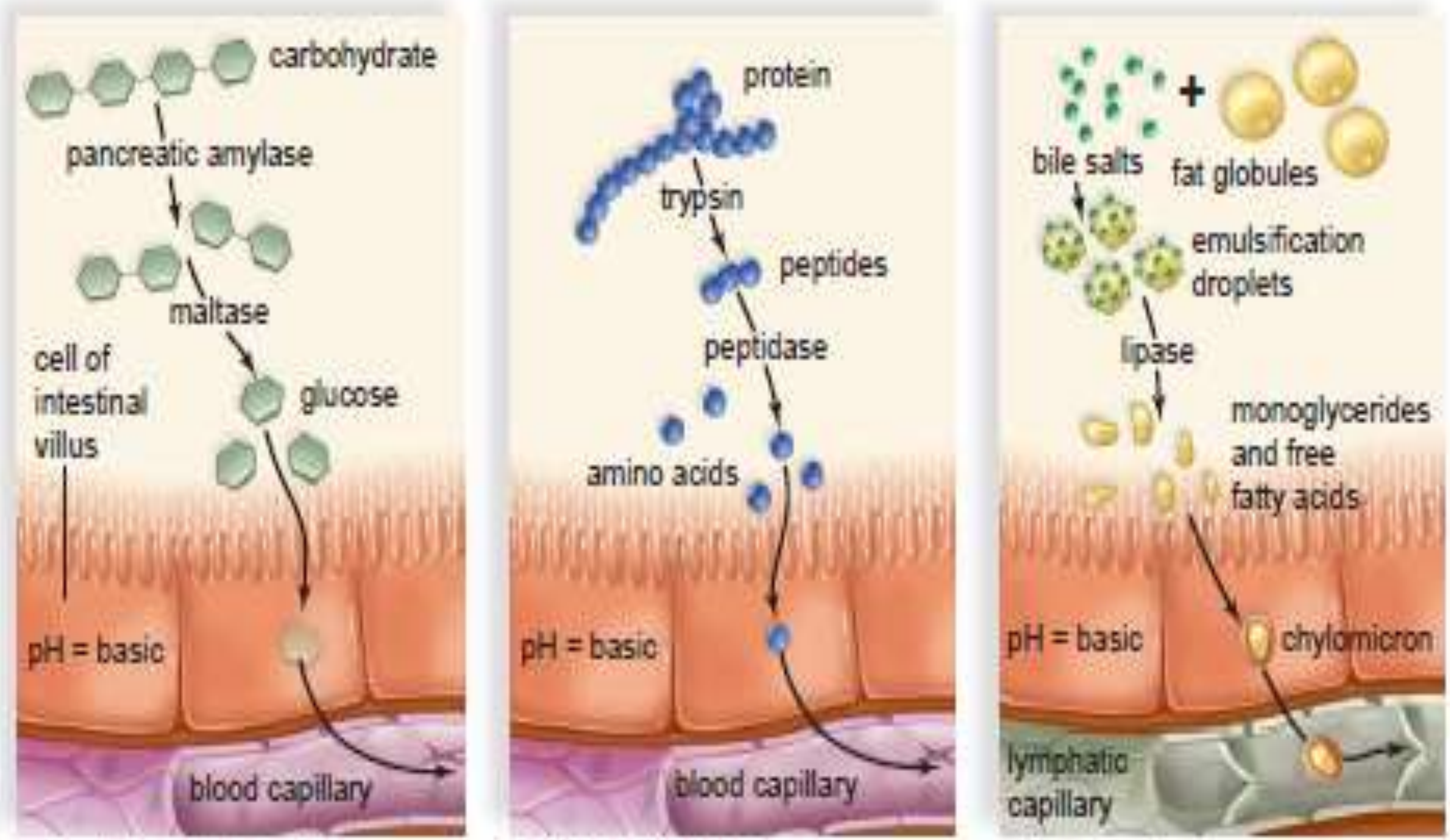
The wall of the small intestine absorbs the molecules—namely, sugars, amino acids, fatty acids, and glycerol—that were the products of the digestive process.

The mucosa of the small intestine contains fingerlike projections called villi (sing., **villus**), which give the intestinal wall a soft. A villus has an outer layer of columnar epithelial cells, and each of these cells has thousands of microscopic extensions called microvilli. Collectively, in electron micrographs, microvilli give the villi a fuzzy border known as a "brush border." The microvilli greatly increase the surface area of the villus for the absorption of nutrients.

A villus contains blood capillaries and a small lymphatic capillary called a **lacteal.**


villus
lacteal
blood
capillaries
goblet
cell
venule
lymphatic
vessel
arteriole
Villi

Enzyme	Produced By	Site of Action	Optimum pH	Digestion
Carbohydrate Digestion				
Salivary amylase	Salivary glands	Mouth	Neutral	Starch + H_2O → maltose
Pancreatic amylase	Pancreas	Small intestine	Basic	Starch + H_2O → maltose
Maltase	Small intestine	Small intestine	Basic	Maltose + H_2O → glucose + glucose
Lactase	Small intestine	Small intestine	Basic	Lactose + H_2O → glucose + galactose
Protein Digestion				
Pepsin	Gastric glands	Stomach	Acidic	Protein + H_2O → peptides
Trypsin	Pancreas	Small intestine	Basic	Protein + H_2O → peptides
Peptidases	Small intestine	Small intestine	Basic	Peptide + H_2O → amino acids
Nucleic Acid Digestion				
Nuclease	Pancreas	Small intestine	Basic	RNA and DNA + H_2O → nucleotides
Nucleosidases	Small intestine	Small intestine	Basic	Nucleotide + H_2O → base + sugar + phosphate
Fat Digestion				
Lipase	Pancreas	Small intestine	Basic	Fat droplet + H_2O → monoglycerides + fatty acids



a. Carbohydrate digestion

b. Protein digestion

c. Fat digestion

The Accessory Organs and Regulation of Secretions

1- **pancreas** is a fish-shaped, spongy, grayish-pink organ that stretches across the back of the abdomen behind the stomach. Most pancreatic cells produce pancreatic juice, which enters the duodenum via the pancreatic duct . Pancreatic juice contains sodium bicarbonate (NaHCO3) and digestive enzymes for all types of food. Sodium bicarbonate neutralizes acid chyme from the stomach. **Pancreatic amylase** digests starch, **trypsin** digests protein, and pancreatic **lipase** digests fat.

The pancreas is also an endocrine gland that secretes the hormone insulin into the blood.

2- The **liver** largest gland in the body, lies mainly in the upper right section of the abdominal cavity, under the diaphragm . The hepatic portal vein brings blood to the liver from the GI tract capillary bed. Capillaries of the lobules filter this blood.

Function of liver

1. Destroys old red blood cells; excretes bilirubin, a breakdown product of hemoglobin in bile, a liver product
2. Detoxifies blood by removing and metabolizing poisonous substances
3. Stores iron (Fe^{2+}) and the fat-soluble vitamins A, D, E, and K
4. Makes plasma proteins, such as albumins and fibrinogen, from amino acids
5. Stores glucose as glycogen after a meal, and breaks down glycogen to glucose to maintain the glucose concentration of blood between eating periods
6. Produces urea after breaking down amino acids
7. Helps regulate blood cholesterol level, converting some to bile salts

Liver Disorders

Hepatitis and cirrhosis are two serious diseases that affect the entire liver and hinder its ability to repair itself. When a person has a liver ailment, bile pigments may leak into the blood causing **jaundice.** Jaundice is a yellowish tint to the whites of the eyes and also to the skin of light-pigmented persons. Jaundice can result from **hepatitis,** inflammation of the liver. Viral hepatitis occurs in several forms. Hepatitis A is usually acquired from sewage-contaminated drinking water and food. Hepatitis B, which is usually spread by sexual contact, can also be spread by blood transfusions or contaminated needles. Vaccines are available for hepatitis A and hepatitis B. Hepatitis C is usually acquired by contact with infected blood and can lead to chronic hepatitis, liver cancer, and death. There is no vaccine for hepatitis C.

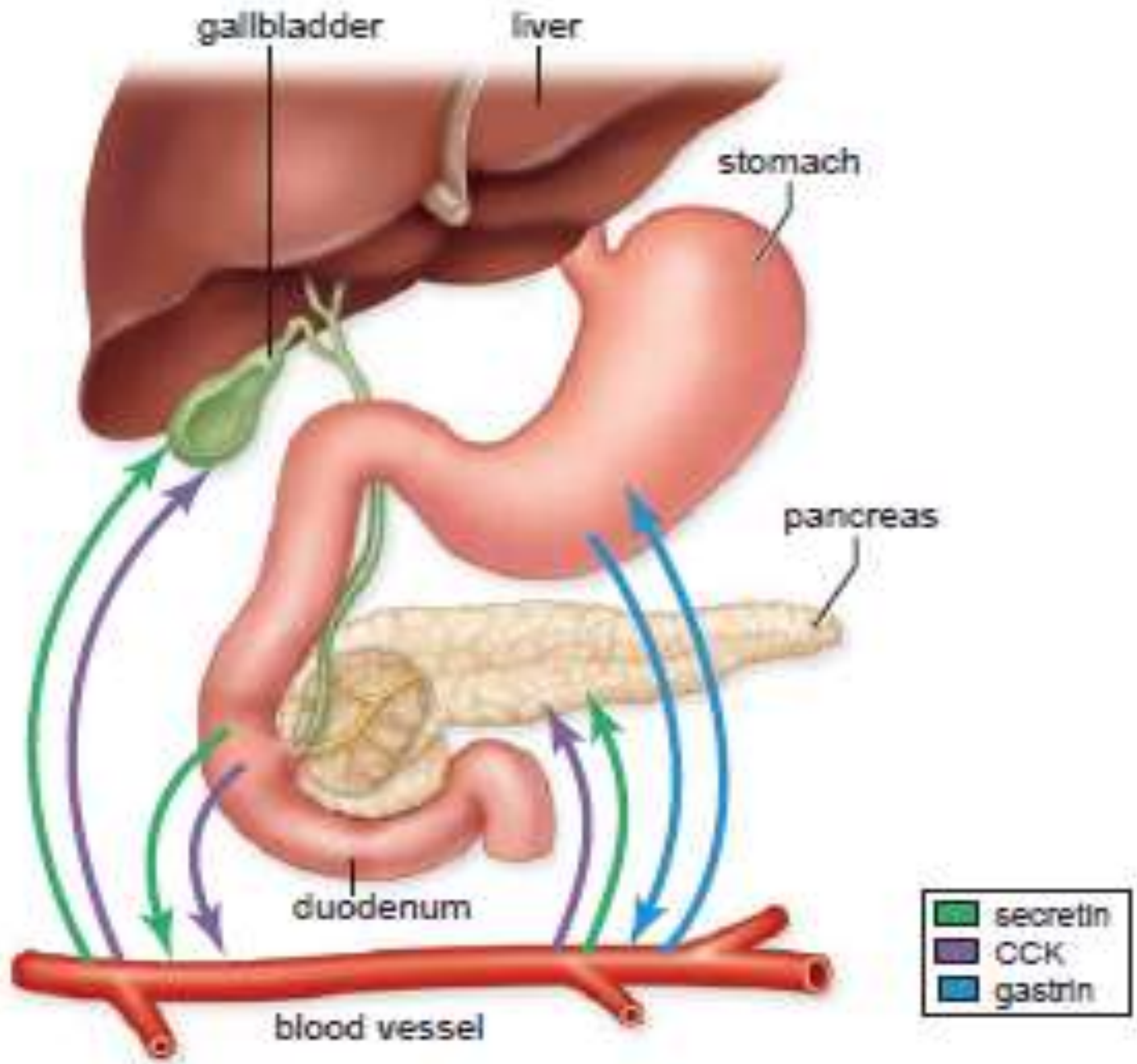
Cirrhosis. First, the organ becomes fatty, and then liver tissue is replaced by inactive fibrous scar tissue. Cirrhosis of the liver is often seen in alcoholics, due to malnutrition and to the excessive amounts of alcohol (a toxin) the liver is forced to break down.. The liver is a vital organ, and its failure leads to death.

Regulation of Digestive Secretions

The secretions of digestive juices are controlled by the nervous system and by digestive hormones. When you look at or smell food, the parasympathetic nervous system automatically stimulates gastric secretion.

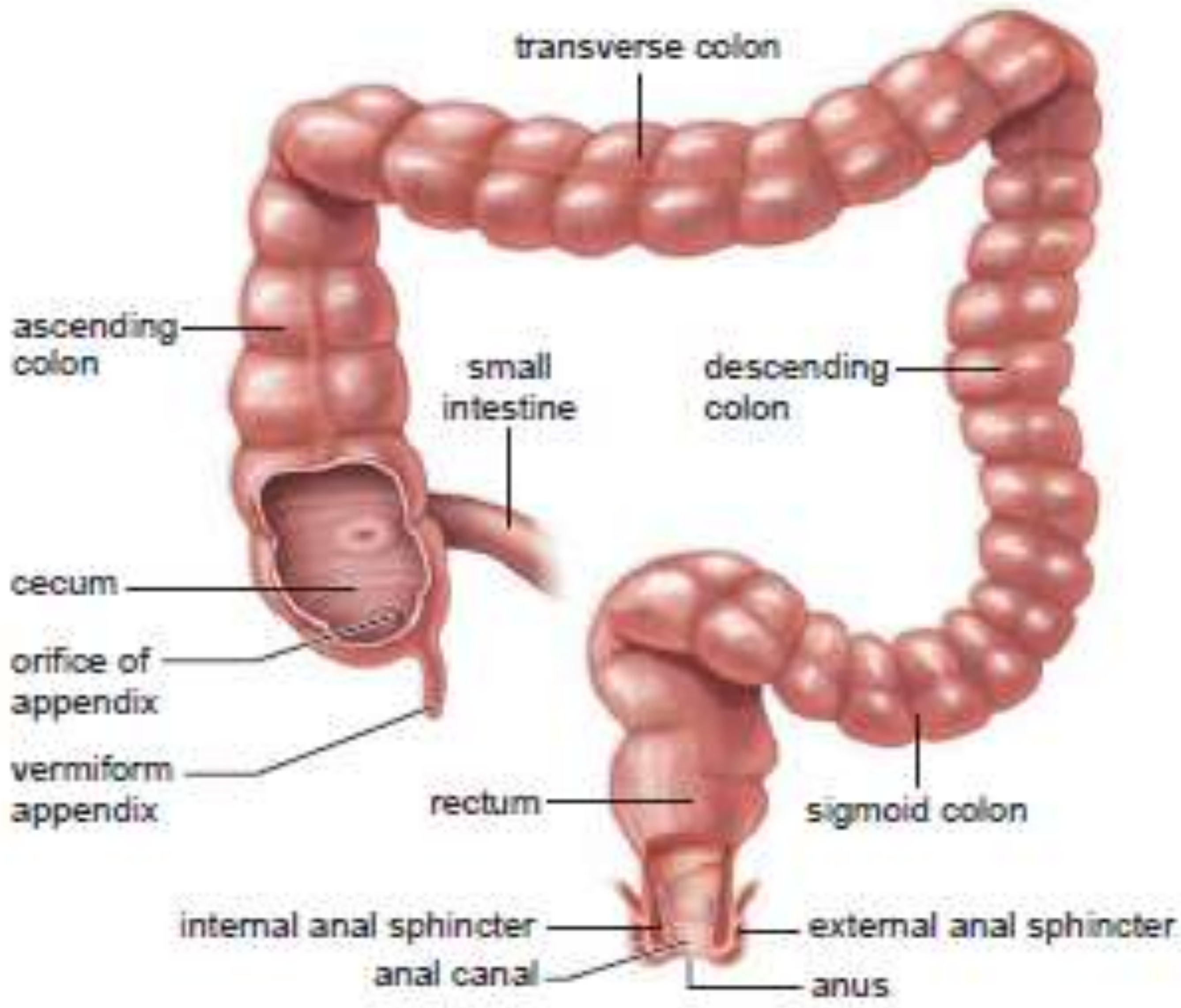
Also, when a person has eaten a meal particularly rich in protein, the stomach produces the hormone gastrin. Gastrin enters the bloodstream, and soon the secretory activity of gastric glands increases.

Cells of the duodenal wall produce two other hormones of particular interest—secretin and cholecystokinin (CCK). Secretin release is stimulated by acid, especially the HCl present in chyme. Partially digested proteins and fat stimulate the release of CCK. Soon after these hormones enter the bloodstream, the pancreas increases its output of pancreatic juice. Pancreatic juice buffers the acidic chyme entering the intestine from the stomach and helps digest food. CCK also causes the liver to increase its production of bile and causes the gallbladder to contract and release stored bile. The bile then aids the digestion of fats that stimulated the release of CCK.


gallbladder
liver
stomach
pancreas
duodenum
blood vessel
secretin
CCK
gastrin

The Large Intestine and Defecation

The **large intestine** includes the cecum, the colon, the rectum, and the anal canal. The large intestine is larger in diameter than the small intestine. The **cecum** is the first portion of the large intestine joining the end of the small intestine. The cecum usually has a small projection called the **vermiform appendix** (*vermiform* means "wormlike"). The **colon** includes the ascending colon, which goes up the right side of the body to the level of the liver; the transverse colon, which crosses the abdominal cavity just below the liver and the stomach; the descending colon, which passes down the left side of the body; and the sigmoid colon, which enters the **rectum**. The rectum opens at the **anus,** where **defecation,** the expulsion of feces.


transverse colon
ascending colon
small intestine
descending colon
cecum
orifice of appendix
vermiform appendix
rectum
sigmoid colon
internal anal sphincter
external anal sphincter
anal canal
anus

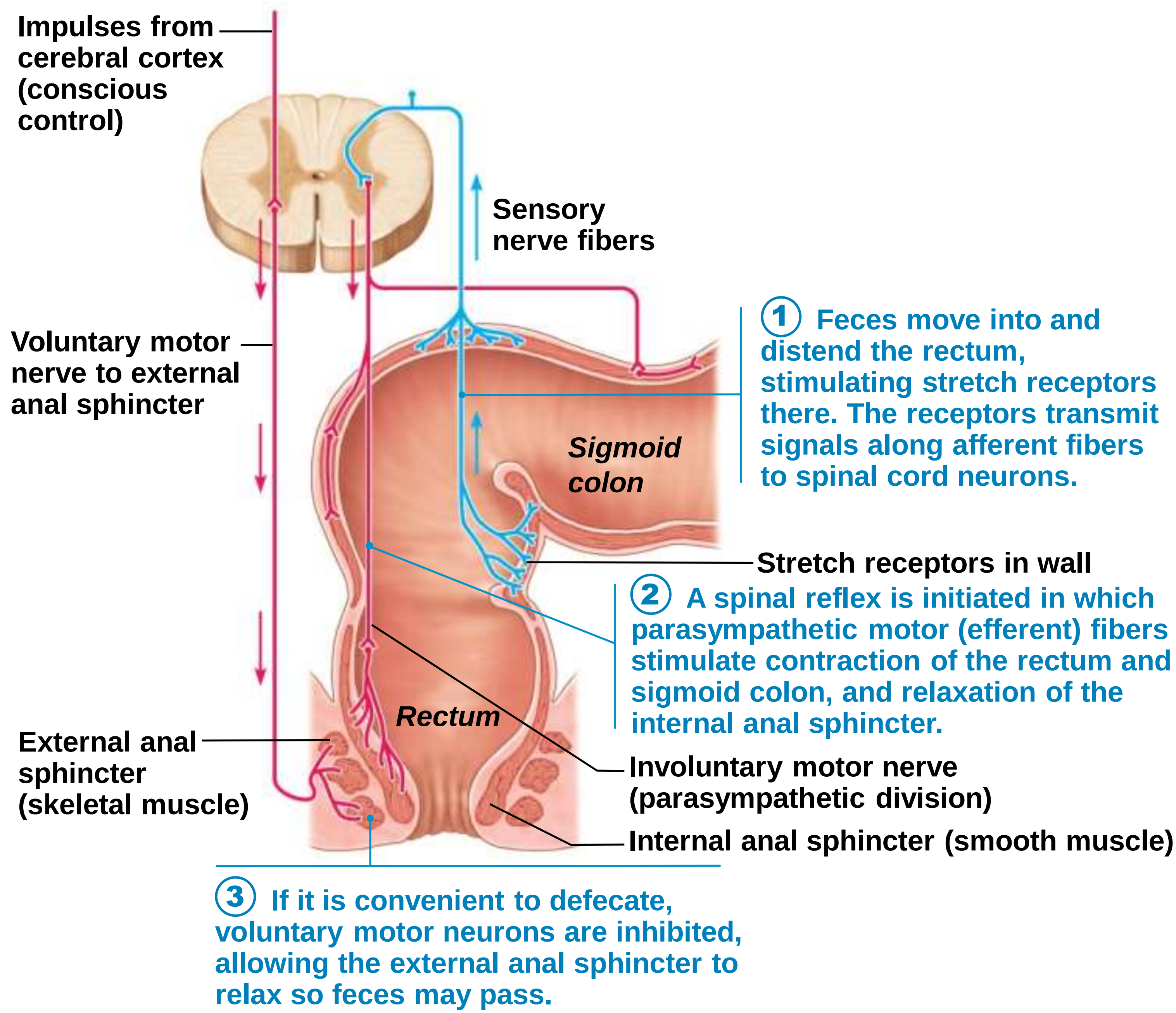
Functions of the Large Intestine

The large intestine does not produce any digestive enzymes, and it does not absorb any nutrients. The function of the large intestine is to absorb water, an important process to prevent dehydration of the body and maintain homeostasis. The large intestine can absorb vitamins produced by intestinal flora.

The large intestine forms feces. The consistency of normal feces is usually three-fourths water and one-fourth solid wastes.

Defecation, ridding the body of feces, is also a function of the large intestine. Peristalsis occurs infrequently in the large intestine, but when it does, feces are forced into the rectum. Feces collect in the rectum until it is appropriate to defecate. At that time, stretching of the rectal wall initiates nerve impulses to the spinal cord. Shortly thereafter, the rectal muscles contract and the anal sphincters relax. This allows the feces to exit the body through the anus

Defecation Reflex



Disorders of the Colon and Rectum

Diarrhea

The major causes of **diarrhea** are infection of the lower intestinal tract and nervous stimulation. The intestinal wall becomes irritated, and peristalsis increases when an infection occurs. Water is not absorbed, and the diarrhea that results rids the body of the infectious organisms. In nervous diarrhea, the nervous system stimulates the intestinal wall and diarrhea results. Prolonged diarrhea can lead to dehydration because of water loss, which can lead to an imbalance of salts in the blood that can affect heart muscle contraction and lead to death.

Constipation

When a person is constipated, the feces are dry and hard, making it difficult for them to be expelled. Diets that lack whole grain foods, as well as ignoring the urge to defecate, are often the causes of **constipation**

Chronic constipation is associated with the development of **hemorrhoids,** enlarged and inflamed blood vessels at the anus.

Diverticulosis

Diverticulosis is the occurrence of little pouches of mucosa where food can collect. The pouches form when the mucosa pushes through weak spots in the muscularis. A frequent site is the last part of the descending colon.

Irritable Bowel Syndrome

Irritable bowel syndrome (IBS), or spastic colon, is a condition in which the muscularis contracts powerfully but without its normal coordination. The symptoms are abdominal cramps; gas; constipation; and urgent, explosive stools

Inflammatory Bowel Disease

Inflammatory bowel disease (IBD) is a collective term for a number of inflammatory disorders. Ulcerative colitis and Crohn’s disease are the most common of these. Ulcerative colitis affects the large intestine and rectum and results in diarrhea, rectal bleeding, abdominal cramps, and urgency in defecation. Crohn’s disease is normally isolated to the small intestine but can affect any area of the digestive tract, including the colon and rectum. It is characterized by the breakdown of the lining of the affected area resulting in ulcers. Ulcers are painful and cause bleeding because they erode the submucosal layer, where there are nerves and blood vessels. This also results in the inability to absorb nutrients at the affected sites. Symptoms of Crohn’s disease include diarrhea, weight loss, abdominal cramping, anemia, bleeding, and malnutrition.

Polyps and Cancer

The colon is subject to the development of **polyps,** small growths arising from the epithelial lining. Polyps, whether benign or cancerous, can be removed surgically. If colon cancer is detected while still confined to a polyp, the expected outcome is a complete cure. It could be that intestinal bacteria convert bile salts to substances that promote the development of cancer. On the other hand, fiber in the diet seems to inhibit the development of colon cancer and regular elimination reduces the time that the colon wall is exposed to any cancer-promoting agents in feces.

Regulation of GI Tract Activities

1. Autonomic nervous system

A . parasympathetic nerves stimulate GI tract activities .

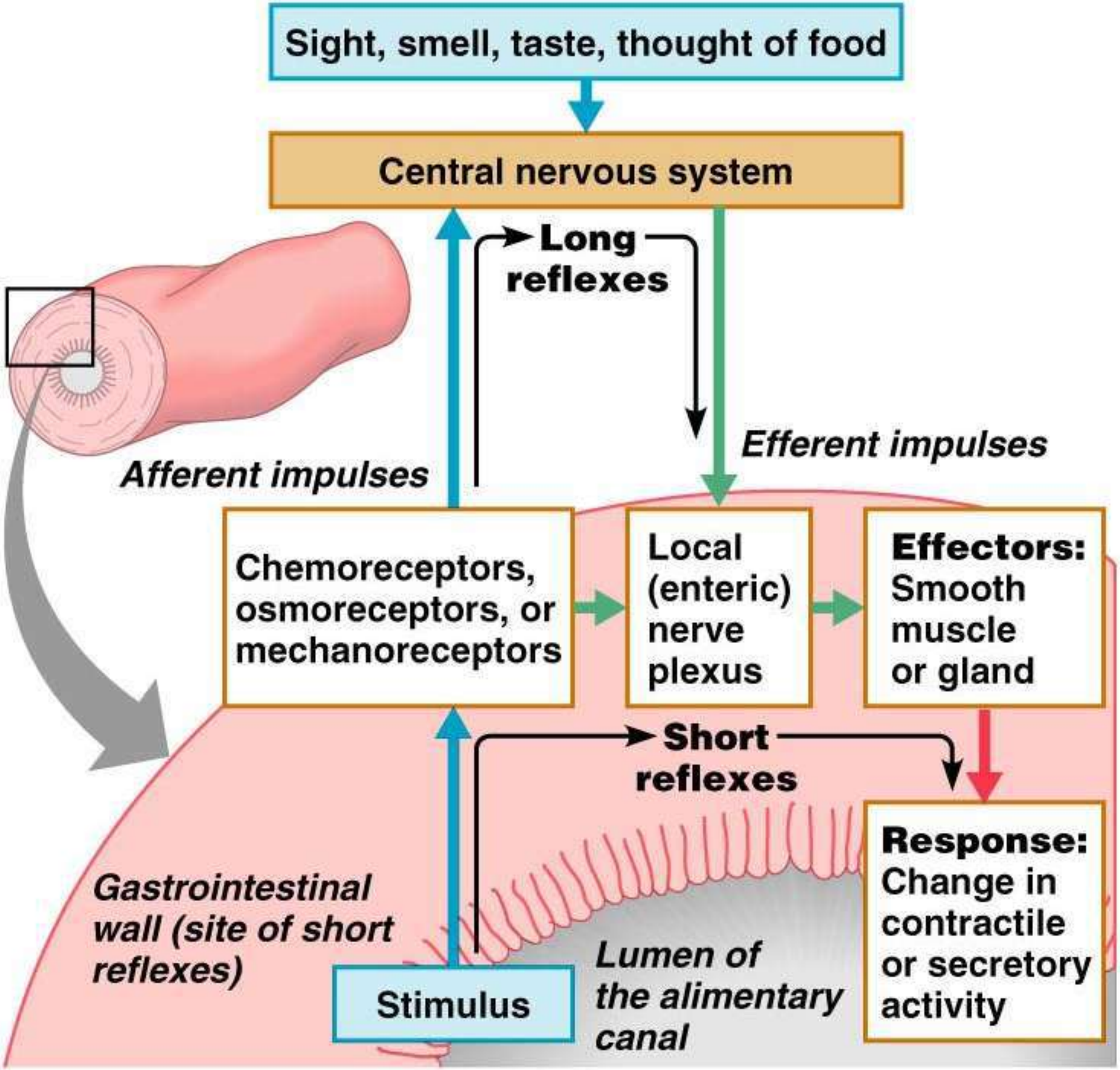
B - sympathetic nerves inhibit GI tract activities .

2. Hormonal control

Hormones from endocrine gland and from GI tract itself help regulate GI tract activities .

3. Reflex mechanism

Regions of the GI tract (especially the stomach and small intestine) use reflexes to stimulate or inhibit one another .


Sight, smell, taste, thought of food
Central nervous system
Long reflexes
Afferent impulses
Efferent impulses
Chemoreceptors, osmoreceptors, or mechanoreceptors
Local (enteric) nerve plexus
Effectors: Smooth muscle or gland
Short reflexes
Response: Change in contractile or secretory activity
Gastrointestinal wall (site of short reflexes)
Stimulus
Lumen of the alimentary canal

Endocrine system

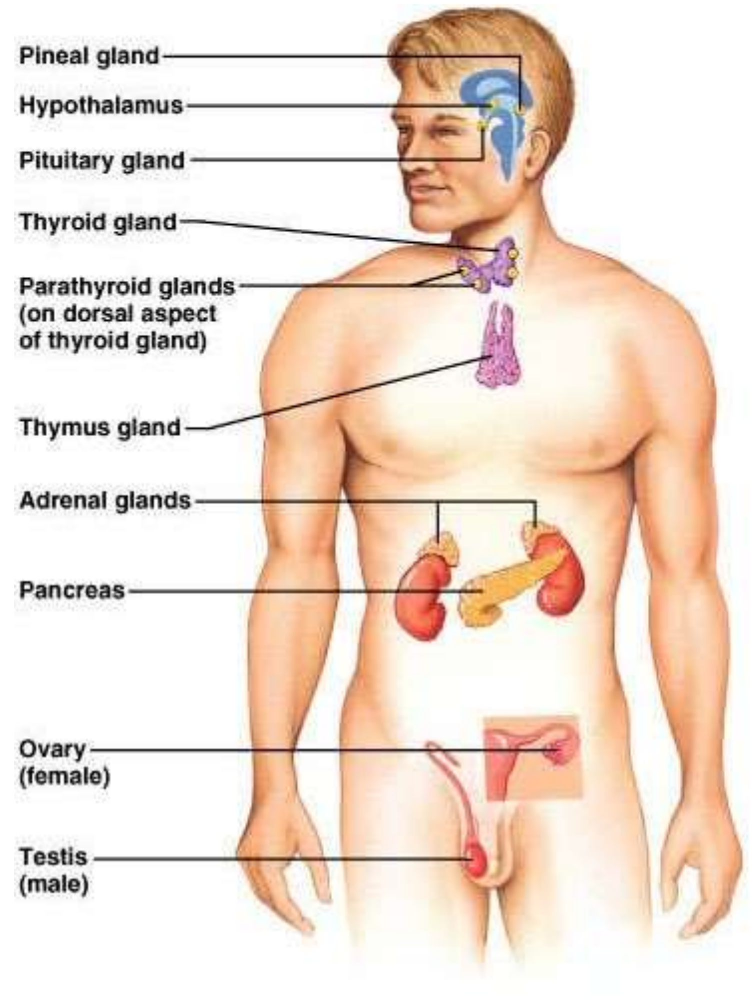
Essam mohammed AL-Fahadawy

Overview of the Endocrine System

- System of ductless glands that secrete hormones
  - Hormones are "messenger molecules"
  - Circulate in the blood
  - Act on distant target cells
  - Target cells respond to the hormones for which they have receptors
  - The effects are dependent on the programmed response of the target cells
  - Hormones are just molecular triggers
- Basic categories of hormones
  - Amino acid based: modified amino acids (or *amines*), peptides (short chains of amino acids), and proteins (long chains of amino acids)
  - Steroids: lipid molecules derived from cholesterol

Endocrine Organs

- Purely endocrine organs
  - Pituitary gland
  - Pineal gland
  - Thyroid gland
  - Parathyroid glands
  - Adrenal: 2 glands
    - Cortex
    - Medulla
- Endocrine cells in other organs
  - Pancreas
  - Thymus
  - Gonads
  - Hypothalamus

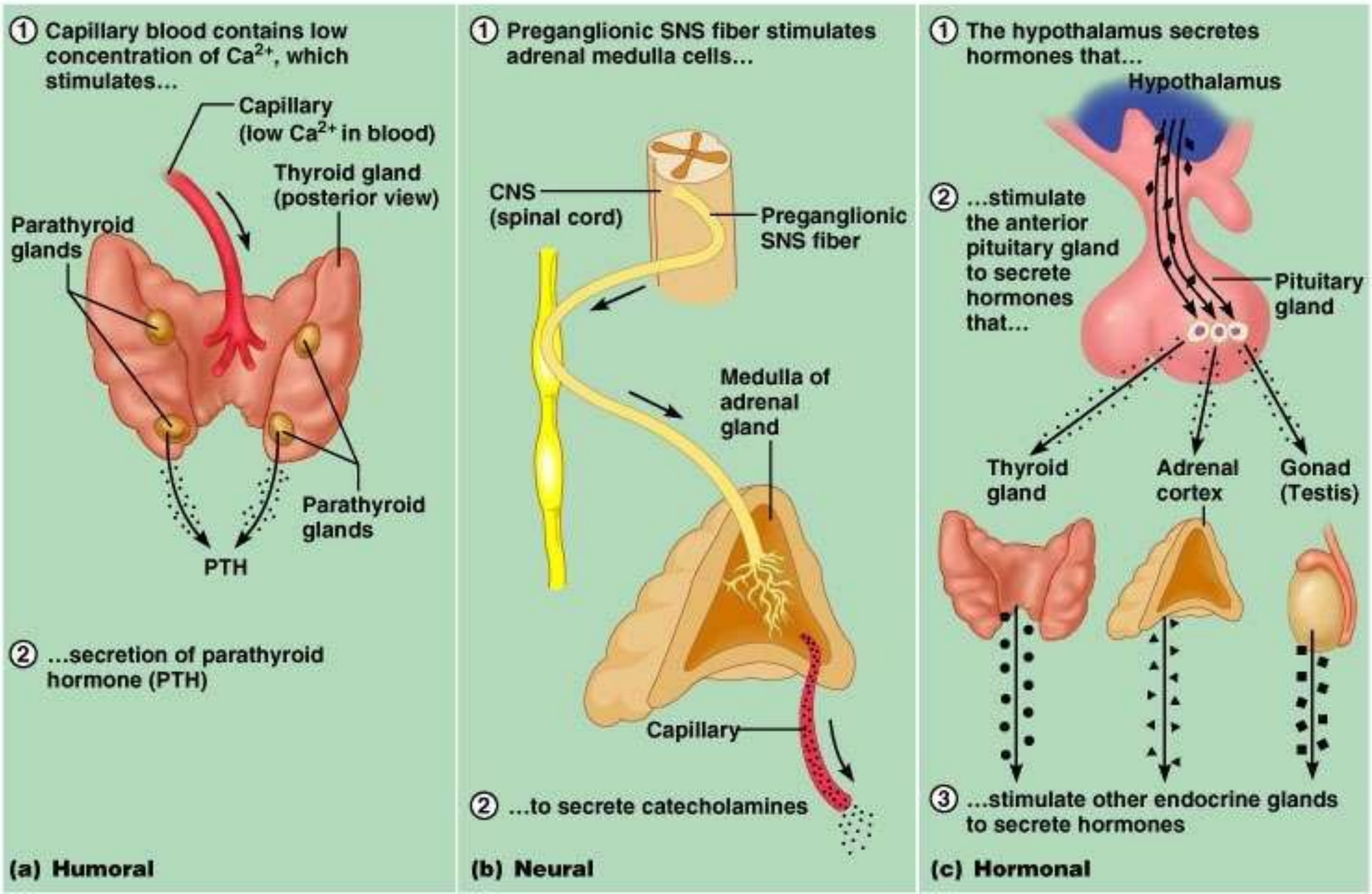


Mechanisms of hormone release

(a) Humoral: in response to changing levels of ions or nutrients in the blood

(b) Neural: stimulation by nerves

(c) Hormonal: stimulation received from other hormones



The Pituitary

Pituitary secretes 9 hormones

Two divisions:

- Anterior pituitary (adenohypophysis)

1. TSH
2. ACTH
3. FSH
4. LH

The first four are "tropic" hormones, they regulate the function of other hormones

5. GH
6. PRL
7. MSH

- Posterior pituitary (neurohypophysis)

8. ADH (antidiuretic hormone), or vasopressin
9. Oxytocin

- TSH: thyroid-stimulating hormone
- ACTH: adrenocorticotropic hormone
- FSH: follicle-stimulating hormone
- LH: luteinizing hormone
- GH: growth hormone
- PRL: prolactin
- MSH: melanocyte-stimulating hormone

- ADH: antidiuretic hormone
- Oxytocin

Hypothalamus controls anterior pituitary hormone release

- Releasing hormones (releasing factors)

  Secreted like neurotransmitters from neuronal axons into capillaries and veins to anterior pituitary (adenohypophysis)

  TRH-----turns on TSH

  CRH-----turns on ACTH

  GnRH (=LHRH)---turns on FSH and LH

  PRF-----turns on PRL

  GHRH----turns on GH

- Inhibiting hormones

  PIF-----turns off PRL

  GH inhibiting hormone ---turns off GH

The four tropic ones regulate the function of other hormones:

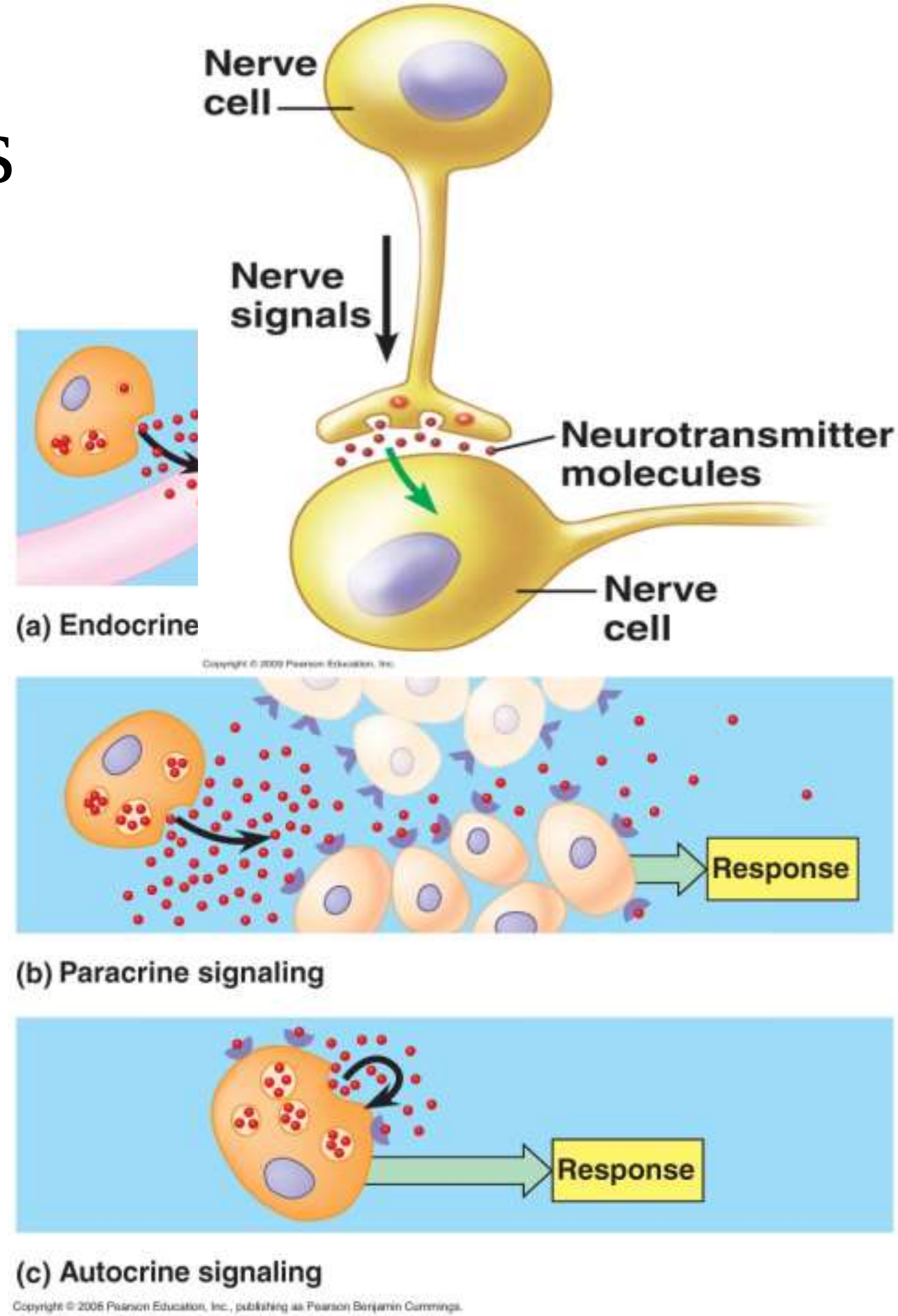
- 1- TSH stimulates the thyroid to produce thyroid hormone
- 2- ACTH stimulates the adrenal cortex to produce corticosteroids: aldosterone and cortisol
- 3- FSH stimulates follicle growth and ovarian estrogen production; stimulates sperm production and androgen-binding protein
- 4- LH has a role in ovulation and the growth of the corpus luteum; stimulates androgen secretion by interstitial cells in testes.
- GH (somatrotropic hormone) stimulates growth of skeletal epiphyseal plates and body to synthesize protein
- PRL stimulates mammary glands in breast to make milk
- MSH stimulates melanocytes; may increase mental alertness

From the posterior pituitary (neurohypophysis)

- ADH (antidiuretic hormone vasopressin) stimulates the kidneys to reclaim more water from the urine, raises blood pressure
- Oxytocin prompts contraction of smooth muscle in reproductive tracts, in females initiating labor and ejection of milk from breasts

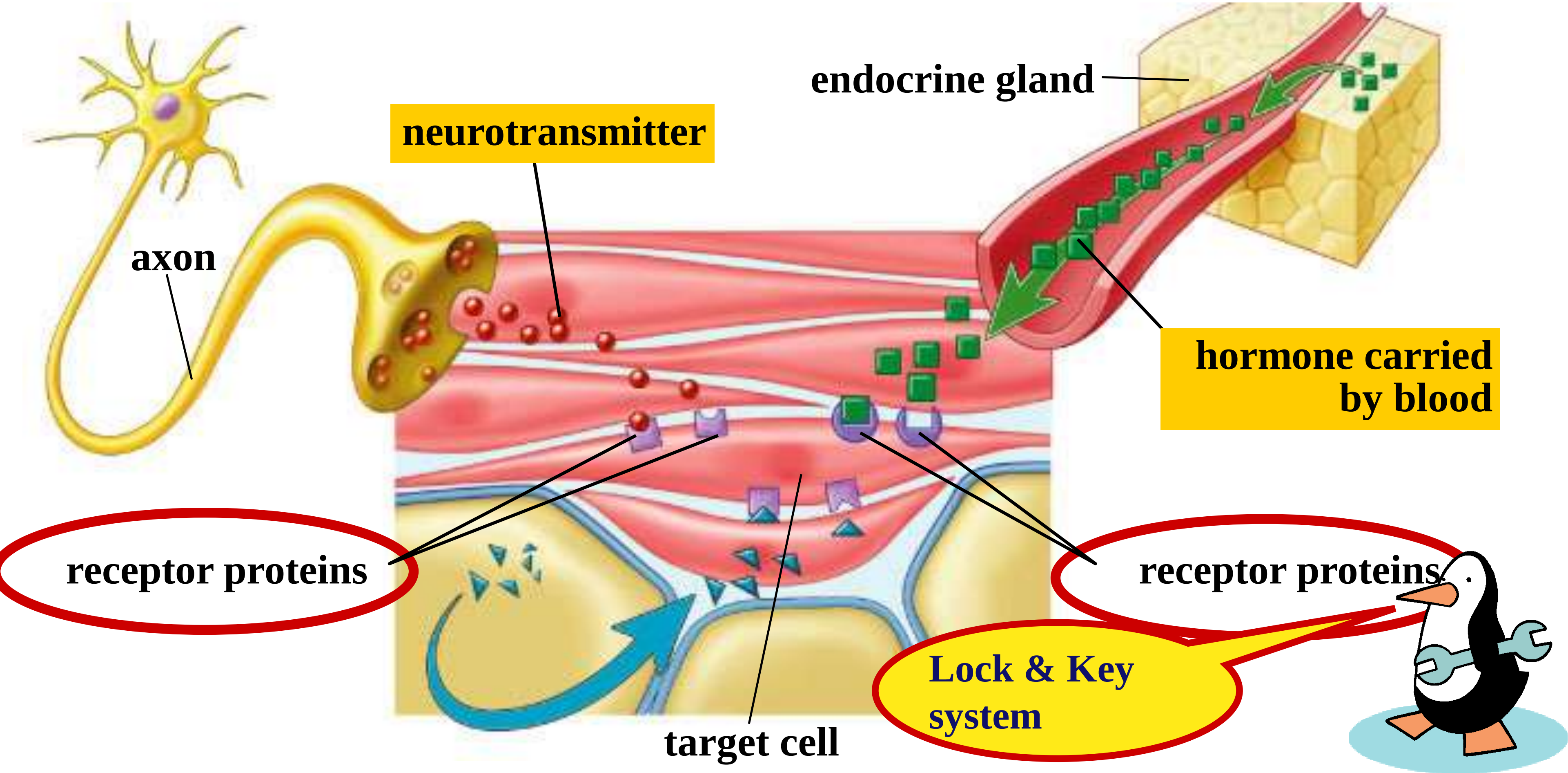
Other Secretory Cells

- **Neurotransmitters**
  - Neural signaling
  - Short distance/directional
- Local Regulators
  - **Paracrine**
  - **Autocrine**



Regulation by chemical messengers

- Neurotransmitters released by neurons
- Hormones release by endocrine glands



Classifying Glands

Endocrine

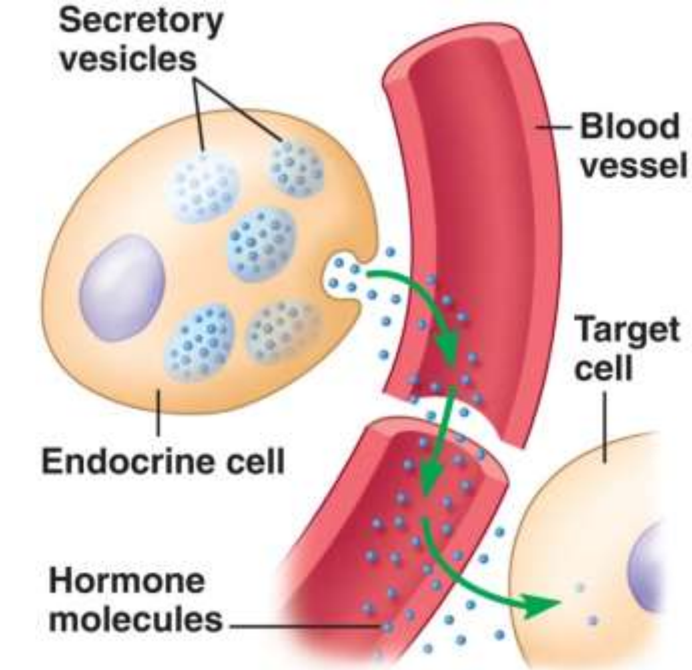
- Lack ducts
- Produces **hormones**
- Pituitary, adrenal, thyroid, etc.

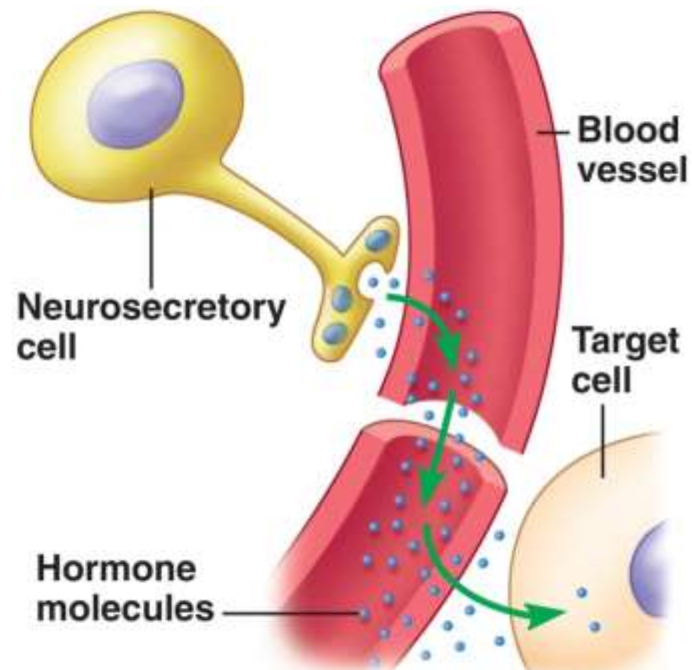
Exocrine

- Possess ducts
- Produce non-hormonal substances
- Sweat, mammary, salivary, etc

Hormones

- Organic secretions
- Blood transports throughout the body
- Anywhere, target cells with specific receptors
  - 1 or many effects
- Regulate metabolic functions of body cells
- **Neurohormones** are similar





Chemical Nature of Hormones

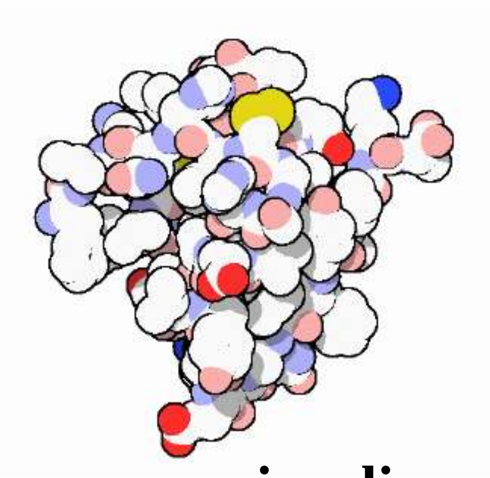
Amino acid-based

- Amino acid or polypeptide chain precursors
- Water soluble
- Example: Epinephrine, oxytocin, and prolactin

Steroid-based

- Cholesterol precursor
- Lipid soluble
- Signal same to release and produce
- Example: Testosterone, estrogen and cortisol

Classes of Hormones



insulin

- Protein-based hormones
  - polypeptides
    - small proteins: insulin, ADH
  - glycoproteins
    - large proteins + carbohydrate: FSH, LH
  - amines
    - modified amino acids: epinephrine, melatonin
- Lipid-based hormones
  - steroids
    - modified cholesterol: sex hormones, aldosterone

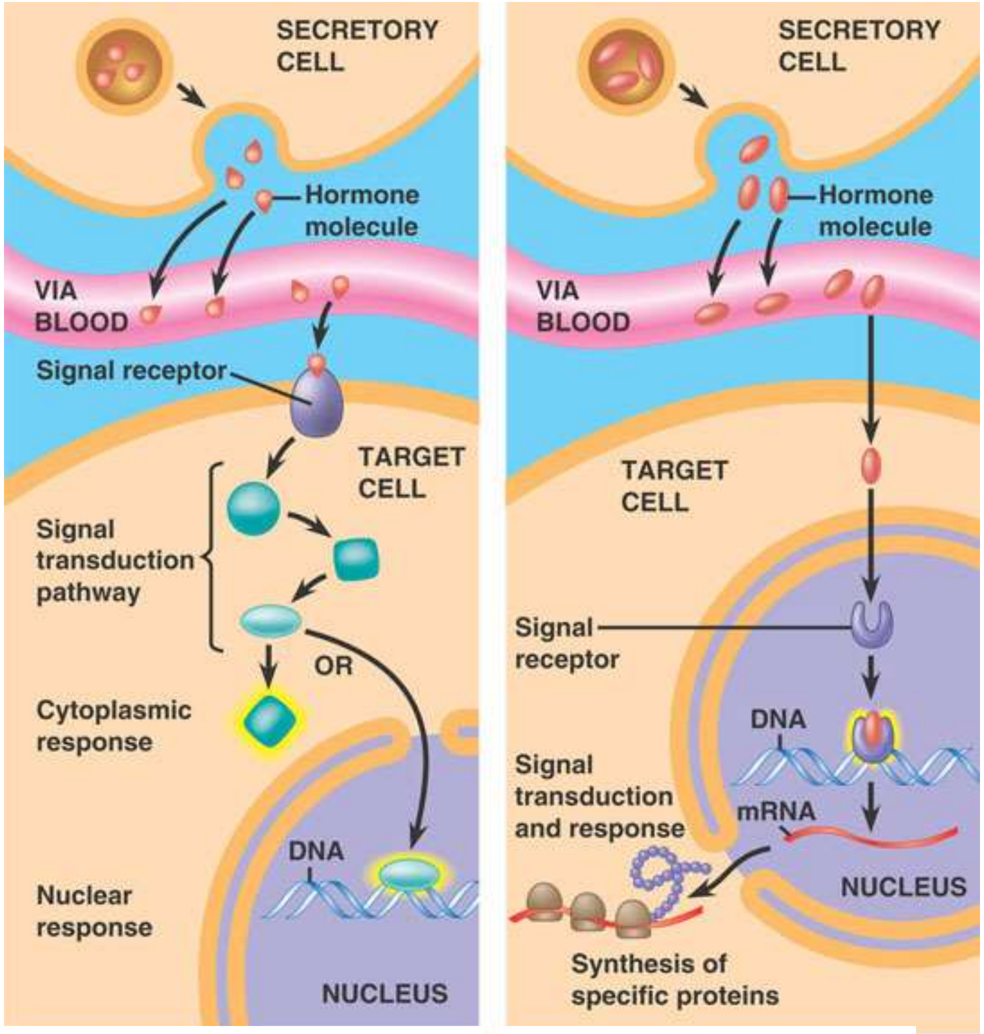
Mechanisms of Hormone Action

Exocytotic release

Free in blood

Binds to PM

Cellular response



WATER-SOLUBLE **LIPID-SOLUBLE**

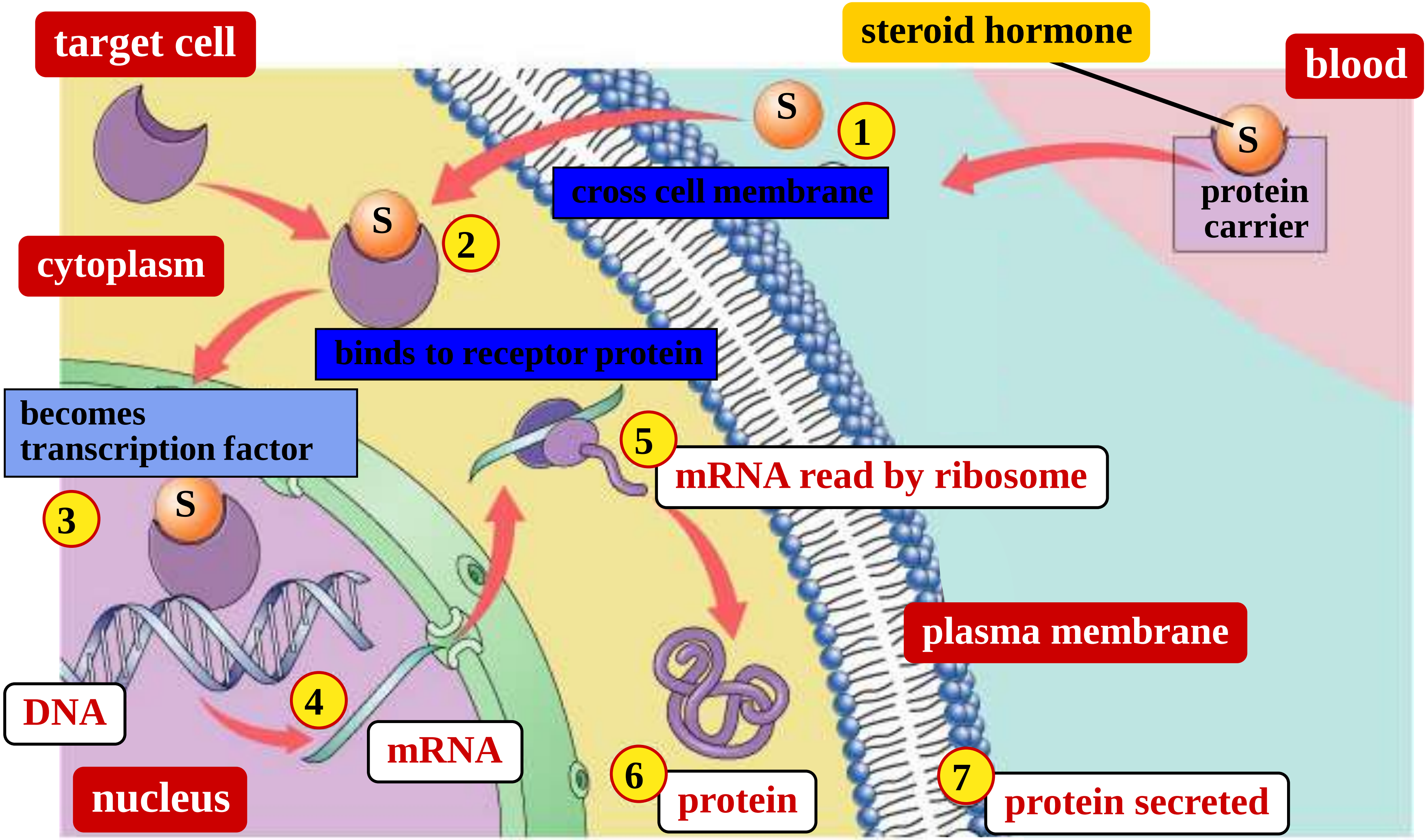
Diffuse out

Transported in blood

Diffuse into cell

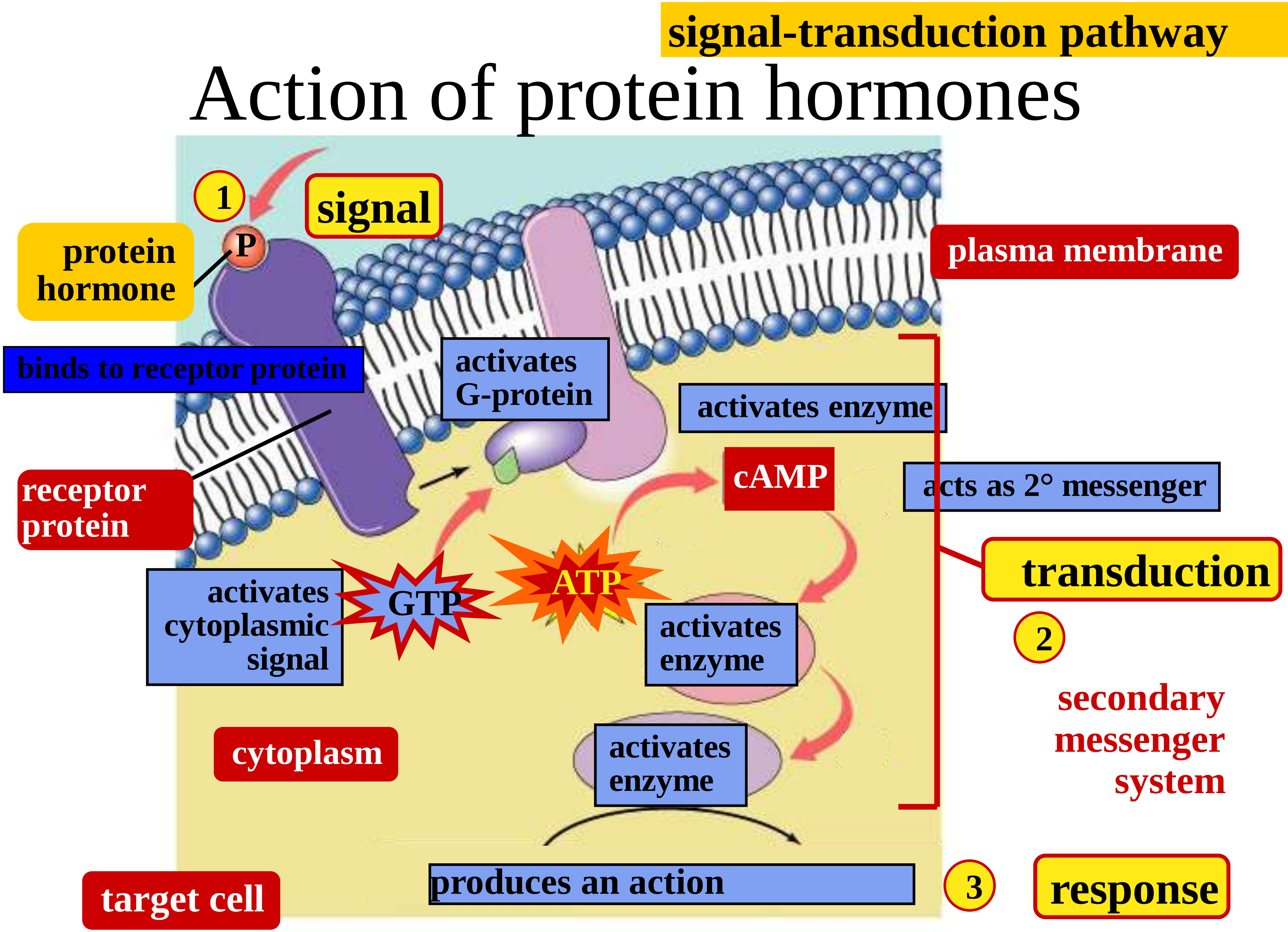
Gene transcription

Action of lipid (steroid) hormones

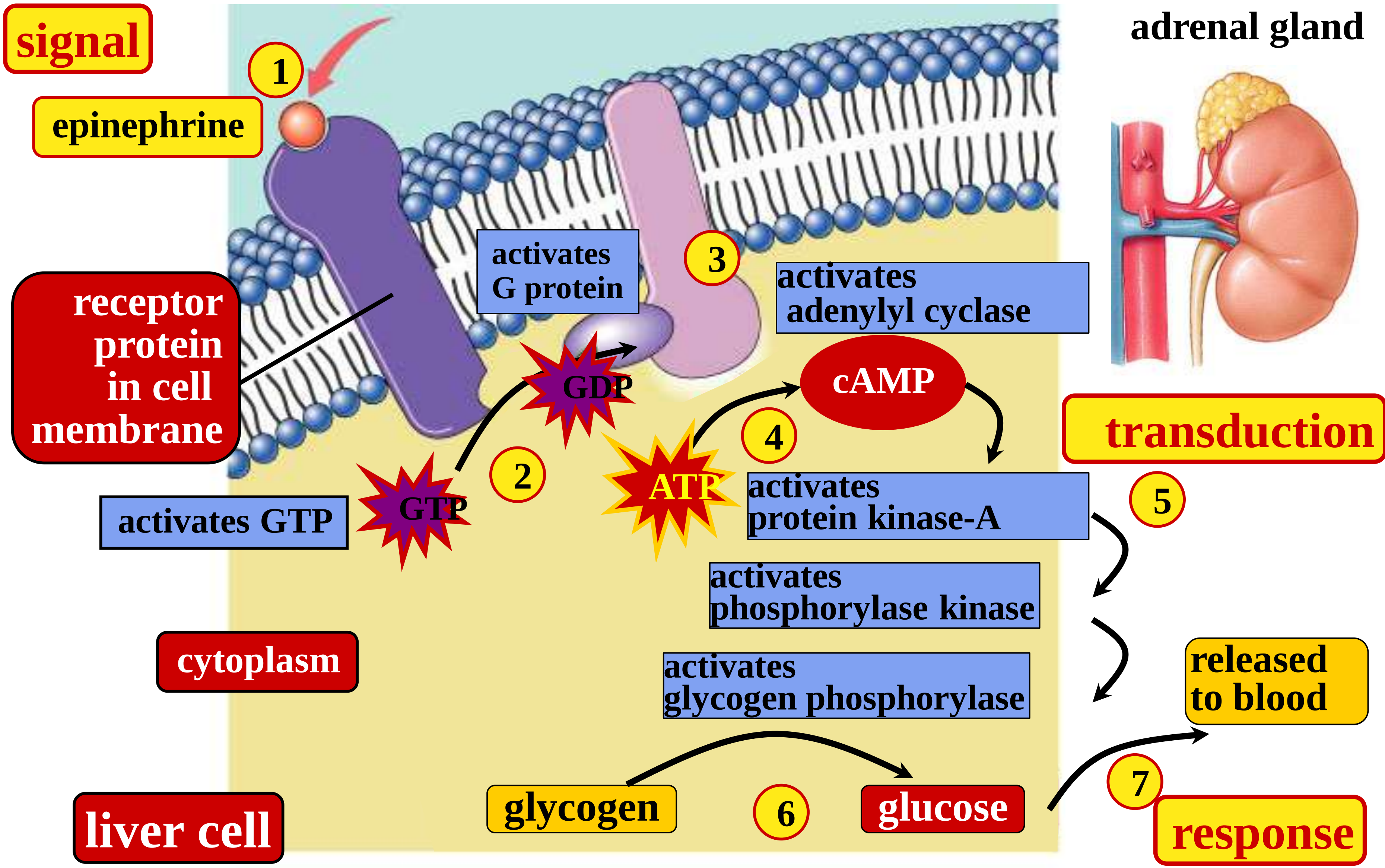


ex: secreted protein = growth factor (hair, bone, muscle, gametes)

Action of protein hormones

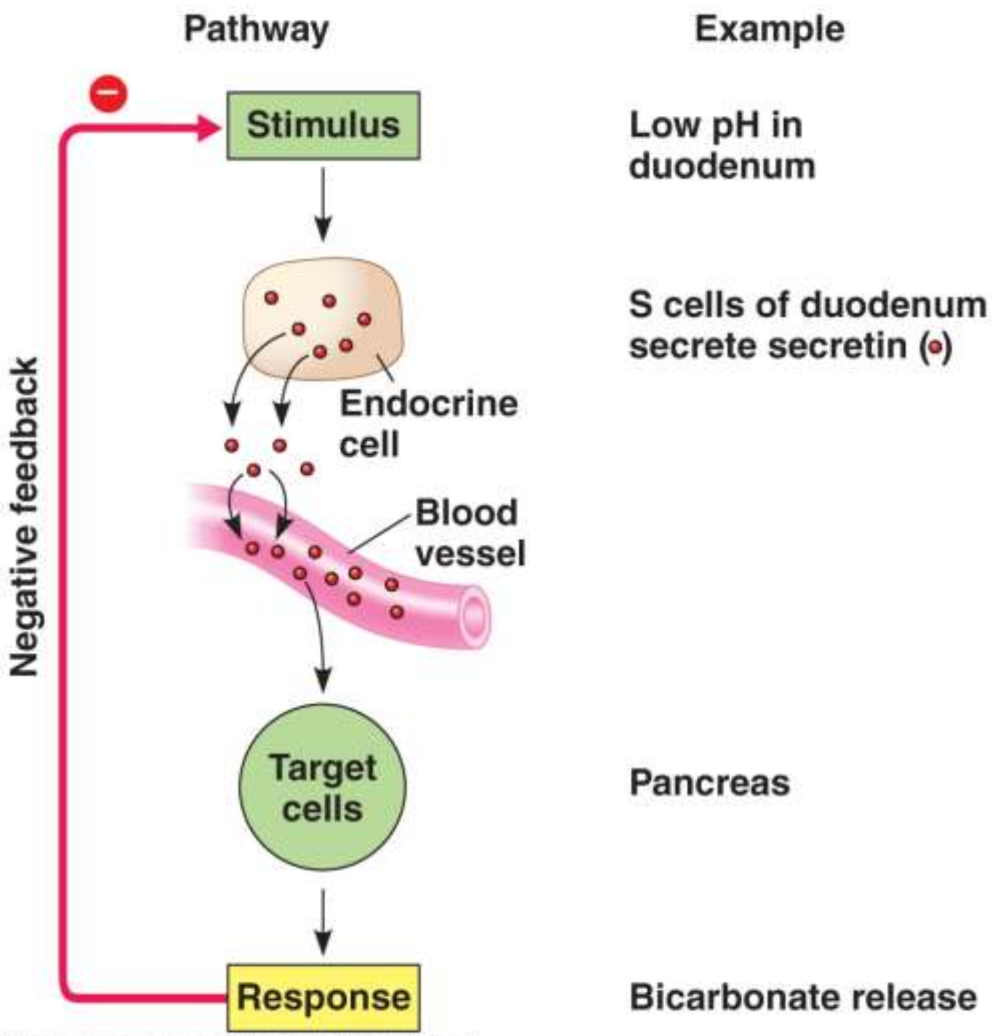


Ex: Action of epinephrine (adrenaline)

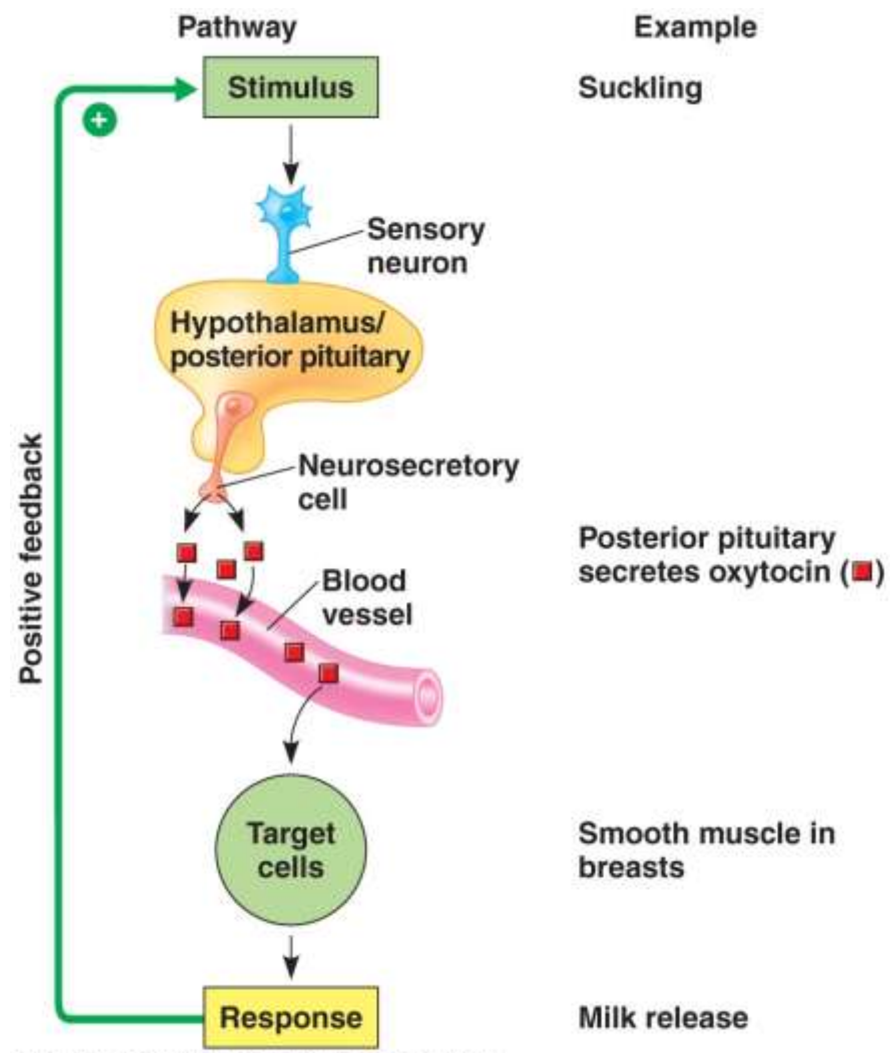


Response

Negative Feedback



Positive Feedback



Endocrine System Control

Feedback

Regulation of Blood Sugar

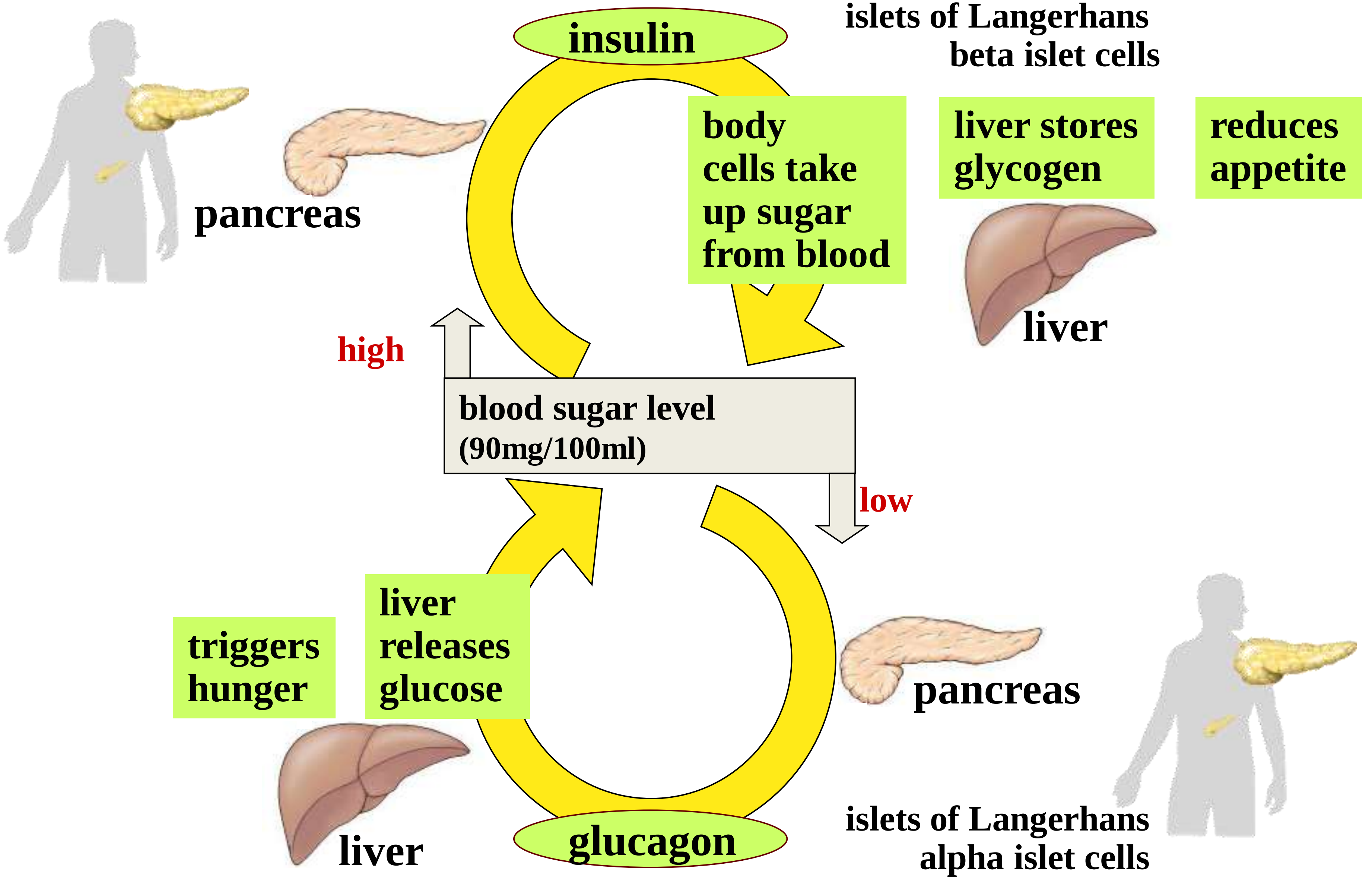
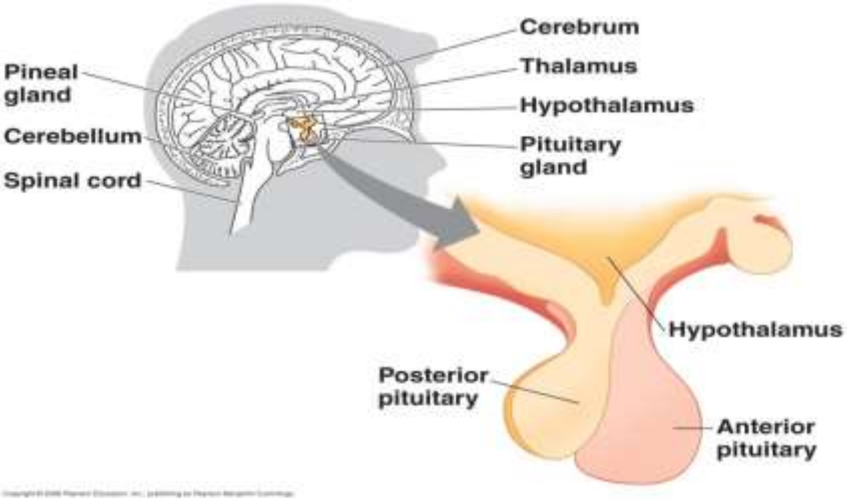


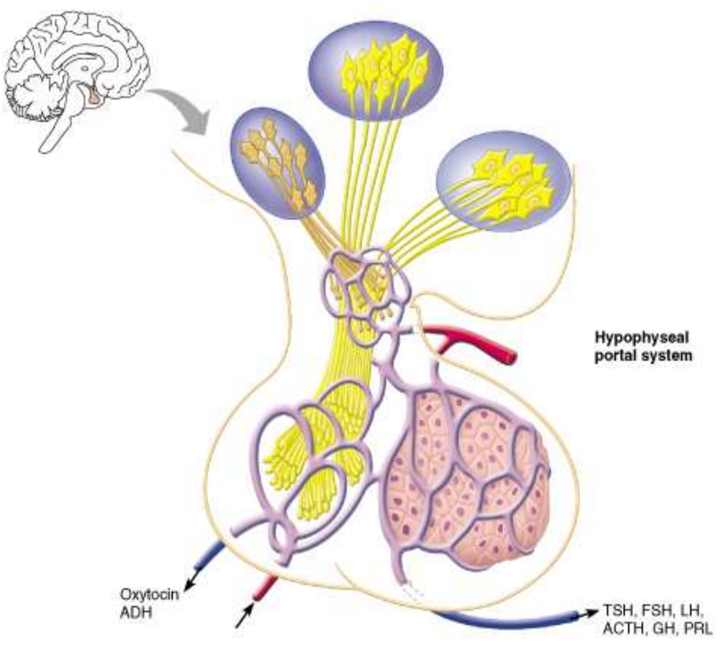
Table 45.1 Major Human Endocrine Glands and Some of Their Hormones

Gland	Hormone	Chemical Class	Representative Actions	Regulated By
Hypothalamus 	Hormones released from the posterior pituitary and hormones that regulate the anterior pituitary (see below)			
Posterior pituitary gland (releases neurohormones made in hypothalamus) 	Oxytocin	Peptide	Stimulates contraction of uterus and mammary gland cells	Nervous system
	Antidiuretic hormone (ADH)	Peptide	Promotes retention of water by kidneys	Water/salt balance
Anterior pituitary gland 	Growth hormone (GH)	Protein	Stimulates growth (especially bones) and metabolic functions	Hypothalamic hormones
	Prolactin (PRL)	Protein	Stimulates milk production and secretion	Hypothalamic hormones
	Follicle-stimulating hormone (FSH)	Glycoprotein	Stimulates production of ova and sperm	Hypothalamic hormones
	Luteinizing hormone (LH)	Glycoprotein	Stimulates ovaries and testes	Hypothalamic hormones
	Thyroid-stimulating hormone (TSH)	Glycoprotein	Stimulates thyroid gland	Hypothalamic hormones
	Adrenocorticotropic hormone (ACTH)	Peptide	Stimulates adrenal cortex to secrete glucocorticoids	Hypothalamic hormones
Thyroid gland 	Triiodothyronine (T_3) and thyroxine (T_4)	Amine	Stimulate and maintain metabolic processes	TSH
	Calcitonin	Peptide	Lowers blood calcium level	Calcium in blood
Parathyroid glands 	Parathyroid hormone (PTH)	Peptide	Raises blood calcium level	Calcium in blood

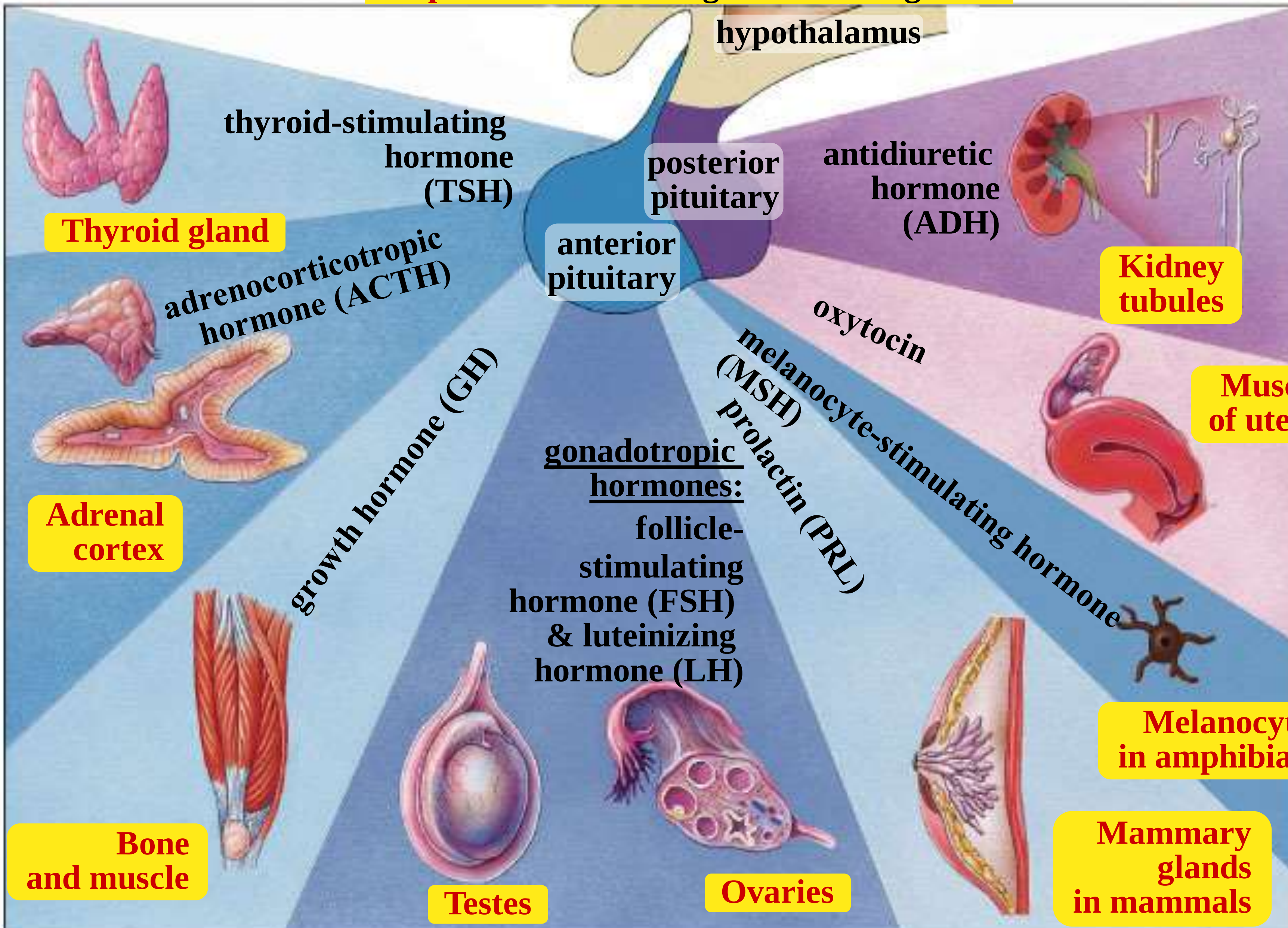
Hypothalmus

- ‘Relay center’
- Pituitary gland
  - Master gland
  - Bipartate structure
    - Posterior lobe
      - Neurosecretory cells
    - Anterior lobe
      - Portal system



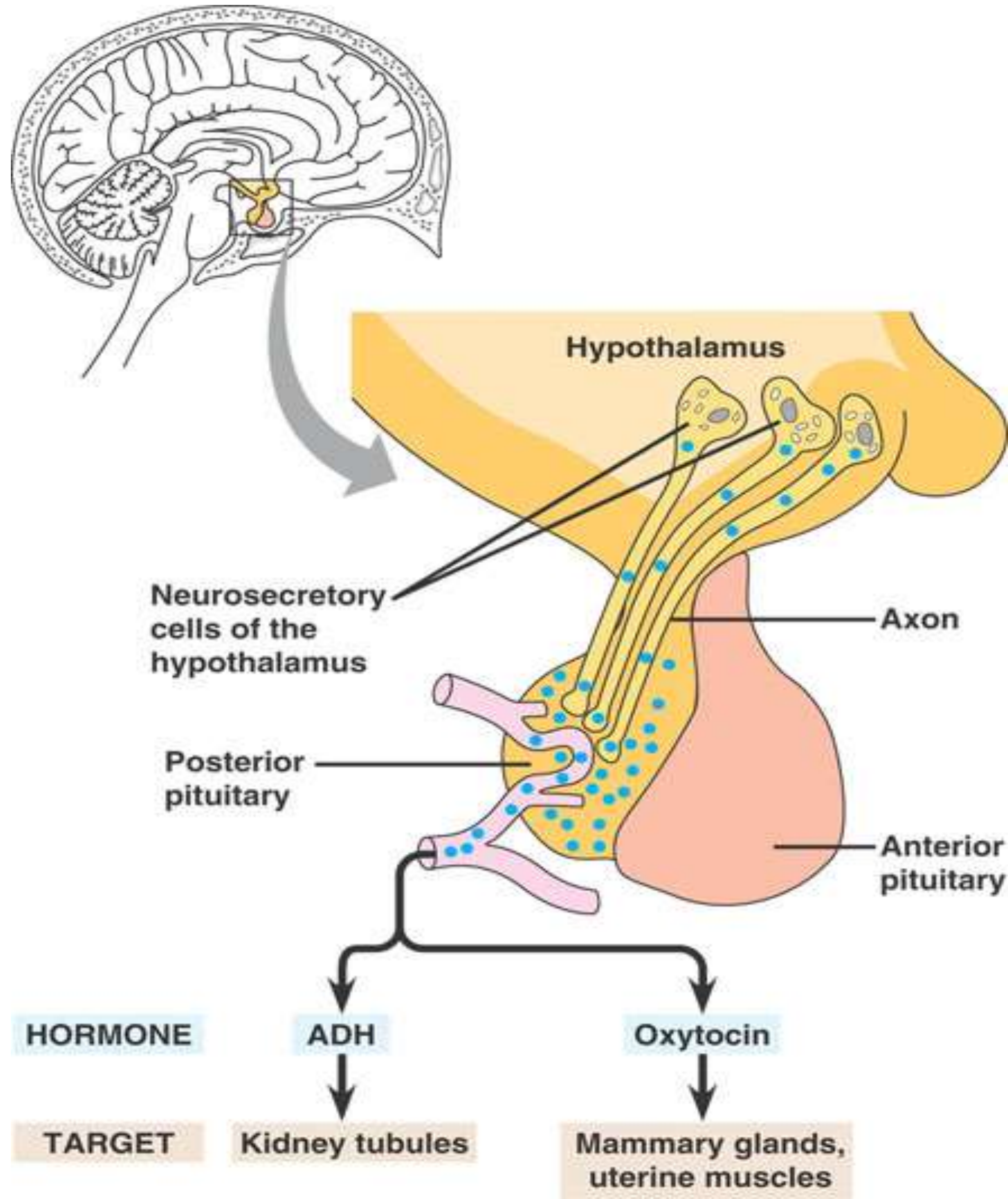


tropic hormones = target endocrine glands



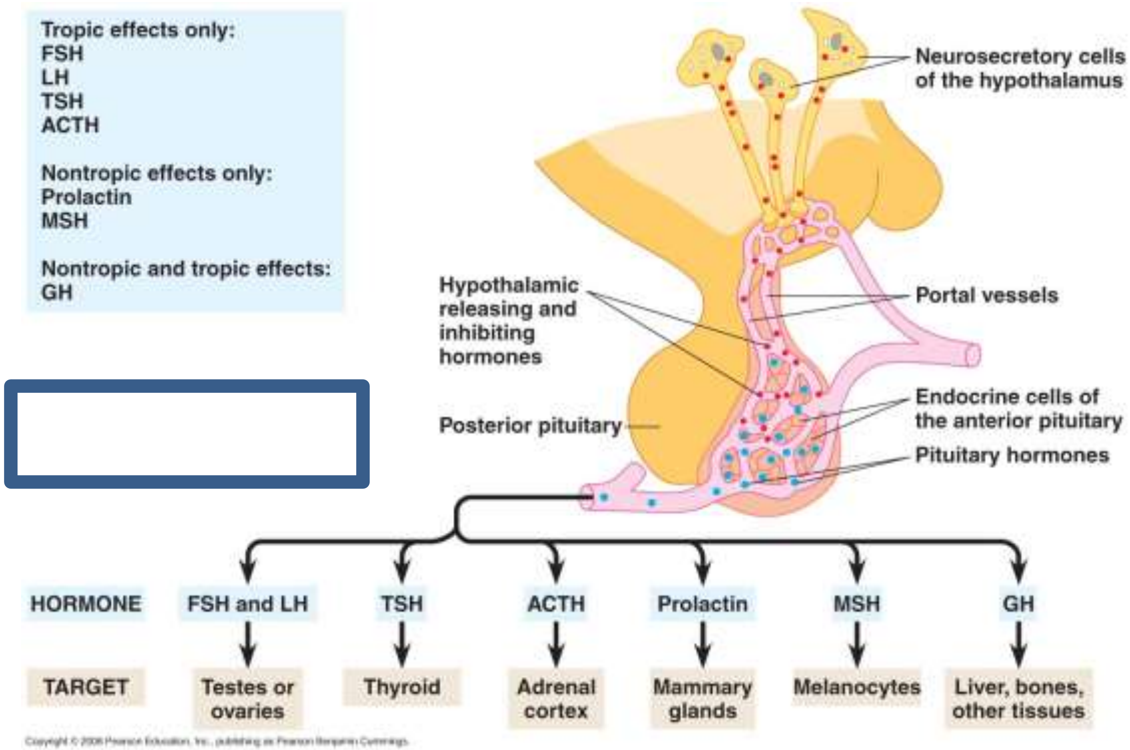
POSTERIOR LOBE

- Hypothalamic storage
- Neurosecretory cells signal exocytosis
- **Neurohormone**s:
  - **Oxytocin**: milk letdown and uterine contractions
  - **ADH**: control water and solute levels



Anterior Lobe

- Hypothalamic control
- Portal system
  - Releasing or inhibiting
- Makes two main types of hormones:
  - **Tropic**: endocrine
  - **Non-tropic**: nonendocrine
- Growth hormone

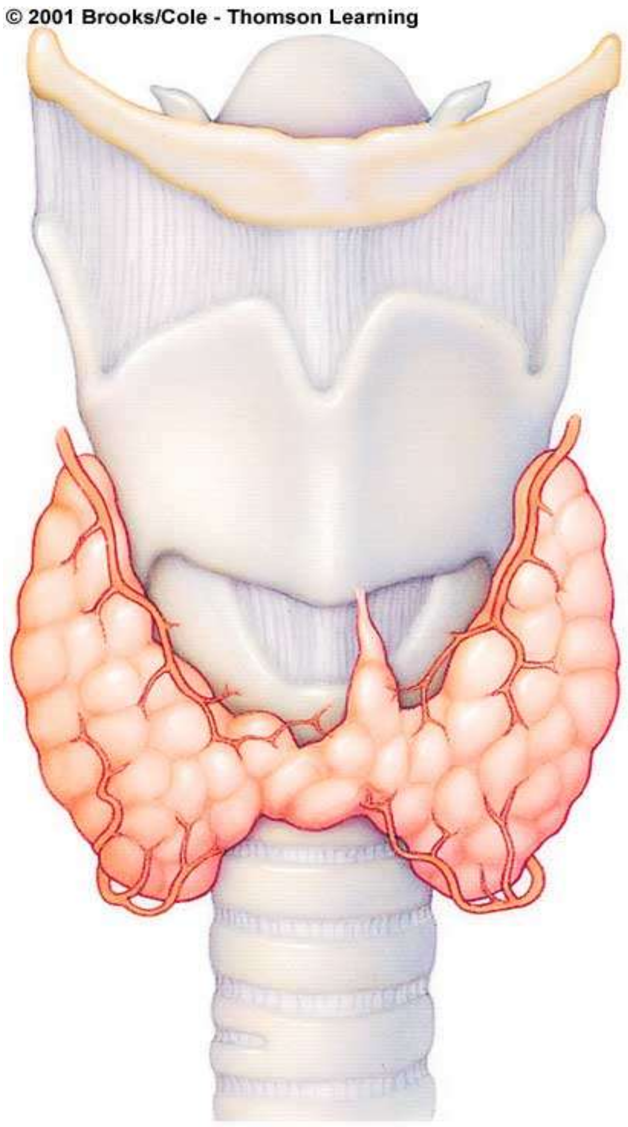


Growth Hormone

- Tropic and non-tropic effects
- Stimulates growth
  - Liver secretes IGF's to stimulate bone & cartilage
    - Size not number
  - Absence can halt growth
- Hypersecretion
  - Gigantism: limbs unchanged
- Hyposecretion
  - Pituitary dwarfism: porportions unchanged
    - Treated with artificial GH w/early diagnosis

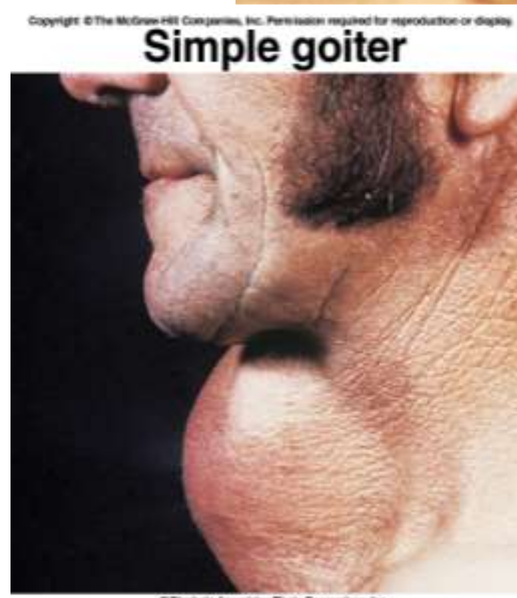
Thyroid Gland

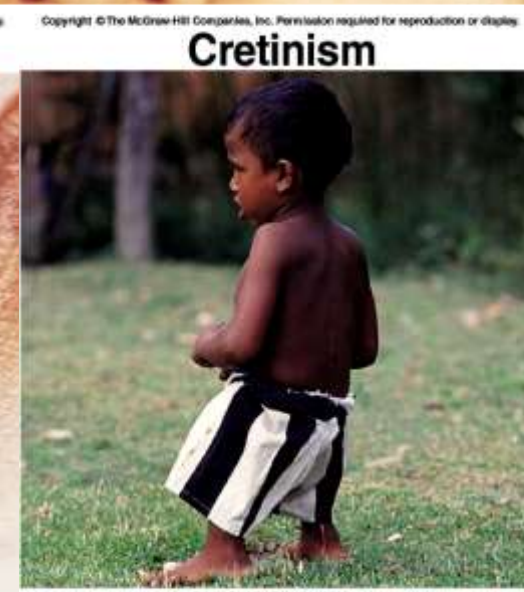
- TSH regulation
  - Metabolism, growth, and development
- Produces amine hormones:
  - T_3 and T_4
    - Growth and O_2 turnover
    - Both, but different cells
  - Calcitonin (childhood)
    - Enhance kidney Ca_{2+} release
- Hyperthyroidism
  - Weight lose, sweating, & irritability
- Hypothyroidism
  - Weight gain, cold intolerance, & lethargy



Thyroid Imbalances

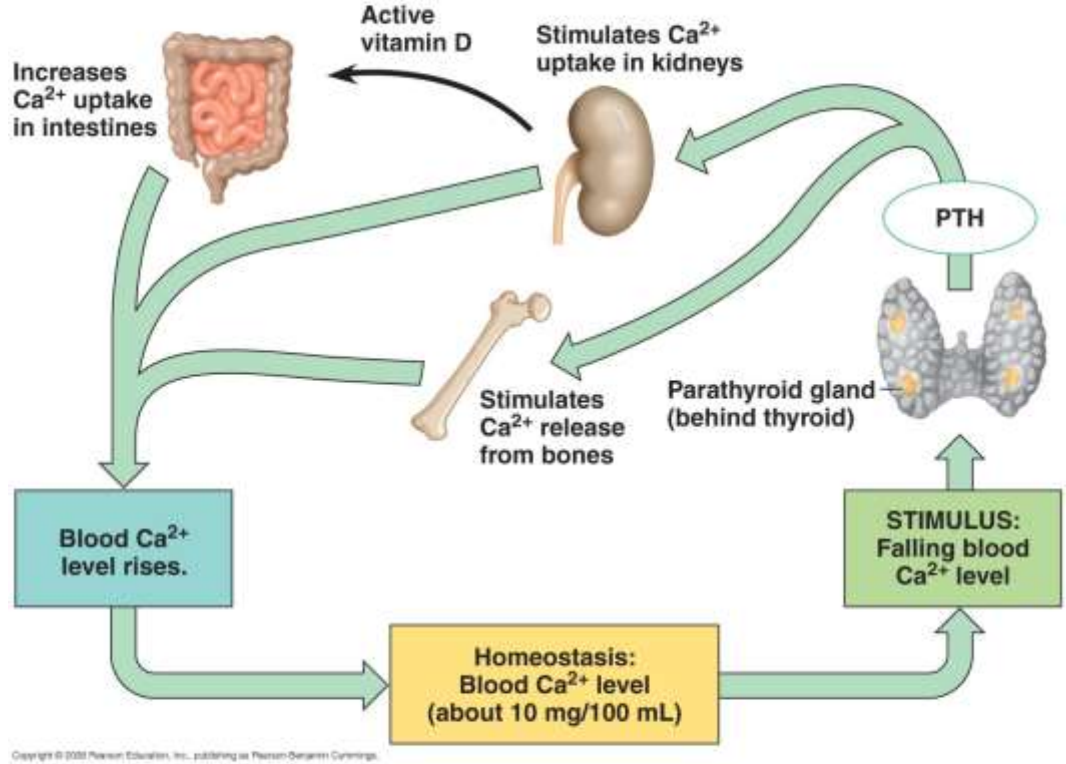
- Grave's Disease
  - Rapid irregular heart beat, nervousness, & sweating
- Goiter
  - Unchecked TSH secretion
- Cretinism
  - Stunted growth



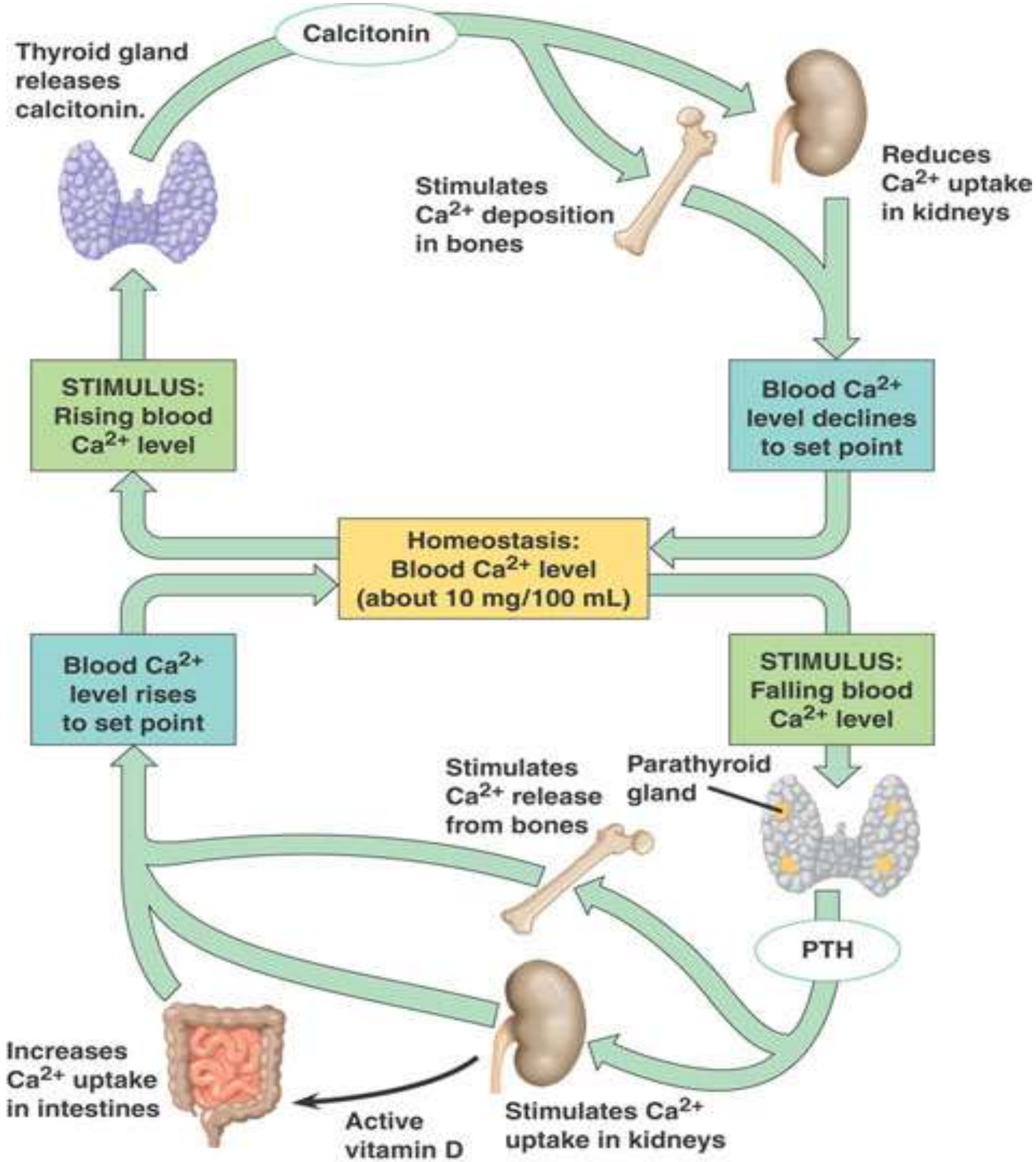


Parathyroid Gland

- PTH
  - Blood Ca^{2+} regulation
- Target tissues
  - Bones
  - Intestines
  - Kidneys

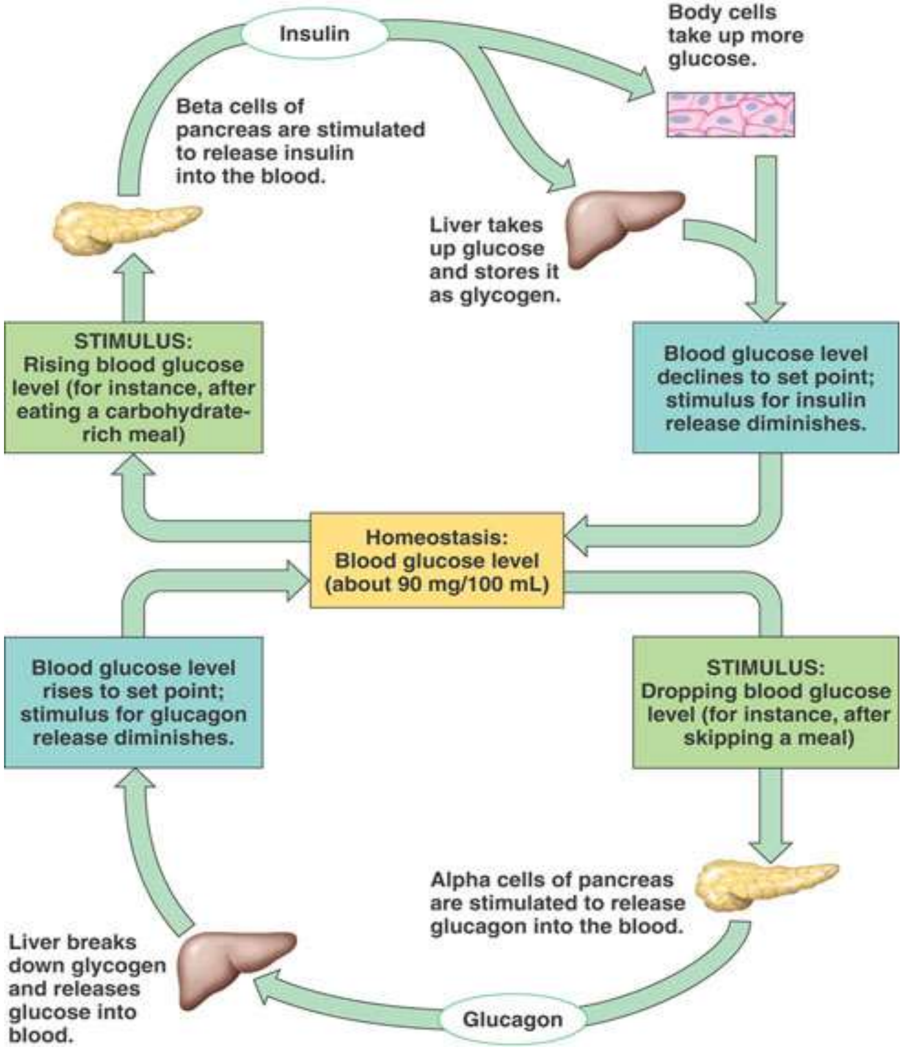


Regulation of Calcium



Pancreas

- Both endocrine and exocrine functions
- Islet of Langerhans
- Produces two hormones:
  - Alpha cells: glucagon
  - Beta cells: insulin

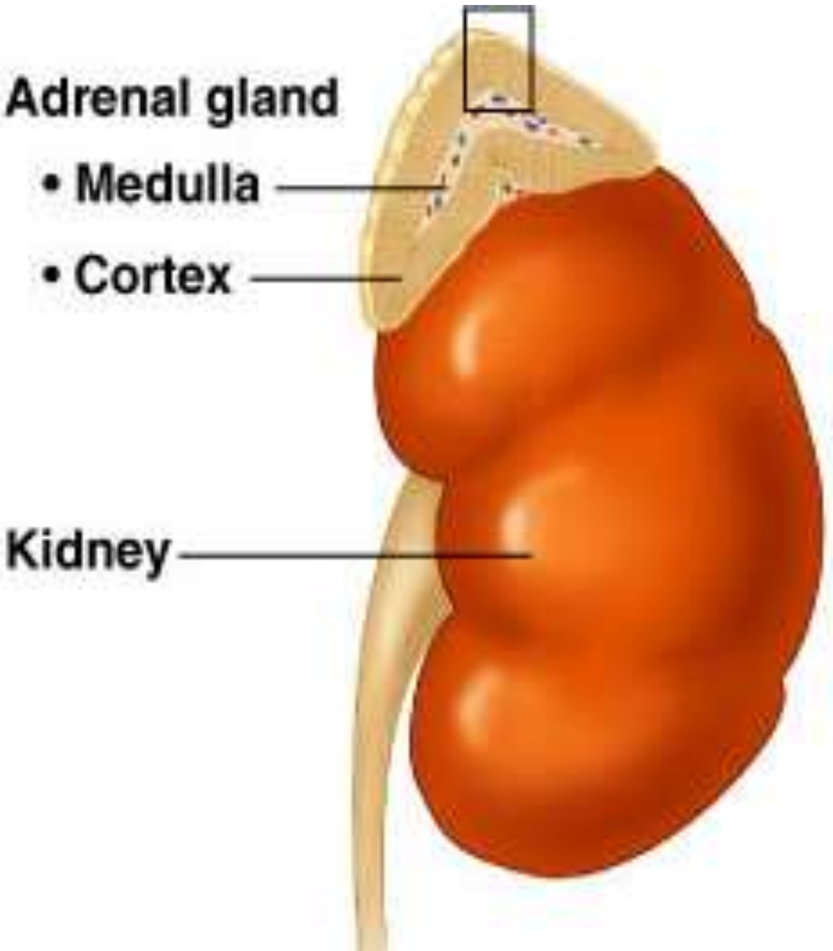


Diabetes Mellitus

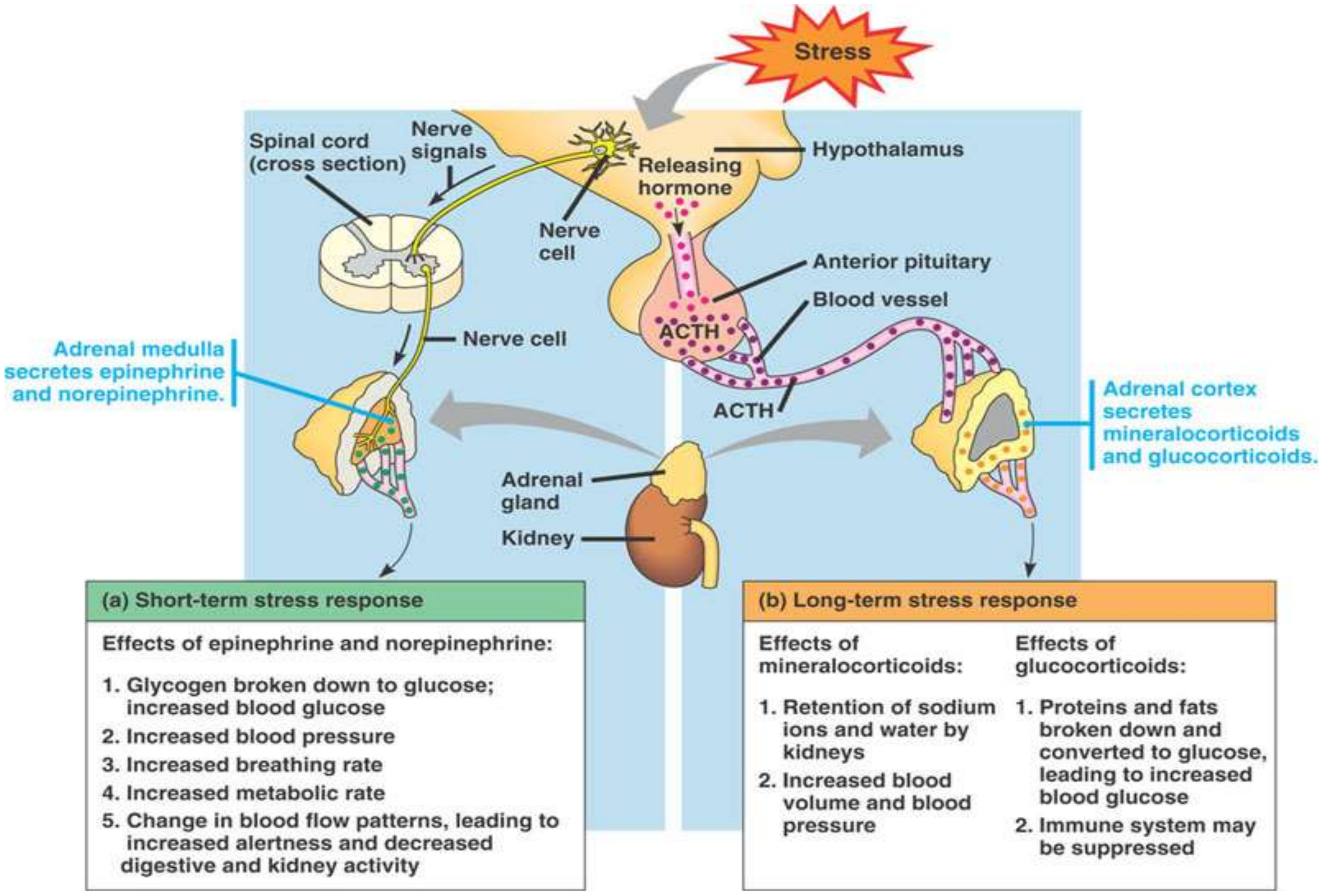
- Deficiency or decreased insulin response
  - Cells can't absorb glucose
- Fats and proteins burned
  - Glucose out in urine
- Treatments but no cure
  - Blindness, dehydration, kidney and cardiovascular disease occur
- **Type 1** (insulin dependent)
  - Autoimmune disease: WBC's attack beta cells
- **Type 2** (non-insulin dependent)
  - Genetics and often associated with obesity

Adrenal Gland

- Two Regions:
  - Adrenal Cortex
  - Adrenal Medulla
- Adrenal Cortex
  - Long-term stress responses
  - Corticosteroids
  - Endocrine response
- Adrenal Medulla
  - Short-term stress responses
  - Epi- or norepinephrine
  - Hypothalamic neural signal

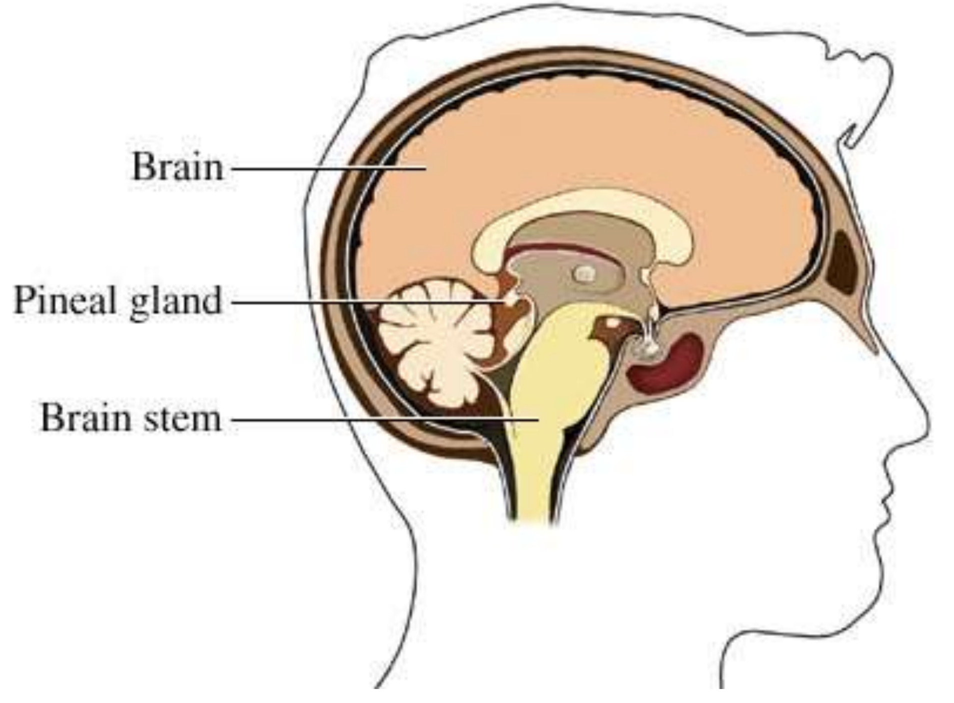


Cortex vs. Medulla



Pineal Gland

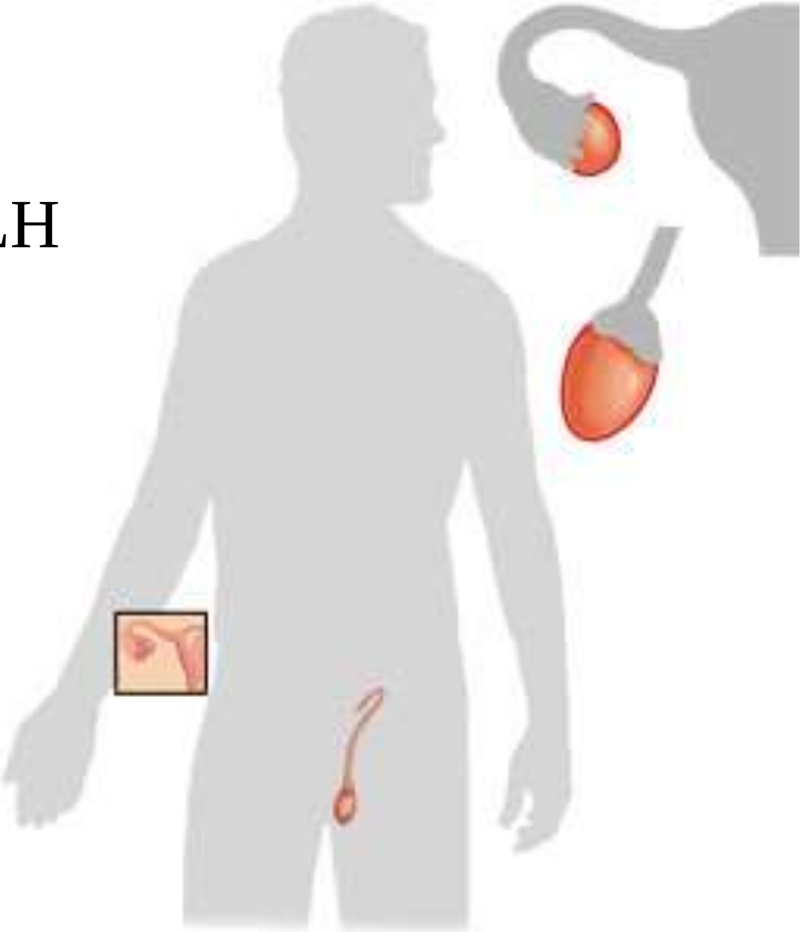
- Produces melatonin
  - Secreted at night
  - Varies by season

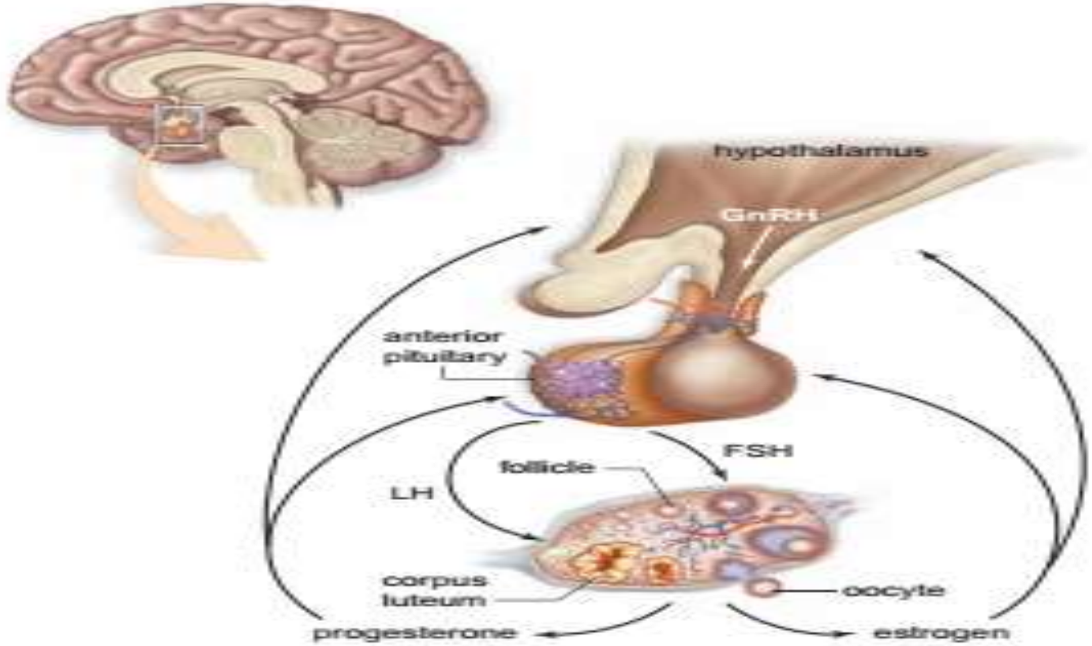


Gonadal Hormones

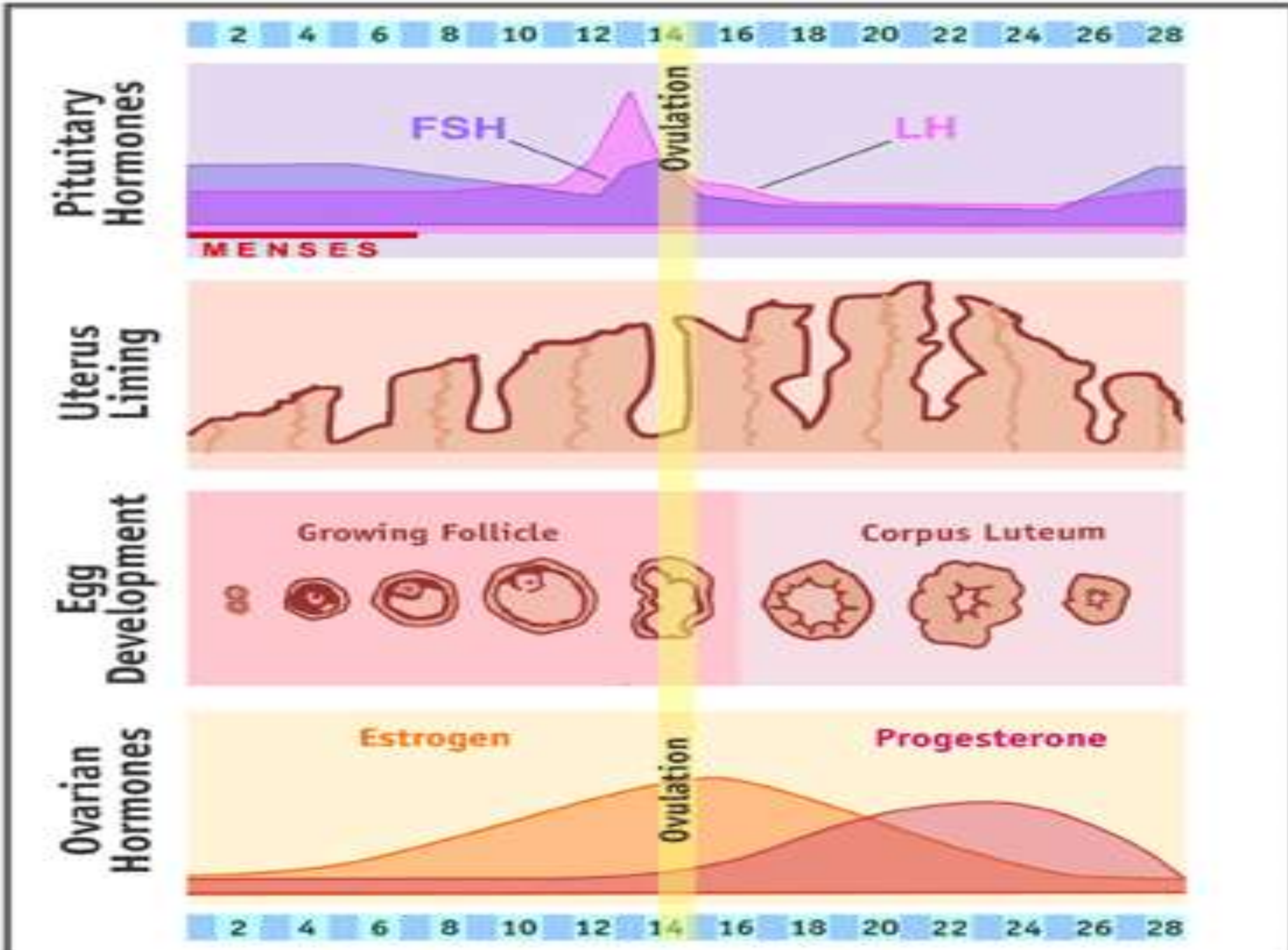
- Gamete development and 2° sex characteristics

- GNRH stimulates FSH and LH
  - Androgens
  - Estrogens
  - Progesterone





Ovarian Cycle	Events	Uterine Cycle	Events
Follicular phase—days 1–13	FSH secretion begins.	Menstruation—days 1–5	Endometrium breaks down.
	Follicle maturation occurs.	Proliferative phase—days 6–13	Endometrium rebuilds.
	Estrogen secretion is prominent.		
Ovulation—day 14*	LH spike occurs.		
Luteal phase—days 15–28	LH secretion continues.	Secretory phase—days 15–28	Endometrium thickens, and glands are secretory.
	Corpus luteum forms.		
	Progesterone secretion is prominent.		



2 4 6 8 10 12 14 16 18 20 22 24 26 28
Pituitary Hormones
FSH
LH
Ovulation
MENSES
Uterus Lining
Egg Development
Growing Follicle
Corpus Luteum
Ovarian Hormones
Estrogen
Progesterone
Ovulation
2 4 6 8 10 12 14 16 18 20 22 24 26 28

The **placenta,** which sustains the developing embryo and later the fetus, originates from both maternal and fetal tissues. It is the region of exchange of molecules between fetal and maternal blood, although the two rarely mix. At first, the placenta produces **human chorionic gonadotropin** (**hCG**), which maintains the corpus luteum in the ovary. (A pregnancy test detects the presence of hCG in the blood or urine.) Rising amounts of hCG stimulate the corpus luteum to produce increasing amounts of progesterone. This progesterone shuts down the hypothalamus and anterior pituitary so that no new follicles begin in the ovary. The progesterone maintains the uterine lining where the embryo now resides. The absence of menstruation is a signal to the woman that she may be pregnant

Pituitary Hormones

Pituitary Hormone	Functions
Follicle-stimulating hormone (FSH)	Stimulates egg maturation in the ovary and release of sex hormones.
Lutenizing hormone	Stimulates maturation of egg and of the corpus luteum surrounding the egg, which affects female sex hormones and the menstrual cycle.
Thyroid-stimulating hormone	Stimulates the thyroid to release thyroxine.
Adrenocorticotropic hormone	Causes the adrenal gland to release cortisol.
Melanocyte-stimulating hormone	Stimulates synthesis of skin pigments.
Growth hormone	Stiimulates growth during infancy and puberty.
Antidiuretic hormone	Signals the kidney to conserve more water.
Oxytocin	Affects childbirth, lactation, and some behaviors.

Endocrine Hormones

Gland	Hormones	Functions
Thyroid	**Thyroxine**	Regulates metabolism
	Calcitonin	Inhibits release of calcium from the bones
Parathyroids	**Parathyroid hormone**	Stimulates the release of calcium from the bones.
Islet cells (in the pancreas)	**Insulin**	Decreases blood sugar by promoting uptake of glucose by cells.
	Glucagon	Increases blood sugar by stimulating breakdown of glycogen in the liver.
Testes	Testosterone	Regulates sperm cell production and secondary sex characteristics.
Ovaries	Estrogen	Stimulates egg maturation, controls secondary sex characteristics.
	Progesterone	Prepares the uterus to receive a fertilized egg.
Adrenal cortex	Epinephrine	Stimulates "fight or flight" response.
Adrenal medulla	Glucocorticoids	Part of stress response, increase blood glucose levels and decrease immune response.
	Aldosterone	Regulates sodium content in the blood.
	Testosterone (in both sexes)	Adult body form (greater muscle mass), libido.
Pineal gland	Melatonin	Sleep cycles, reproductive cycles in many mammals.

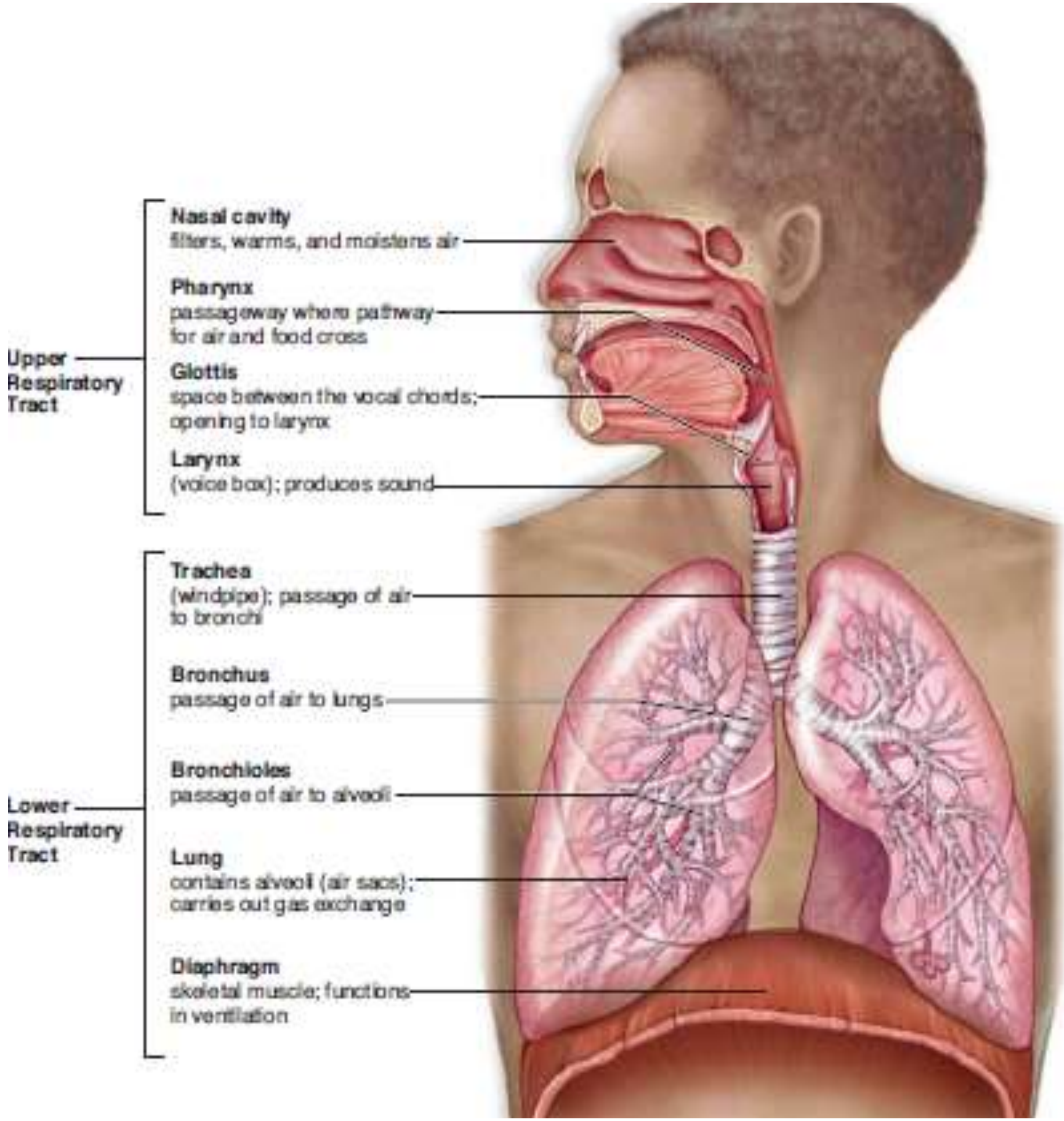
Respiratory system

Essam Mohammed Alfhadawy

The Respiratory System

The organs of the respiratory system ensure that oxygen enters the body and carbon dioxide leaves the body. During **inspiration,** or inhalation (breathing in), air is conducted from the atmosphere to the lungs by a series of cavities, tubes, and openings. During **expiration,** or exhalation (breathing out), air is conducted from the lungs to the atmosphere by way of the same structures.

Ventilation is another term for breathing that includes both inspiration and expiration. Once ventilation has occurred, the respiratory system depends on the cardiovascular system to transport oxygen (O2) from the lungs to the tissues and carbon dioxide (CO2) from the tissues to the lungs. During cellular respiration, cells use up O2 and produce CO2.


Upper Respiratory Tract
Nasal cavity
filters, warms, and moistens air
Pharynx
passageway where pathway for air and food cross
Glottis
space between the vocal chords; opening to larynx
Larynx
(voice box); produces sound
Lower Respiratory Tract
Trachea
(windpipe); passage of air to bronchi
Bronchus
passage of air to lungs
Bronchioles
passage of air to alveoli
Lung
contains alveoli (air sacs); carries out gas exchange
Diaphragm
skeletal muscle; functions in ventilation

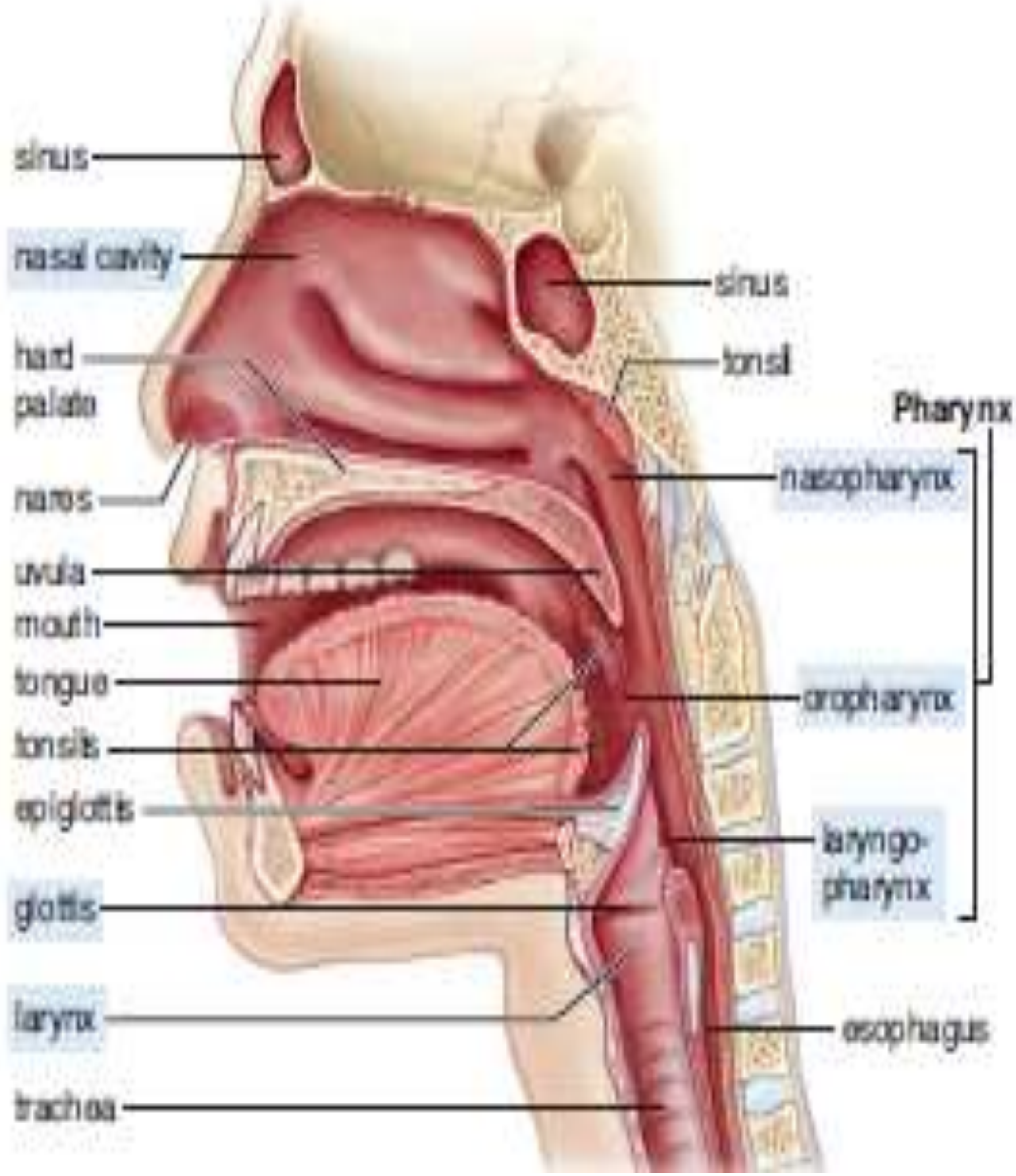
The Upper Respiratory Tract

The nasal cavities, pharynx, and larynx are the organs of the upper respiratory tract.

The Nose

The nose opens to the **nasal cavities.** The nasal cavities are narrow canals separated from each other by a septum composed of bone and cartilage . Air entering the nasal cavities is met by large stiff hairs that act as a screening device. The hairs filter the air and trap small particles (dust, mold spores, pollen, etc.). The rest of the nasal cavities are lined by mucous membrane. The mucus secreted by this membrane helps trap dust and move it to the pharynx, where it can be swallowed or expectorated by coughing or spitting. Under the mucous layer is the submucosa. The submucosa contains a large number of capillaries that help warm and moisten the incoming air, but they also make us more susceptible to nose bleeds if the nose suffers an injury. When we breath out on a cold day, the moisture in the air condenses so that we can see our breath. In the narrow upper recesses of the nasal cavities are special ciliated cells that act as odor receptor.

Nerves lead from these cells to the brain, where the impulses generated by the odor receptors are interpreted as smell.
The tear (lacrimal) glands drain into the nasal cavities by way of tear ducts. When you cry, your nose runs as tears drain from the eye surface into the nose. The nasal cavities also connect with the sinuses (cavities) of the skull. At times, fluid may accumulate in these sinuses, causing an excess of pressure, resulting in a sinus headache. Air in the nasal cavities passes into the nasopharynx, the upper portion of the pharynx. Connected to the nasopharynx are tubes called **auditory** (**eustachian**) **tubes** that connect to the middle ear. When air pressure inside the middle ears equalizes with the air pressure in the nasopharynx, the auditory tube openings may create a "popping" sensation. When in a plane taking off or landing, some people chew gum or yawn in an effort to move air from the ears and prevent the popping.



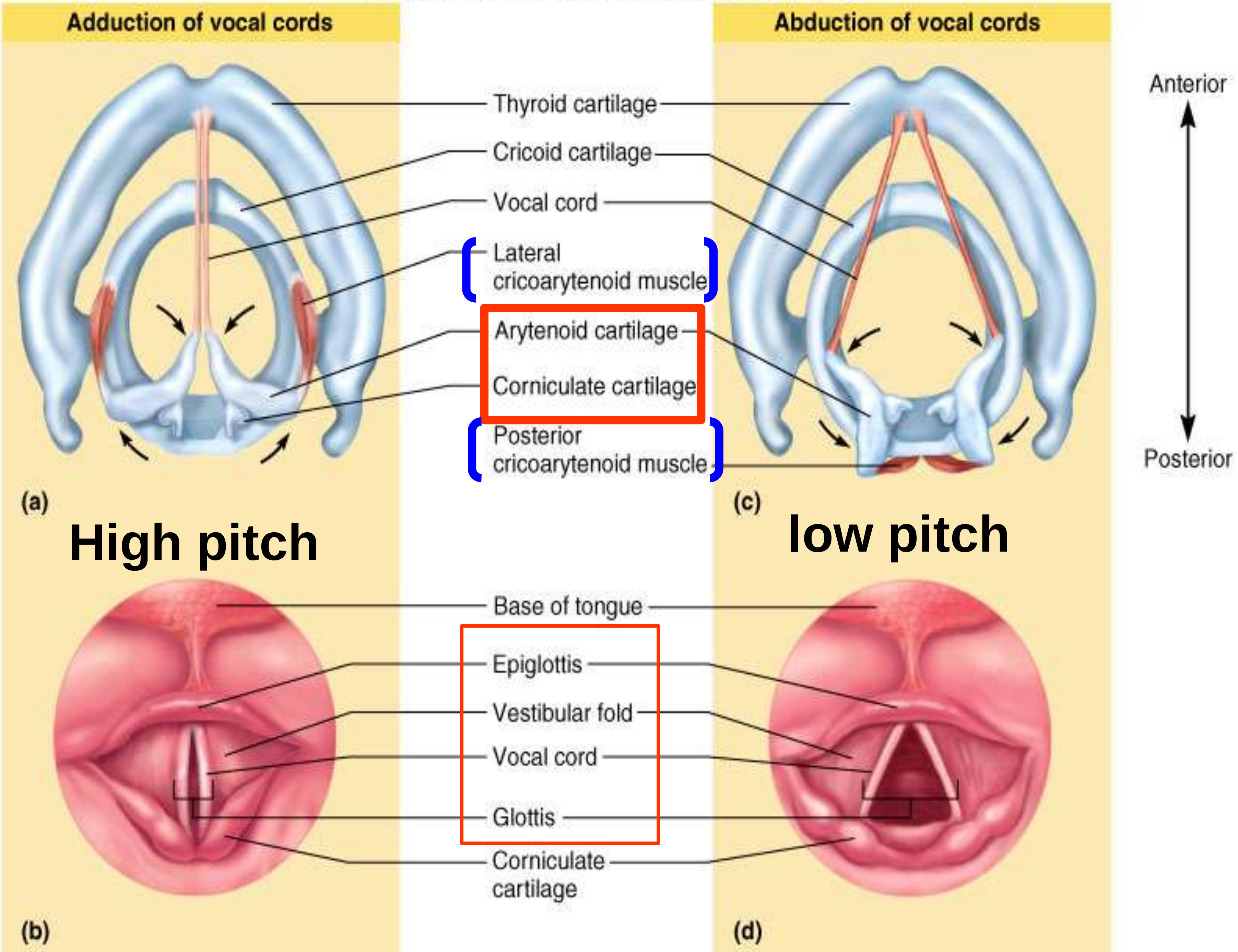
sinus
nasal cavity
hard palate
nares
uvula
mouth
tongue
tonsils
epiglottis
glottis
larynx
trachea
sinus
tonsil
Pharynx
nasopharynx
oropharynx
laryngo-pharynx
esophagus

The Pharynx:

The **pharynx** is a funnel-shaped passageway that connects the nasal and oral cavities to the larynx. Therefore, the pharynx, commonly referred to as the "throat," has three parts: the nasopharynx, where the nasal cavities open above the soft palate; the oropharynx, where the oral cavity opens; and the laryngopharynx, which opens into the larynx. The **tonsils** form a protective ring at the junction of the oral cavity and the pharynx. The tonsils contain lymphocytes, which protect against invasion of inhaled foreign antigens. The tonsils are the primary defense during breathing, because inhaled air passes directly over the tonsils.

The Larynx

The **larynx** is a cartilaginous structure that serves as a passageway for air between the pharynx and the trachea. The larynx is called the *voice box* because it houses the vocal cords. The **vocal cords** are mucosal folds supported by elastic ligaments, and the slit between the vocal cords is called the **glottis** . When air is expelled through the glottis, the vocal cords vibrate, producing sound. At the time of puberty, the growth of the larynx and the vocal cords is much more rapid and accentuated in the male than in the female, causing the deeper voice. The high or low pitch of the voice is regulated when speaking and singing by changing the tension on the vocal cords. The greater the tension, as when the glottis becomes narrower, the higher the pitch. When the glottis is wider, the pitch is lower .



Adduction of vocal cords
Abduction of vocal cords
Thyroid cartilage
Cricoid cartilage
Vocal cord
Lateral cricoarytenoid muscle
Arytenoid cartilage
Corniculate cartilage
Posterior cricoarytenoid muscle
Anterior
Posterior
(a)
High pitch
(c)
low pitch
Base of tongue
Epiglottis
Vestibular fold
Vocal cord
Glottis
Corniculate cartilage
(b)
(d)

Upper Respiratory Tract Functions

- Passageway for respiration
- Receptors for smell
- Filters incoming air to filter larger foreign material
- Moistens and warms incoming air
- Resonating chambers for voice

The Lower Respiratory Tract

The lower respiratory tract consists of the trachea, the bronchial tree, and the lungs

The Trachea

The **trachea,** commonly called the windpipe, is a tube connecting the larynx to the primary bronchi. Its walls consist of connective tissue and smooth muscle reinforced by C-shaped cartilaginous rings. The rings prevent the trachea from collapsing. The trachea lies anterior to the esophagus. The mucous membrane that lines the trachea has an outer layer of pseudostratified ciliated columnar epithelium and goblet cells. The goblet cells produce mucus, which traps debris in the air as it passes through the trachea. The mucus is then swept toward the pharynx and away from the lungs by the cilia that project from the epithelium. When one coughs, the tracheal wall contracts, narrowing its diameter. Therefore, coughing causes air to move more rapidly through the trachea, helping to expel mucus and foreign objects. Smoking is known to destroy the cilia; consequently, the soot in cigarette smoke collects in the lungs.

The Bronchial Tree

The trachea divides into right and left primary bronchi (sing., **bronchus**), which lead into the right and left lungs. The bronchi branch into a few secondary bronchi that also branch, until the branches become about 1 mm in diameter and are called **bronchioles.** The bronchi resemble the trachea in structure. As the bronchial tubes divide and subdivide, their walls become thinner, and the small rings of cartilage are no longer present. During an asthma attack, the smooth muscle of the bronchioles contracts, causing bronchiolar constriction and characteristic wheezing. Each bronchiole leads to an elongated space enclosed by a multitude of air pockets or sacs called alveoli (sing., **alveolus**)

The Lungs

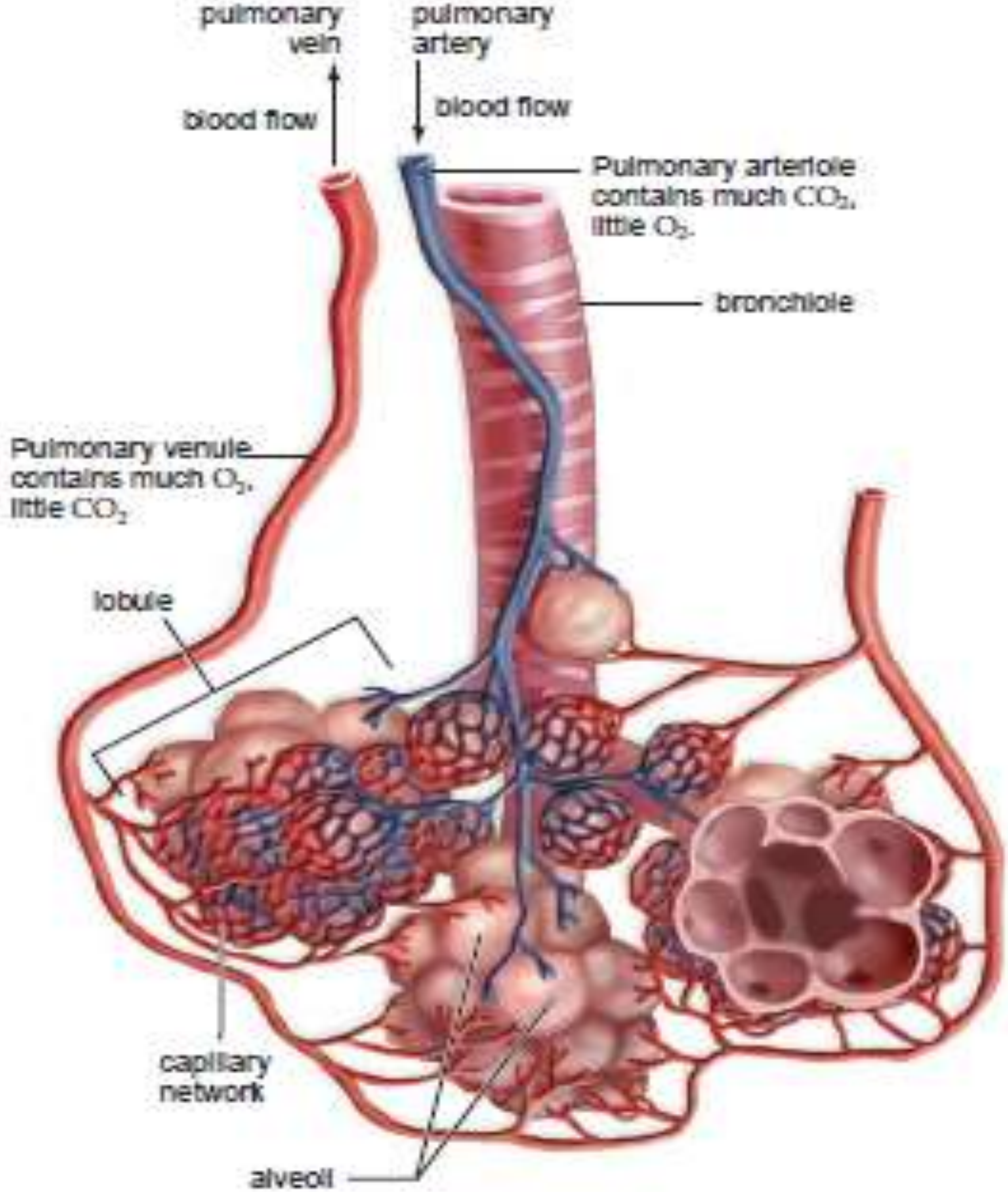
The **lungs** are paired, cone-shaped organs in the thoracic cavity. The lungs are on either side of the trachea. The right lung has three lobes, and the left lung has two lobes, allowing room for the heart, which points left. Each lobe is further divided into lobules, and each lobule has a bronchiole serving many alveoli. Each lung is enclosed by pleurae (sing., **pleura**), two layers of serous membrane that produces serous fluid. The parietal pleura adheres to the thoracic cavity wall, and the visceral pleura adheres to the surface of the lung. Surface tension holds the two pleural layers together. Therefore, the lungs must follow the movement of the thorax when breathing occurs. When someone has pleurisy, these layers are inflamed. Breathing, sneezing, and coughing are quite painful because the layers rub against each other.

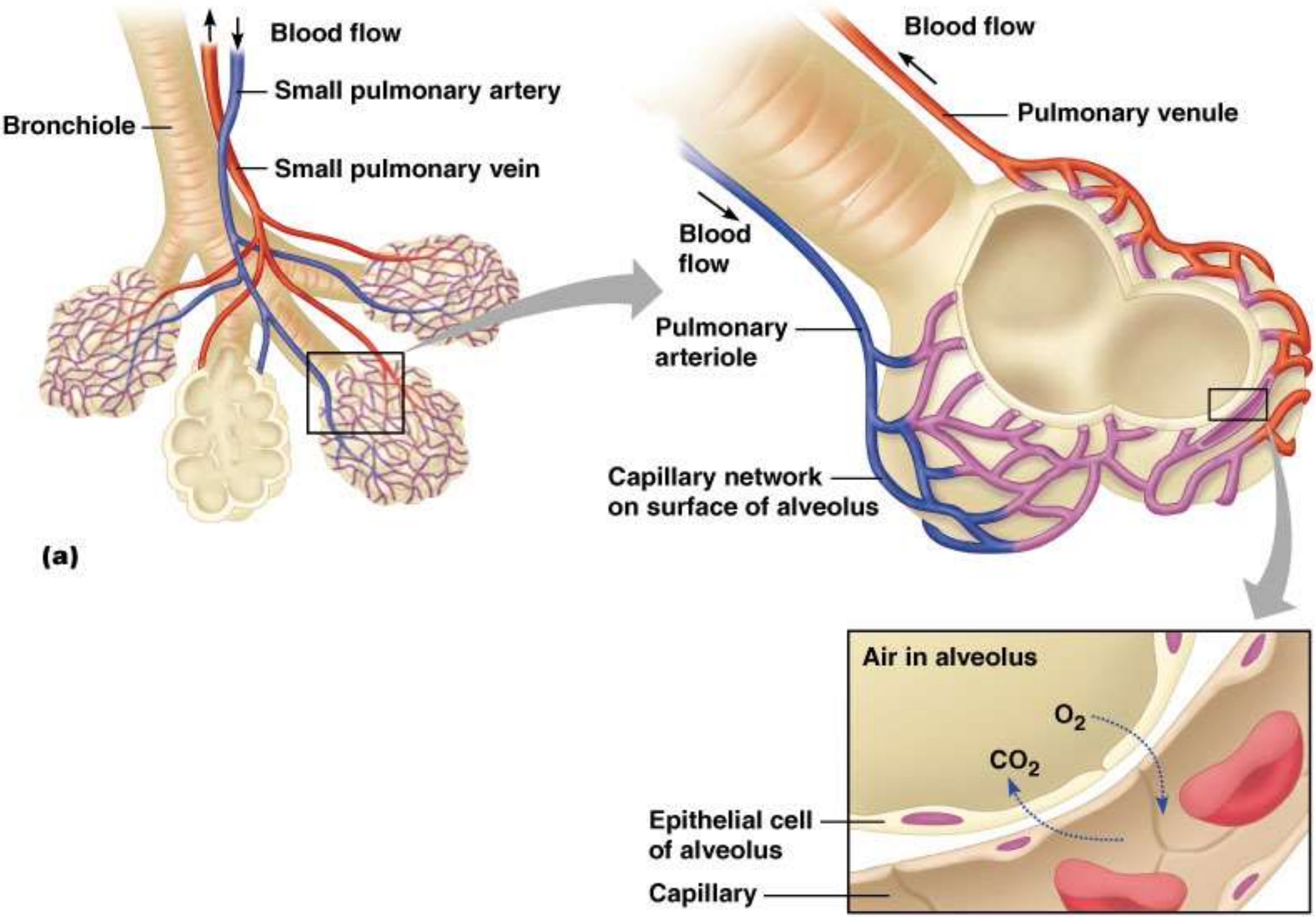
The Alveoli

Each alveolar sac is surrounded by blood capillaries. The walls of the sac and the capillaries are largely simple squamous epithelium. Gas exchange occurs between air in the alveoli and blood in the capillaries. Oxygen diffuses across the alveolar wall and enters the bloodstream, and carbon dioxide diffuses from the blood across the alveolar wall to enter the alveoli. The alveoli of human lungs are lined with a **surfactant,** a film of lipoprotein that lowers the surface tension of water and prevents the alveoli from closing. The lungs collapse in some newborn babies—especially premature infants—who lack this film. The condition, called **infant respiratory distress syndrome,** is now treatable by surfactant replacement therapy.

Organs in the Respiratory System

STRUCTURE	FUNCTION
nose / nasal cavity	warms, moistens, & filters air as it is inhaled
pharynx (throat)	passageway for air, leads to trachea
larynx	the voice box, where vocal cords are located
trachea (windpipe)	keeps the windpipe "open" trachea is lined with fine hairs called *cilia* which filter air before it reaches the lungs
bronchi	two branches at the end of the trachea, each lead to a lung
bronchioles	a network of smaller branches leading from the bronchi into the lung tissue & ultimately to air sacs
alveoli	the functional respiratory units in the lung where gases are exchanged

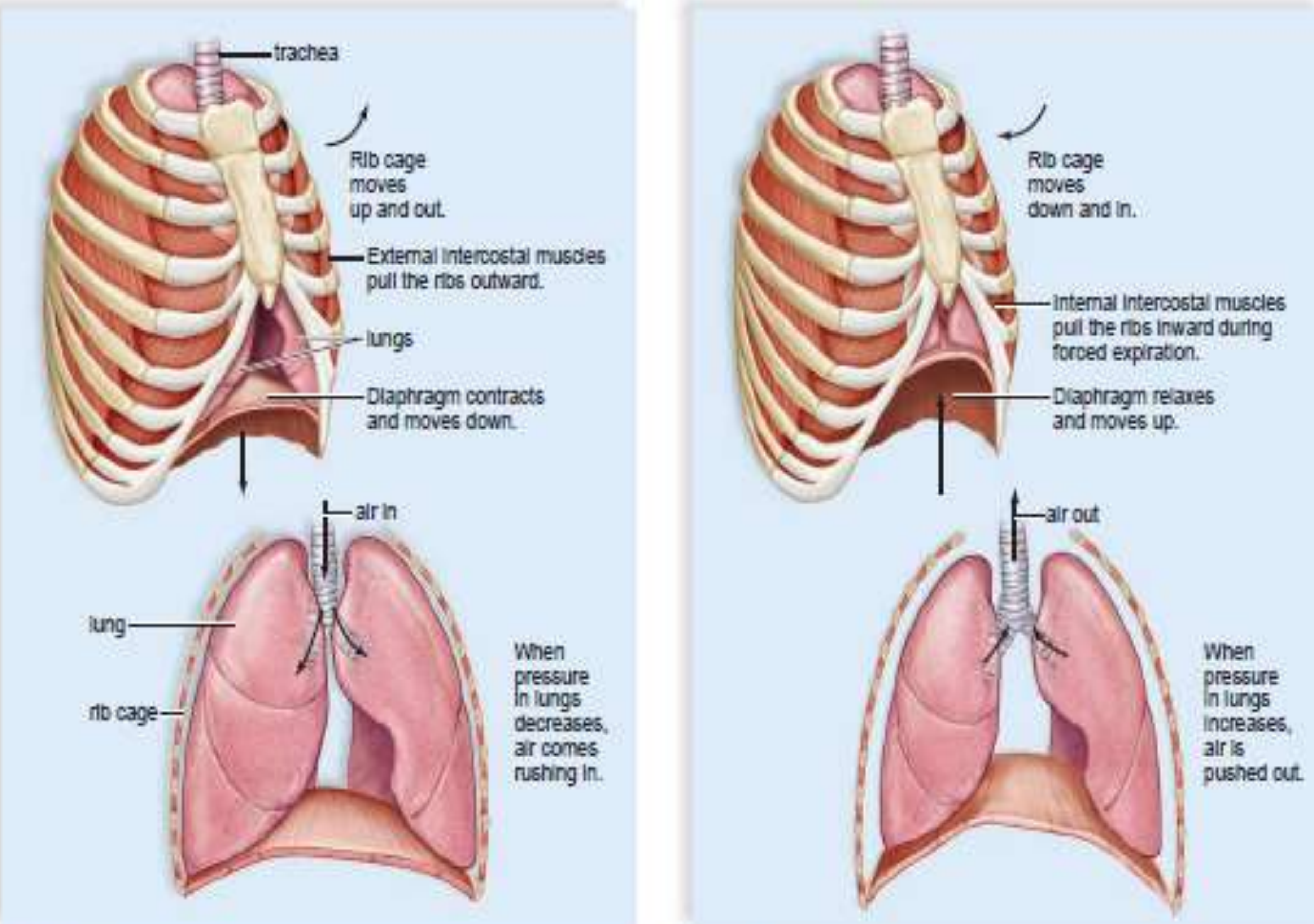

pulmonary vein
pulmonary artery
blood flow
blood flow
Pulmonary arteriole contains much CO_2, little O_2.
bronchiole
Pulmonary venule contains much O_2, little CO_2
lobule
capillary network
alveoli



Blood flow
Small pulmonary artery
Bronchiole
Small pulmonary vein
(a)
Blood flow
Pulmonary venule
Blood flow
Pulmonary arteriole
Capillary network on surface of alveolus
Air in alveolus
O_2
CO_2
Epithelial cell of alveolus
Capillary

Inspiration Mechanism

Inspiration is the active phase of ventilation because the diaphragm and the external intercostal muscles contract. In its relaxed state, the diaphragm is dome-shaped. During inspiration, it contracts and becomes a flattened sheet of muscle. Also, the external intercostal muscles contract, causing the rib cage to move upward and outward. Following contraction of the diaphragm and the external intercostal muscles, the volume of the thoracic cavity is larger than it was before. As the thoracic volume increases, the lungs increase in volume as well because the lung adheres to the wall of the thoracic cavity. As the lung volume increases, the air pressure within the alveoli decreases, creating a partial vacuum. In other words, alveolar pressure is now less than atmospheric pressure (air pressure outside the lungs) *humans inhale by negative pressure*. . Air will naturally flow from outside the body into the respiratory passages and into the alveoli.



a. Inspiration

b. Expiration

Expiration Mechanism

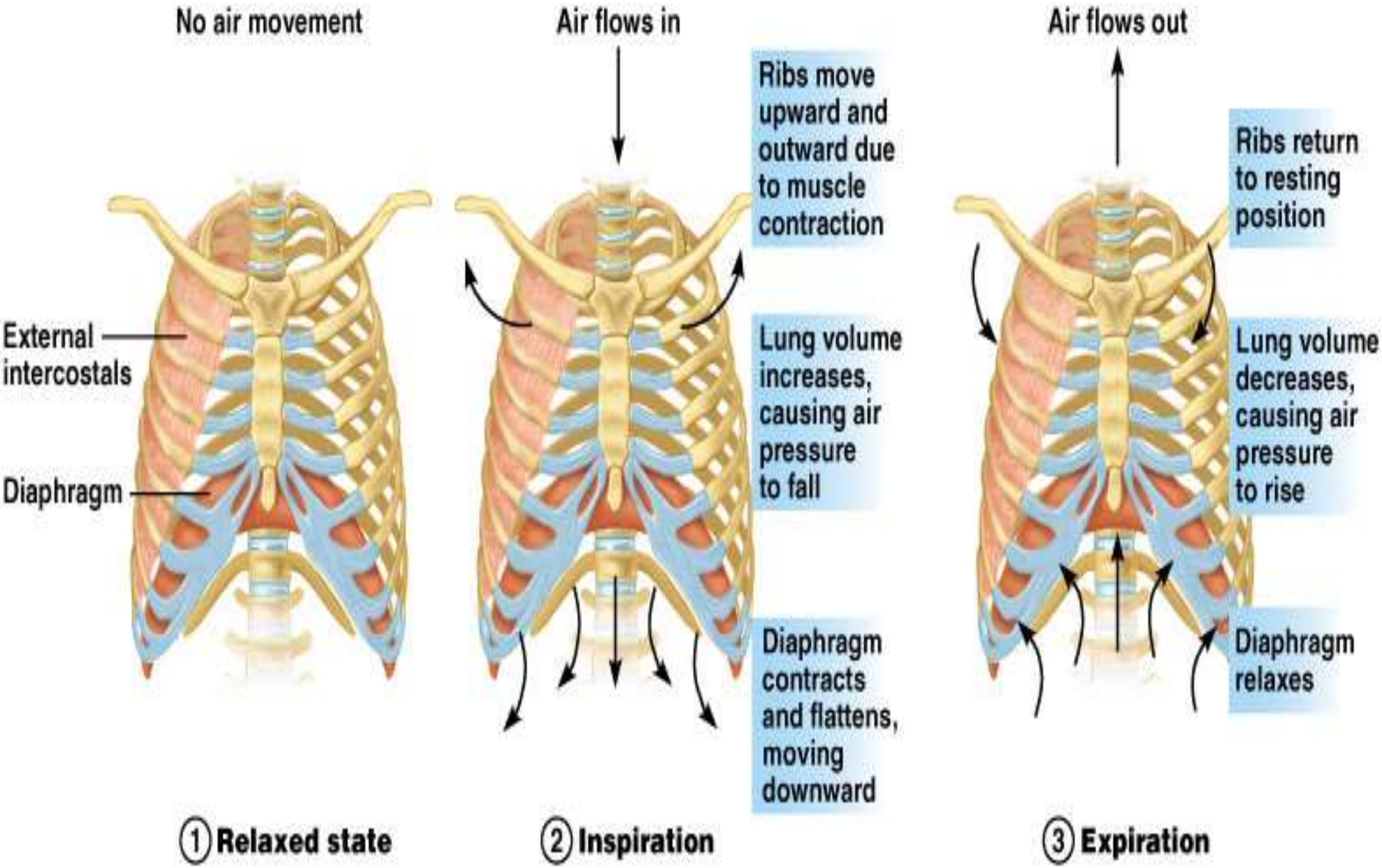
During expiration, the diaphragm and external intercostal muscles relax. The rib cage returns to its resting position, moving down and inward. The elastic properties of the thoracic wall and lung tissue help them to recoil.

As the volume of the bellows decreases, the air pressure inside increases. Now air flows out. Also, as the lungs recoil. The importance of the reduced intrapleural pressure is demonstrated when in an accident the thoracic cavity is punctured (a “punctured lung”). Air now enters the intrapleural space, causing the lung to collapse.

Process of Breathing: Pressure Gradient

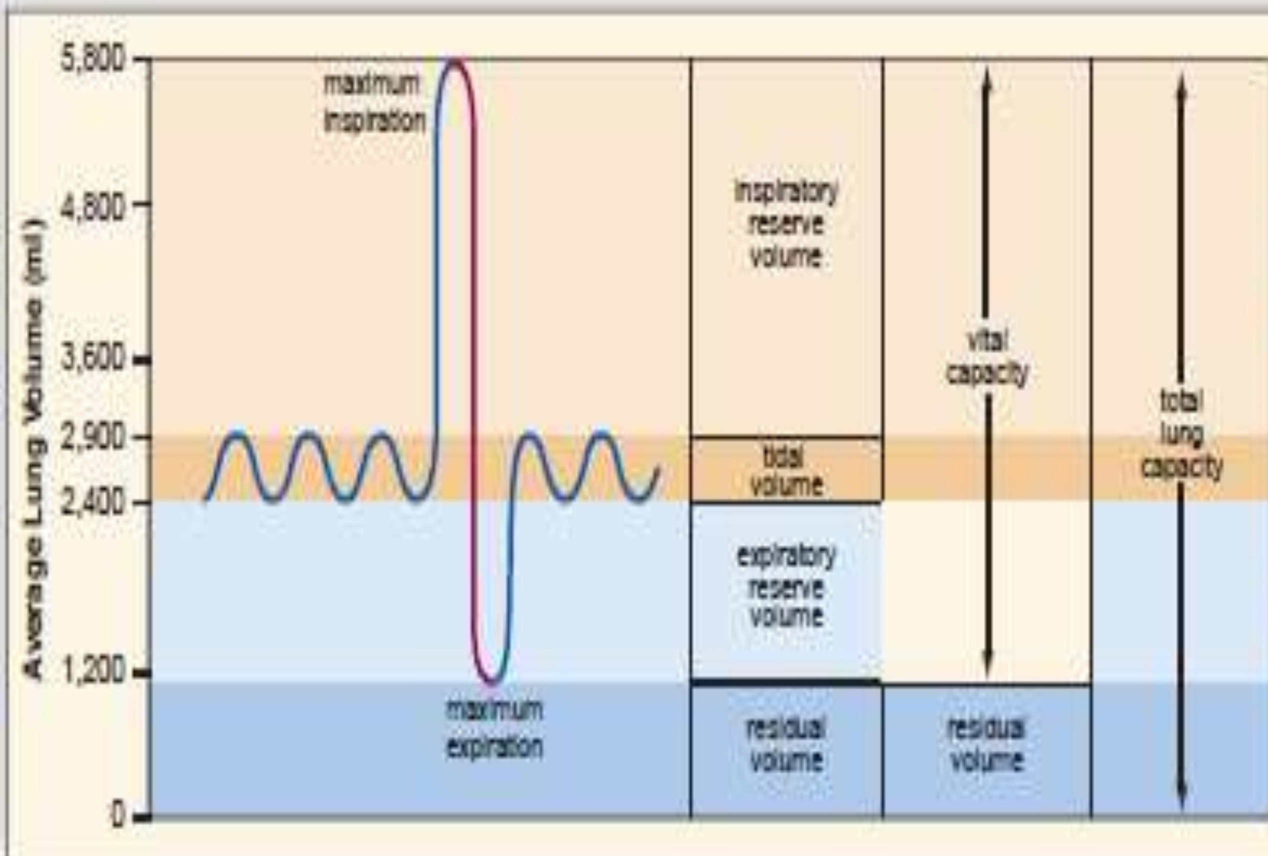
- Inspiration/Expiration: air in/air out
- Cycle:
  - Relaxed state: diaphragm and intercostal muscles relaxed
  - Inspiration: diaphragm contracts, pulling muscle down, intercostal muscles contract elevating chest wall and expanding volume of chest, lowering pressure in lungs, pulling in air
  - Expiration: muscles relax, diaphragm resumes dome shape, intercostal muscles allow chest to lower resulting in increase of pressure in chest and expulsion of air

Respiratory Cycle



Measurement of Lung Function

- Lung volumes and vital capacity
  - Tidal volume: volume of air inhaled and exhaled in a single breath
  - Dead space volume: the air that remains in the airways and does not participate in gas exchange
  - Vital capacity: the maximal volume that can be exhaled after maximal inhalation. It is possible to increase the amount of air inhaled and, therefore, the amount exhaled by deep breathing.
  - Inspiratory reserve volume: the amount of air that can be inhaled beyond the tidal volume
- Lung volumes and vital capacity (continued)
  - Expiratory reserve volume: the amount of air that can be forcibly exhaled beyond the tidal volume
  - Residual volume: the amount of air remaining in the lungs, even after a forceful maximal expiration



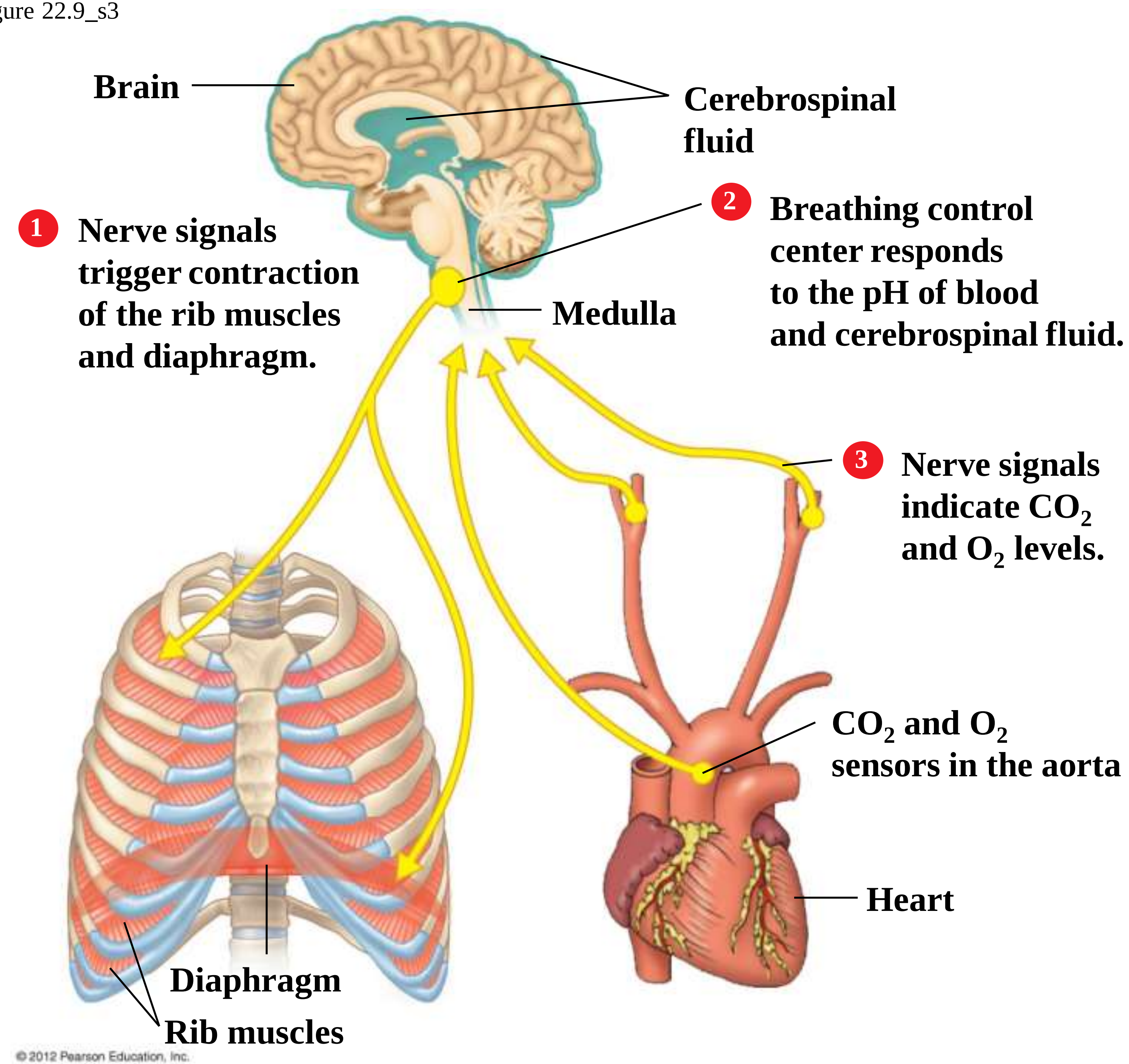
5,800
4,800
3,600
2,900
2,400
1,200
0
Average Lung Volume (ml)
maximum inspiration
maximum expiration
inspiratory reserve volume
tidal volume
expiratory reserve volume
residual volume
vital capacity
residual volume
total lung capacity

Control of Ventilation

Nervous Control of Breathing

The rhythm of ventilation is controlled by a **respiratory control center** located in the medulla oblongata of the brain. The respiratory control center automatically sends out nerve signals to the diaphragm and the external intercostal muscles of the rib cage, causing inspiration to occur. When the respiratory center stops sending nerve signals to the diaphragm and the rib cage, the muscles relax and expiration occurs.

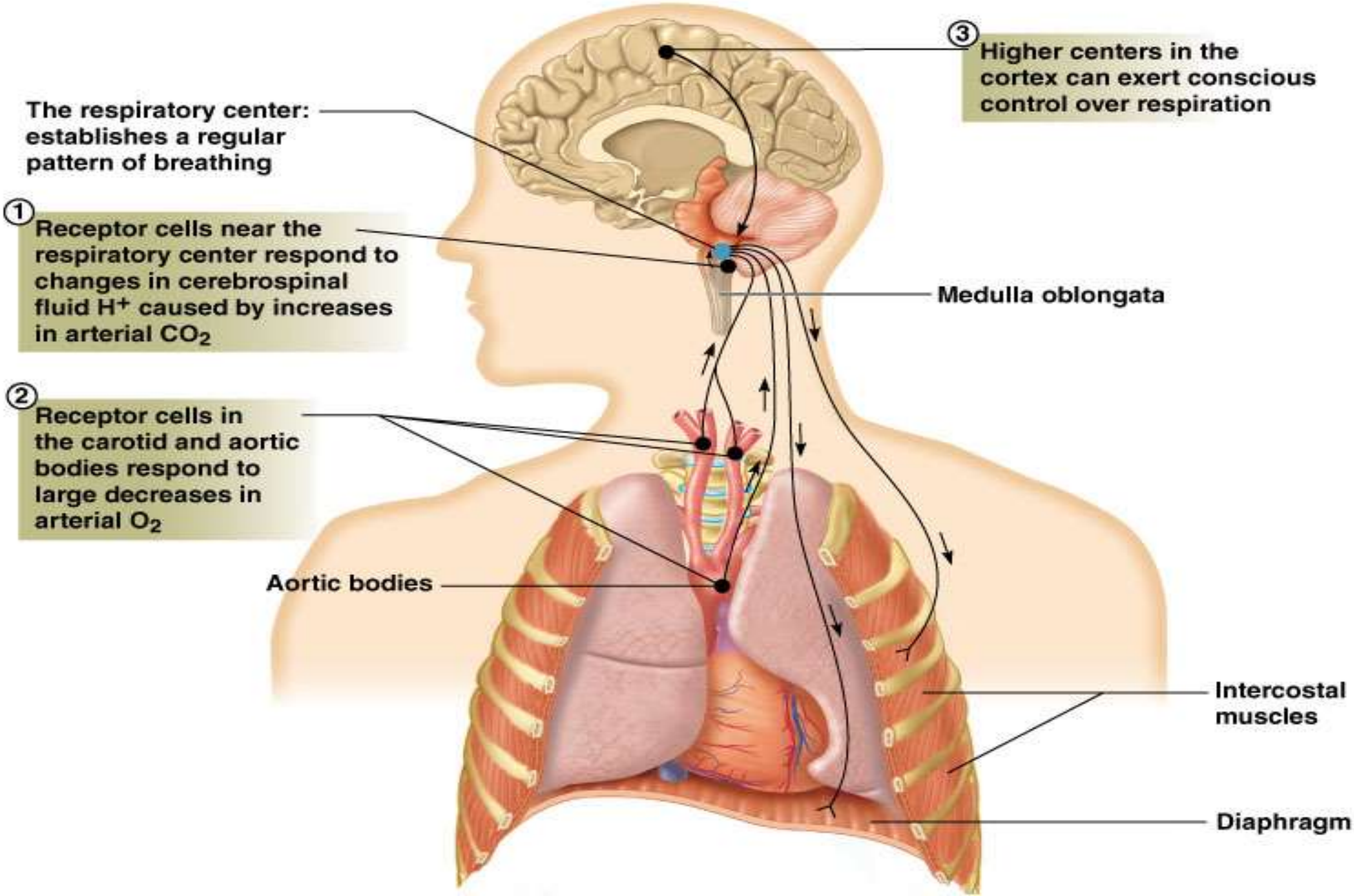
Figure 22.9_s3



.Chemical Control of Breathing

cells produce carbon dioxide, which enters the blood. There, carbon dioxide combines with water, forming an acid, which breaks down and gives of hydrogen ions (H+). These hydrogen ions can change the pH of the blood. **Chemoreceptors** are sensory receptors in the body that are sensitive to chemical composition of body fluids. Two sets of chemoreceptors sensitive to pH can cause breathing to speed up. A centrally placed set is located in the medulla oblongata of the brain stem, and a peripherally placed set is in the circulatory system. Carotid bodies, located in the carotid arteries, and aortic bodies, located in the aorta, are sensitive to blood pH.

Regulation of Breathing



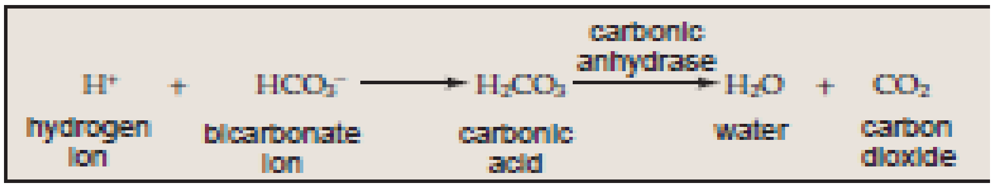
Gas Exchanges in the Body

Gas exchange is critical to homeostasis. Oxygen needed to produce energy must be supplied to all the cells, and carbon dioxide must be removed from the body during gas exchange. As mentioned previously, respiration includes the exchange of gases not only in the lungs but also in the tissues.

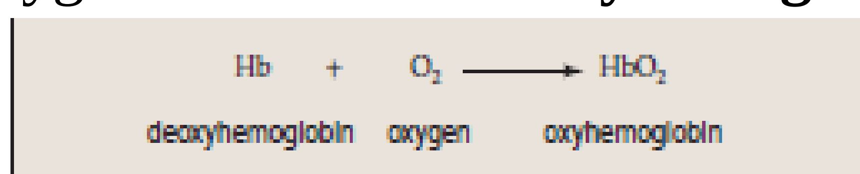
Gases exert pressure, and the amount of pressure each gas exerts is called its partial pressure, symbolized as PO2 and PCO2. If the partial pressure of oxygen differs across a membrane, oxygen will diffuse from the higher to lower partial pressure.

External respiration refers to the exchange of gases between air in the alveoli and blood in the pulmonary capillaries . Blood in the pulmonary capillaries has a higher PCO2 than atmospheric air. Therefore, *CO2 diffuses out of the plasma into the lungs*. Most of the CO2 is carried in plasma as **bicarbonate ions** (HCO3 −)

The enzyme **carbonic anhydrase** speeds the breakdown of carbonic acid (H2CO3) in red blood cells. The blood will have fewer hydrogen ions, and alkalosis, a high blood pH, results. In that case, breathing is inhibited, and you may suffer from various symptoms ranging from dizziness to continuous contractions of the skeletal muscles.



Hydrogen ions build up in the blood and acidosis occurs. Buffers may compensate for the low pH, and breathing most likely increases. Extreme changes in blood pH affect enzyme function, which may lead to coma and death. The pressure pattern for O2 during external respiration is the reverse of that for CO2. Blood in the pulmonary capillaries is low in oxygen, and alveolar air contains a higher partial pressure of oxygen. Therefore, *O2 diffuses into plasma and then into red blood cells in the lungs*. Hemoglobin takes up this oxygen and becomes **oxyhemoglobin** (HbO2).

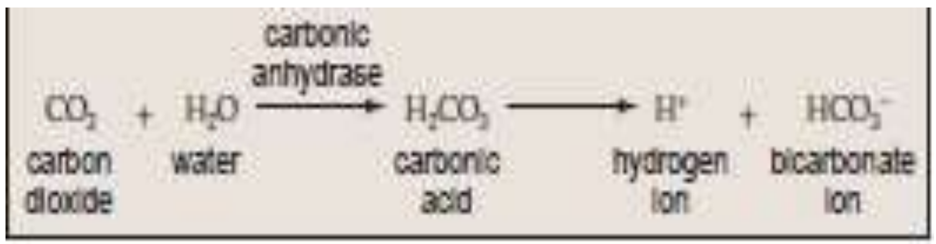


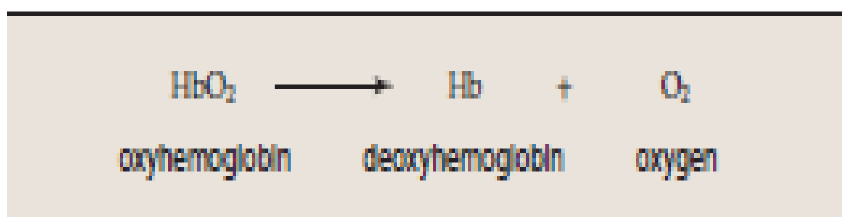
Internal Respiration

refers to the exchange of gases between the blood in systemic capillaries and the tissue cells. Blood entering systemic capillaries is a bright red color because red blood cells contain oxyhemoglobin.

Oxygen diffuses out of the blood into the tissues because the PO_2 of tissue fluid is lower than that of blood. The lower PO_2 is due to cells continuously using up oxygen in cellular respiration . Carbon dioxide diffuses into the blood from the tissues because the PCO_2 of tissue fluid is higher than that of blood. Carbon dioxide is produced during cellular respiration and collects in tissue fluid. After CO_2 diffuses into the blood, most enters the red blood cells, where a small amount is taken up by hemoglobin, forming **carbaminohemoglobin** ($HbCO_2$). In plasma, CO_2 combines with water, forming carbonic acid (H_2CO_3), which dissociates to hydrogen ions (H^+) and bicarbonate ions (HCO_3^-).

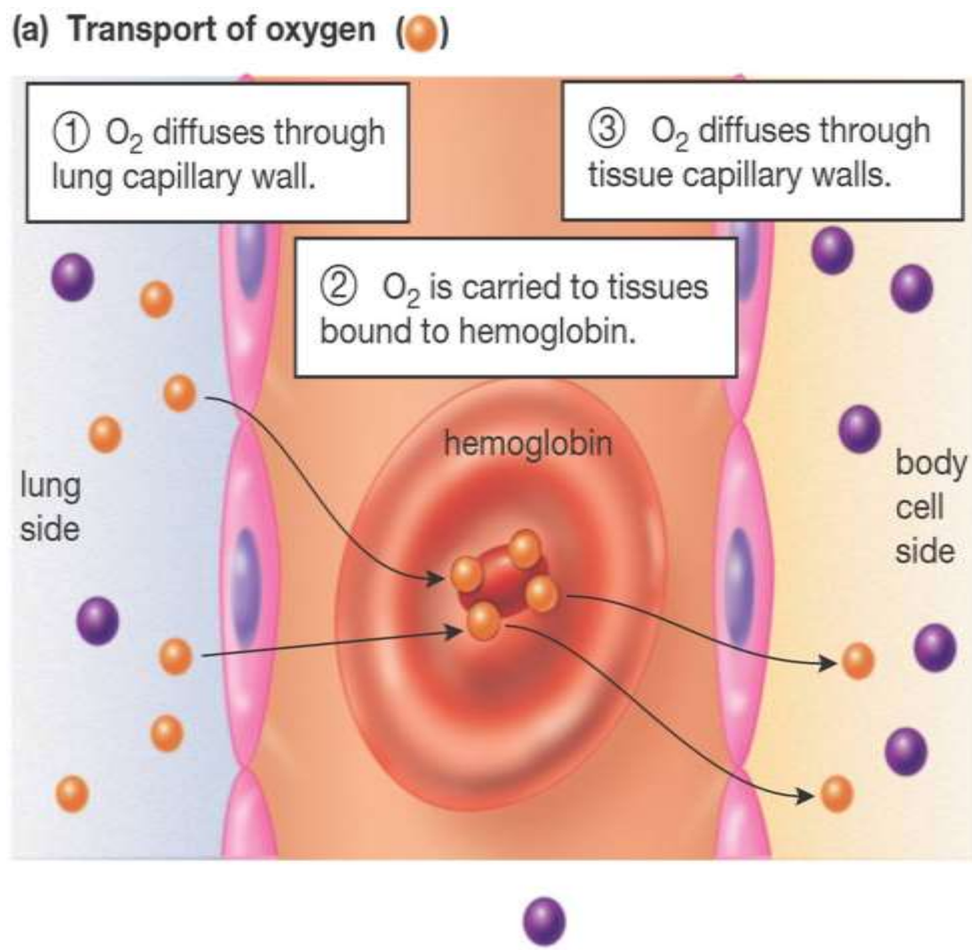
The enzyme carbonic anhydrase, mentioned previously, speeds the reaction in red blood cells. Bicarbonate ions (HCO3–) diffuse out of red blood cells and are carried in the plasma. The globin portion of hemoglobin combines with excess hydrogen ions produced by the overall reaction, and Hb becomes HHb, called **reduced hemoglobin.**
In this way, the pH of blood remains fairly constant. Blood that leaves the systemic capillaries is a dark maroon color because red blood cells contain reduced hemoglobin.





Oxygen transport

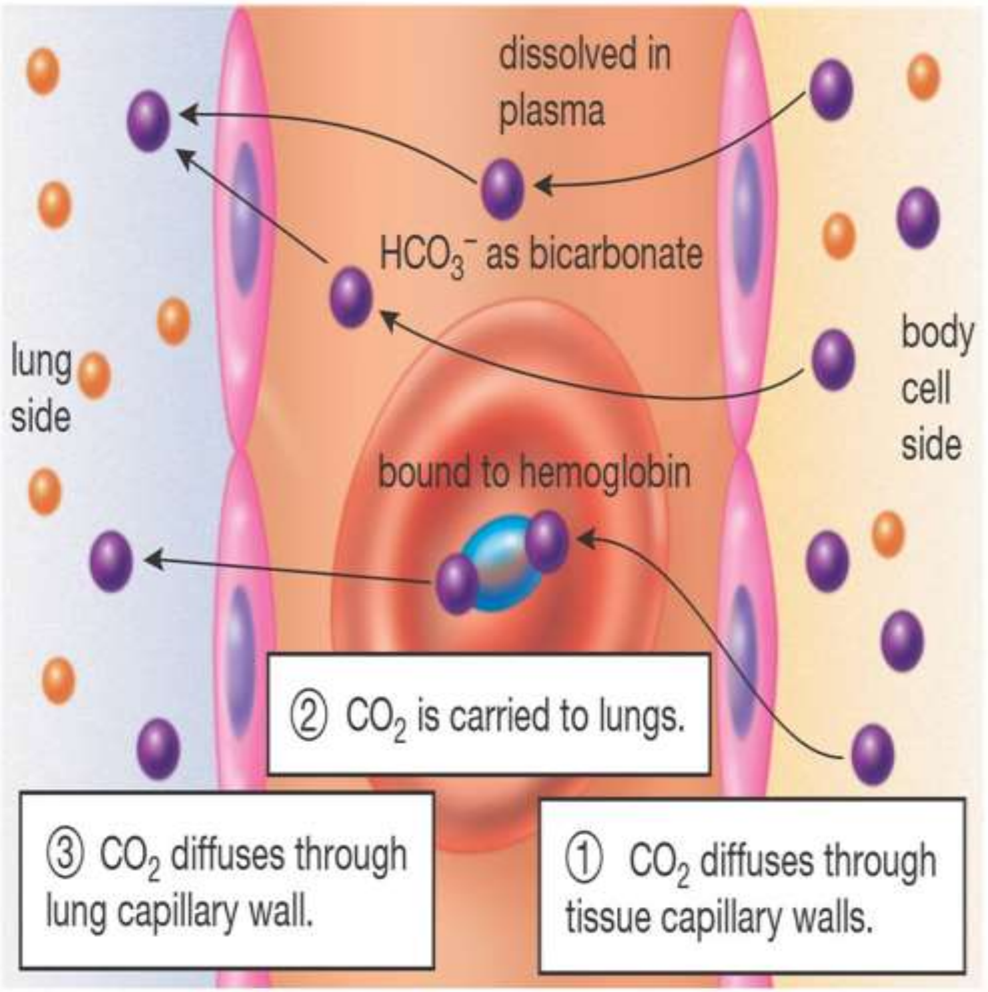
- Hemoglobin binds to oxygen that diffuses into the blood stream.
- What are some advantages to using hemoglobin to transport oxygen?

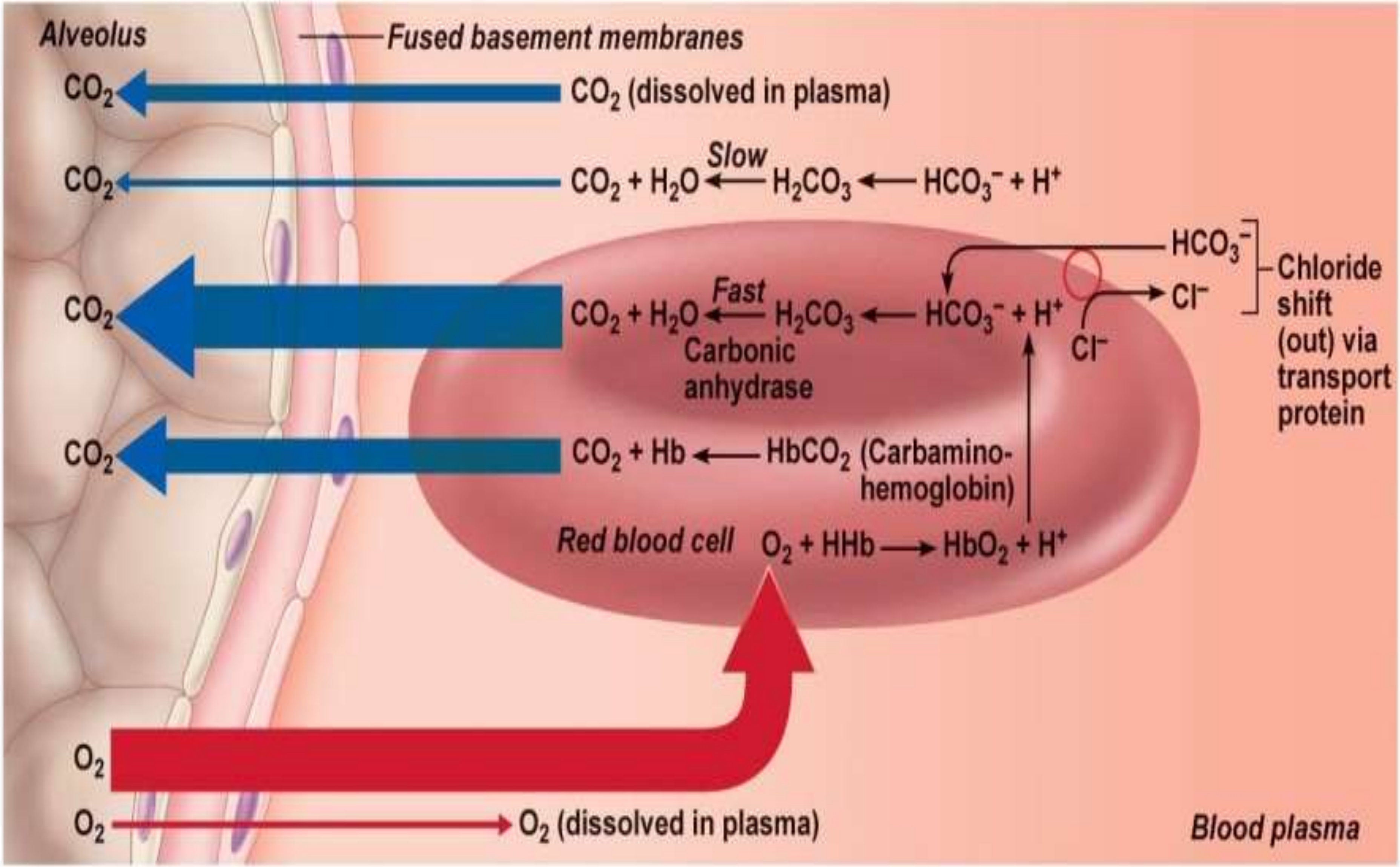


Carbon dioxide transport

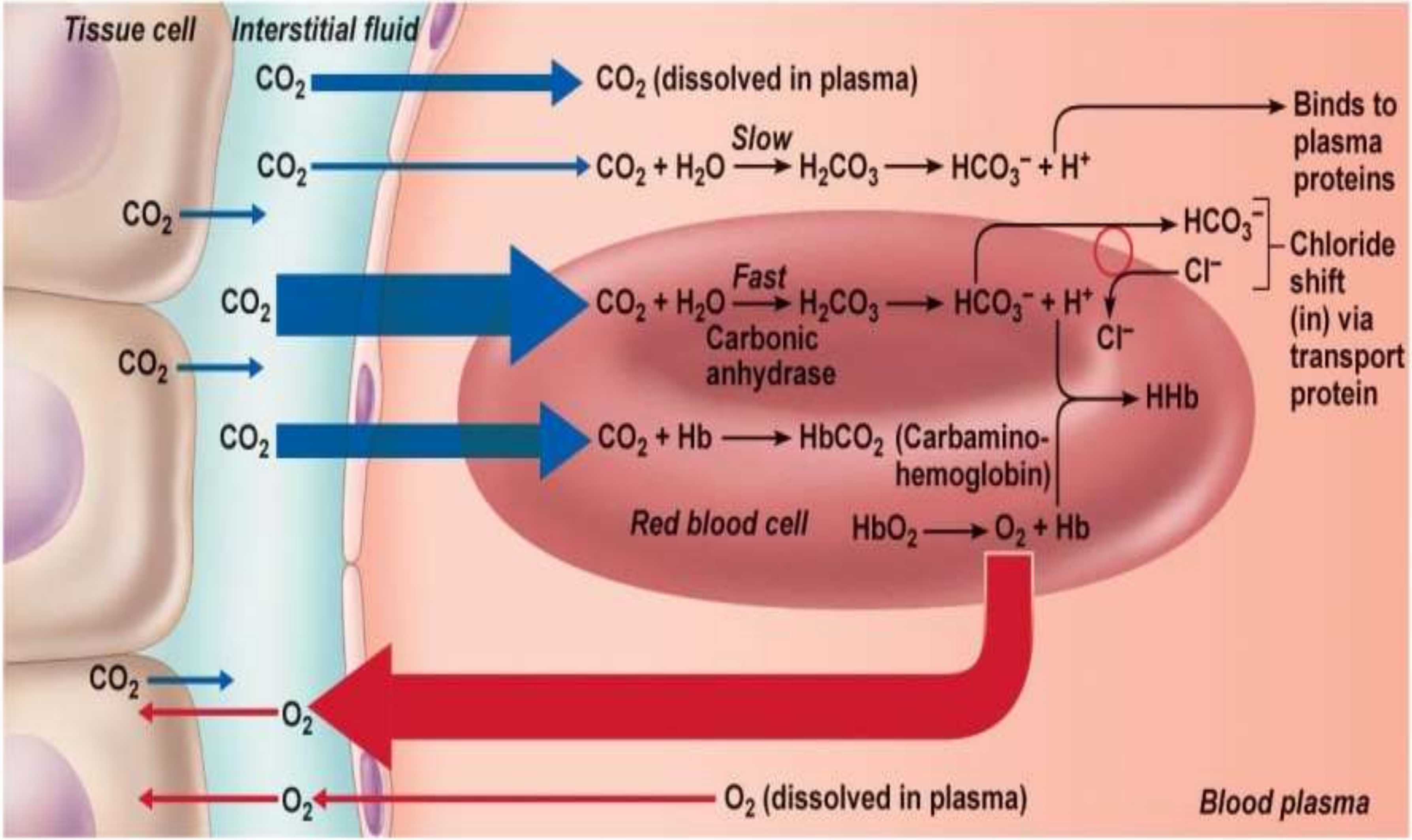
- Carbon dioxide can dissolve in plasma, and about 70% forms bicarbonate ions.
- Some carbon dioxide can bind to hemoglobin for transport.

(b) Transport of carbon dioxide

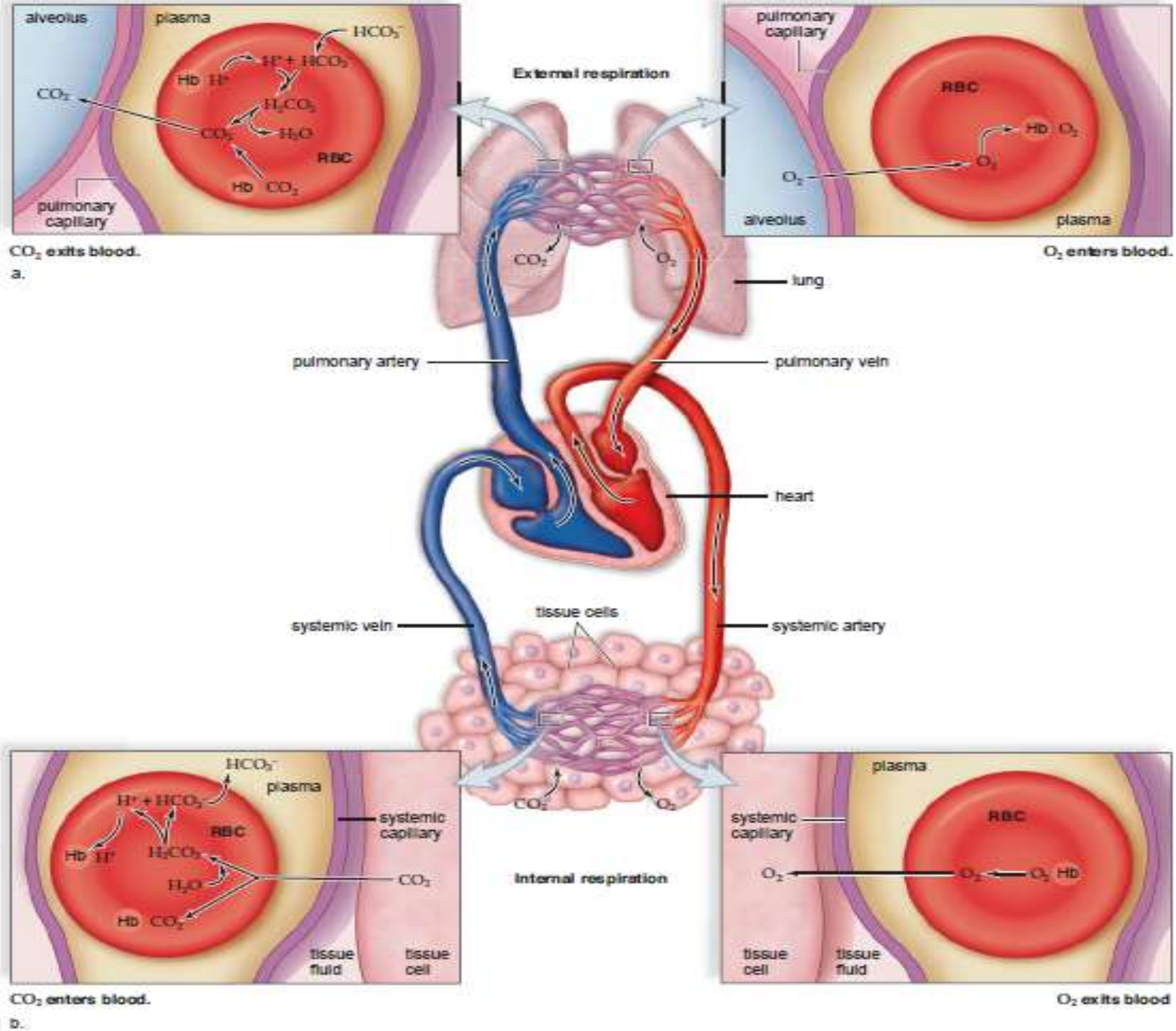


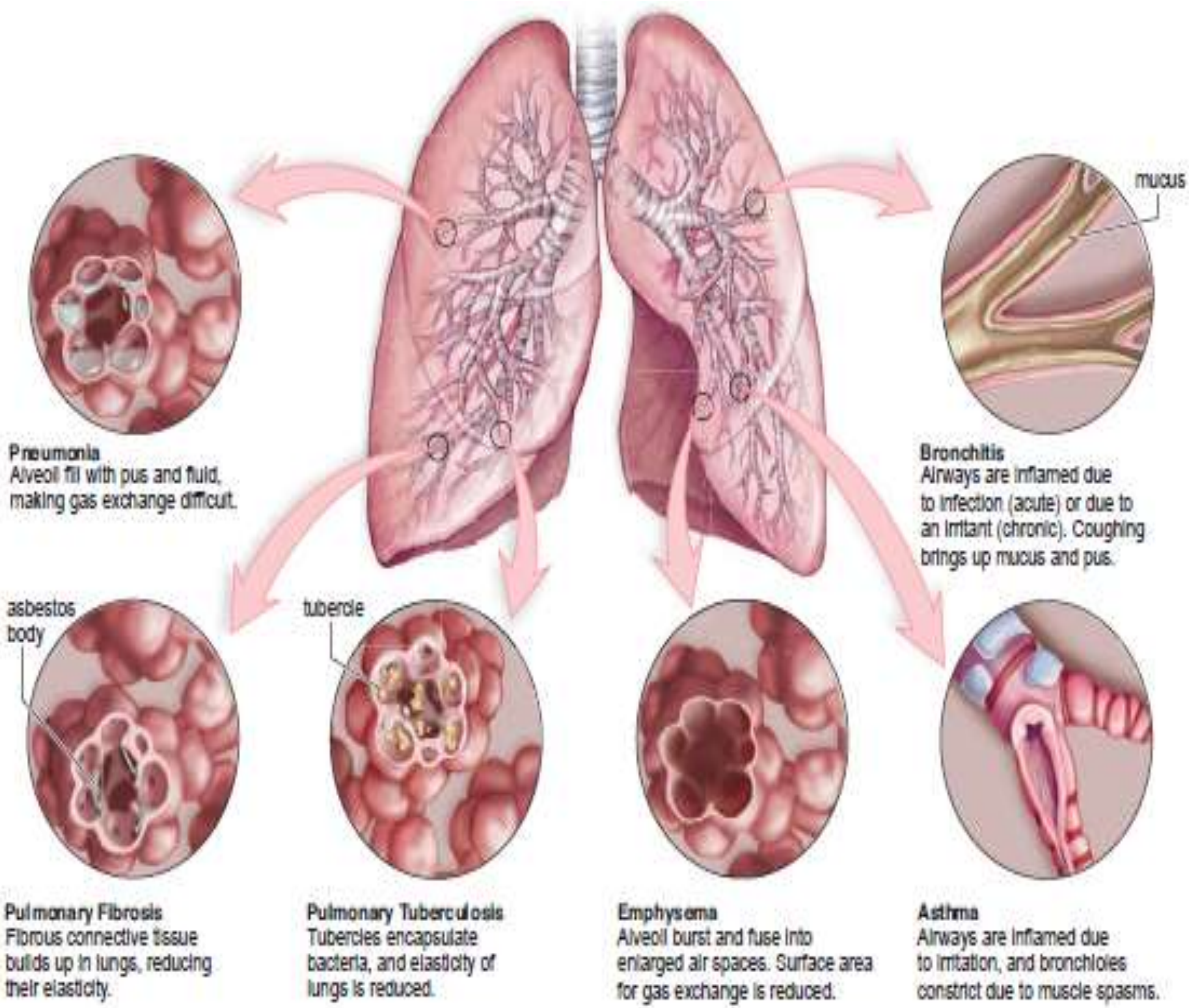


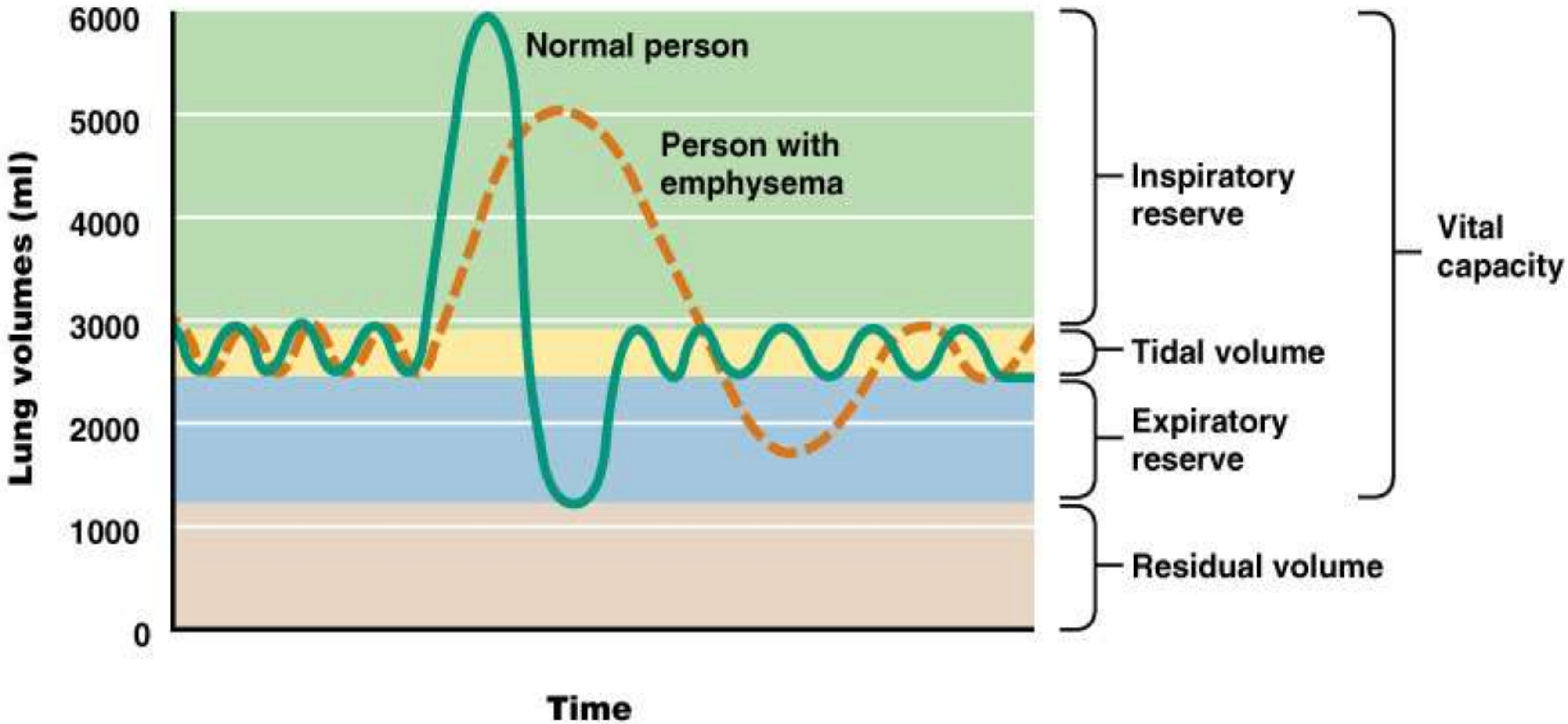
(b) Oxygen pickup and carbon dioxide release in the lungs



(a) Oxygen release and carbon dioxide pickup at the tissues


alveolus
plasma
HCO_3^-
$H^+ + HCO_3^-$
Hb H^+
CO_2
H_2CO_3
CO_2
H_2O
RBC
Hb CO_2
pulmonary capillary
CO_2 exits blood.
a.
External respiration
pulmonary capillary
RBC
Hb O_2
O_2
O_2
alveolus
plasma
O_2 enters blood.
CO_2
O_2
lung
pulmonary artery
pulmonary vein
heart
tissue cells
systemic vein
systemic artery
CO_2
O_2
HCO_3^-
plasma
$H^+ + HCO_3^-$
RBC
systemic capillary
Hb H^+
H_2CO_3
H_2O
CO_2
Hb CO_2
tissue fluid
tissue cell
CO_2 enters blood.
b.
Internal respiration
plasma
RBC
systemic capillary
O_2
O_2
O_2 Hb
tissue cell
tissue fluid
O_2 exits blood


mucus
Pneumonia
Alveoli fill with pus and fluid, making gas exchange difficult.
Bronchitis
Airways are inflamed due to infection (acute) or due to an irritant (chronic). Coughing brings up mucus and pus.
asbestos body
tubercle
Pulmonary Fibrosis
Fibrous connective tissue builds up in lungs, reducing their elasticity.
Pulmonary Tuberculosis
Tubercles encapsulate bacteria, and elasticity of lungs is reduced.
Emphysema
Alveoli burst and fuse into enlarged air spaces. Surface area for gas exchange is reduced.
Asthma
Airways are inflamed due to irritation, and bronchioles constrict due to muscle spasms.


6000
5000
4000
3000
2000
1000
0
Lung volumes (ml)
Normal person
Person with emphysema
Inspiratory reserve
Tidal volume
Expiratory reserve
Residual volume
Vital capacity
Time

(a)

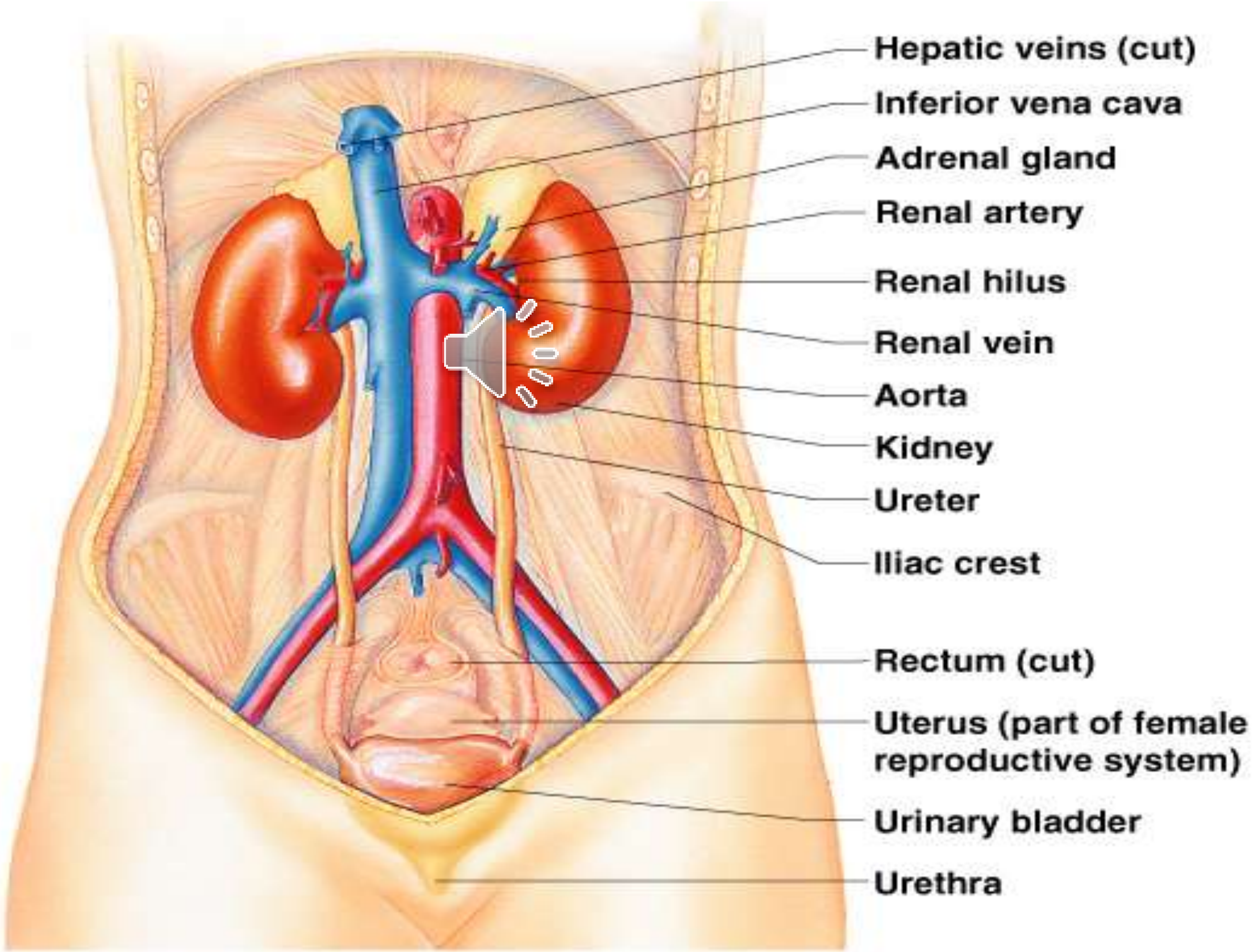
Renal system

Essam mohammed AL-Fahadawy

The urinary system is the organ system of the body that plays a major role in maintaining the salt, water, and pH homeostasis of the blood. These organs carry out the process of **excretion,** or the removal of metabolic waste from the body. These metabolic waste materials are the by-products of the normal activities of the cells and tissues.

Organs of the Urinary System

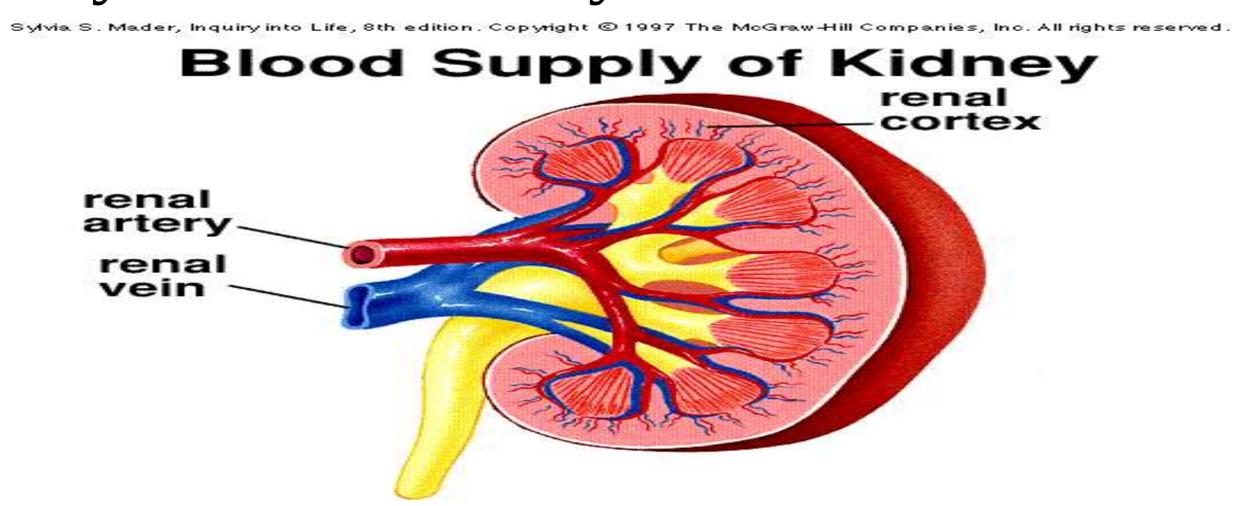
The urinary system consists of the kidneys, ureters, urinary bladder, and urethra.



(a)

Kidneys

The **kidneys** are paired organs located near the small of the back on either side of the vertebral column. The kidneys are bean shaped and reddish-brown in color. The organs are covered by a tough capsule of fibrous connective tissue, called a renal capsule.. The concave side of a kidney has a depression where a **renal artery** enters and a **renal vein** and a ureter exit the kidney. The renal artery transports blood to be filtered to the kidneys, and the renal vein carries filtered blood away from the kidneys.



Ureters

The **ureters** conduct urine from the kidneys to the bladder.

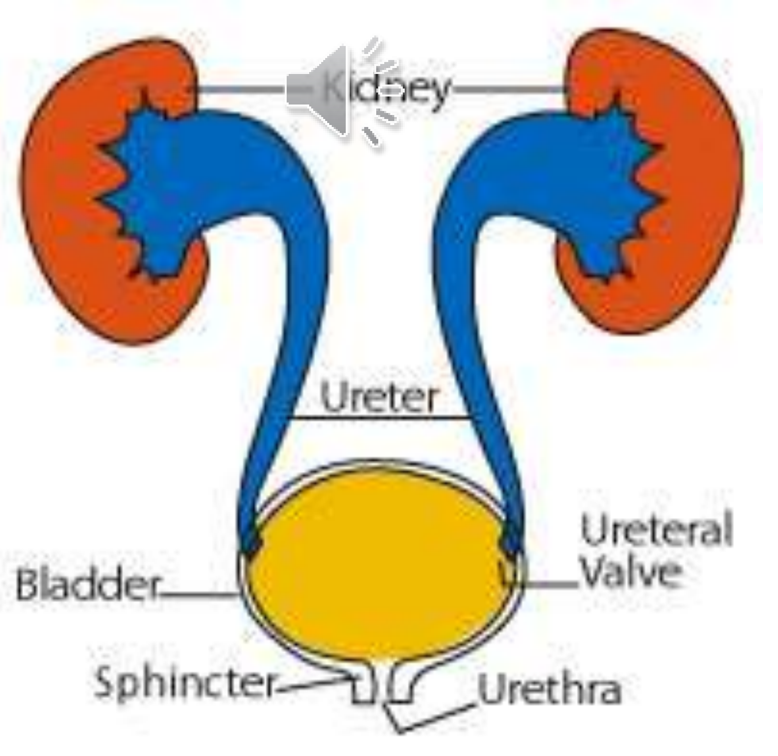
They are small, muscular tubes about 25 cm long and 5 mm in diameter. The wall of a ureter has three layers: an inner mucosa (mucous membrane), a smooth muscle layer, and an outer fibrous coat of connective tissue. Peristaltic contractions cause urine to enter the bladder even if a person is lying down.

Urinary Bladder

The **urinary bladder** stores urine until it is expelled from the body. The bladder has three openings: two for the ureters and one for the urethra, which drains the bladder. The bladder wall is expandable because it contains a middle layer of circular fibers of smooth muscle and two layers of longitudinal smooth muscle. The epithelium of the mucosa becomes thinner, and folds in the mucosa called rugae disappear as the bladder enlarges. The bladder's rugae are similar to those of the stomach. A layer of transitional epithelium enables the bladder to stretch and contain an increased volume of urine.

Urinary Bladder

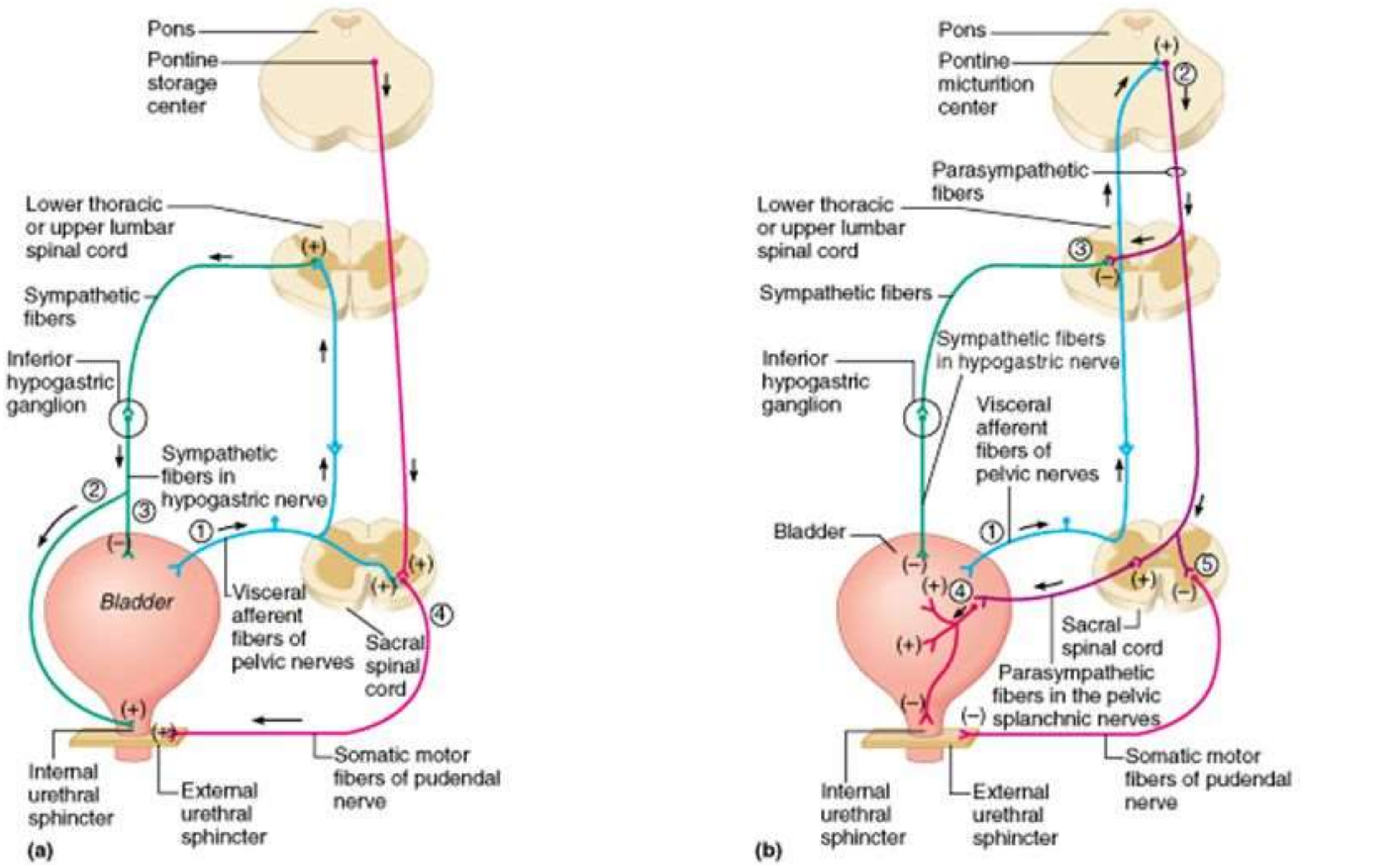
- Smooth muscle bag
- Stores waste solution - urine



After urine enters the bladder from a ureter, small folds of bladder mucosa act like a valve to prevent backward flow. Two sphincters in close proximity are found where the urethra exits the bladder. The internal sphincter occurs around the opening to the urethra. It is composed of smooth muscle and is involuntarily controlled. An external sphincter is composed of skeletal muscle that can be voluntarily controlled.

When the urinary bladder fills to about 250 mL with urine, stretch receptors are activated by the enlargement of the bladder. These receptors send sensory nerve signals to the spinal cord. Subsequently, motor nerve impulses from the spinal cord cause the urinary bladder to contract and the sphincters to relax so that urination, also called **micturition**

The micturition reflex



Urethra

The **urethra** is a small tube that extends from the urinary bladder to an external opening. Therefore, its function is to remove urine from the body. The urethra has a different length in females than in males. As the urethra leaves the male urinary bladder, it is encircled by the prostate gland. The prostate sometimes enlarges, restricting the flow of urine in the urethra.

In females, the reproductive and urinary systems are not connected. However, in males, the urethra carries urine during urination and sperm during ejaculation.

Functions of the Urinary System

As the kidneys produce urine, they carry out the following functions that contribute to homeostasis.

Excretion of Metabolic Wastes

The kidneys excrete metabolic wastes, notably nitrogenous wastes. Urea is the primary nitrogenous end product of metabolism in human beings, but humans also excrete some ammonium, creatinine, and uric acid.

Urea is a by-product of amino acid metabolism. The breakdown of amino acids in the liver releases ammonia, a compound that is very toxic to cells. The liver rapidly combines the ammonia with carbon dioxide to produce urea, which is much less harmful.

Creatine phosphate is a high-energy phosphate reserve molecule in muscles. The metabolic breakdown of creatine phosphate results in **creatinine.**

The breakdown of nucleotides, such as those containing adenine and thymine, produces **uric acid.** Uric acid is present in blood, crystals form and precipitate out. Crystals of uric acid sometimes collect in the joints, producing a painful ailment called **gout.**

Maintenance of Water–Salt Balance

A principal function of the kidneys is to maintain the appropriate water–salt balance of the blood. Blood volume is intimately associated with the salt balance of the body. NaCl, have the ability to cause osmosis—the diffusion of water, in this case, into the blood. The more salts there are in the blood, the greater the blood volume and the greater the blood pressure. In this way, the kidneys are involved in regulating blood pressure.

The kidneys also maintain the appropriate level of other ions, such as potassium ions (K^+), bicarbonate ions (HCO_3^-), and calcium ions (Ca^{2+}), in the blood .

Maintenance of Acid–Base Balance

The kidneys regulate the acid–base balance of the blood. For a person to remain healthy, the blood pH should be just about 7.4. The kidneys monitor and help control blood pH, mainly by excreting hydrogen ions (H^+) and reabsorbing the bicarbonate ions (HCO_3^-) as needed to keep blood pH at 7.4. Urine usually has a pH of 6 or lower because our diet often contains acidic foods.

Secretion of Hormones

The kidneys assist the endocrine system in hormone secretion. The kidneys release **renin,** an enzyme that leads to aldosterone secretion. Aldosterone is a hormone produced by the adrenal glands, which lie atop the kidneys. An aldosterone is involved in regulating the water–salt balance of the blood.

Erythropoietin (**EPO**) is a hormone secreted by the kidneys. When blood oxygen decreases, EPO increases red blood cell synthesis by stem cells in the bone marrow. When the concentration of red blood cells increases, blood oxygen increases also. Failing kidneys produce less EPO, resulting in fewer red blood cells and symptoms of fatigue. Supplemental EPO will increase red blood cell synthesis and energy levels.

The three regions of a kidney.

(1) The **renal cortex** is an outer, granulated layer that dips down in between a radially striated inner layer called the renal medulla.

(2) The **renal medulla** consists of cone-shaped tissue masses called renal pyramids.

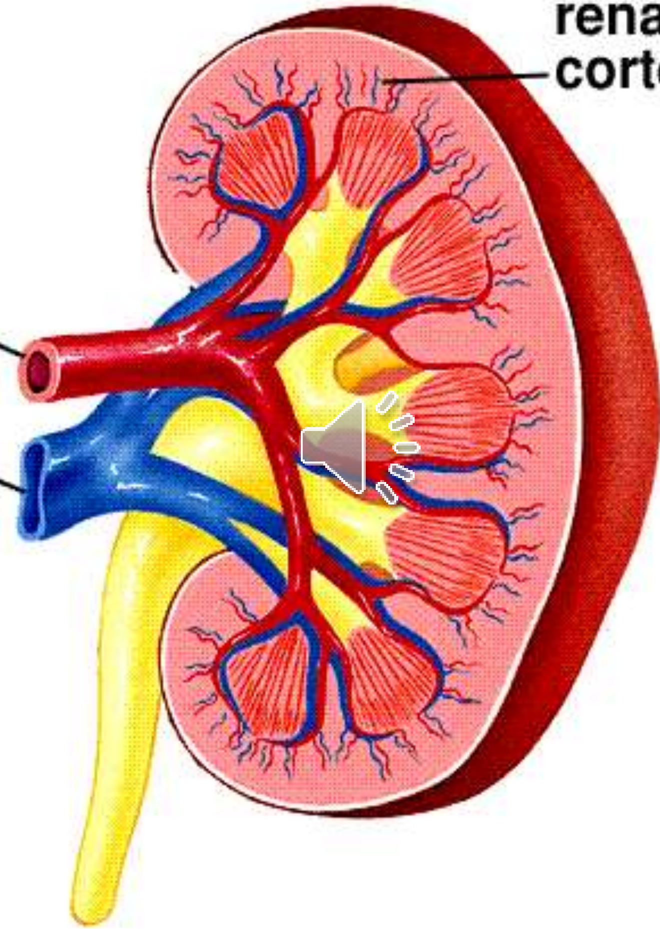
(3) The **renal pelvis** is a central space, or cavity, continuous with the ureter .

Microscopically, the kidney is composed of over 1 million **nephrons,** sometimes called renal, or kidney, tubules.

The nephrons filter the blood and produce urine.

Each nephron is positioned so that the urine flows into a collecting duct. Several nephrons enter the same collecting duct. The collecting ducts eventually enter the renal pelvis.

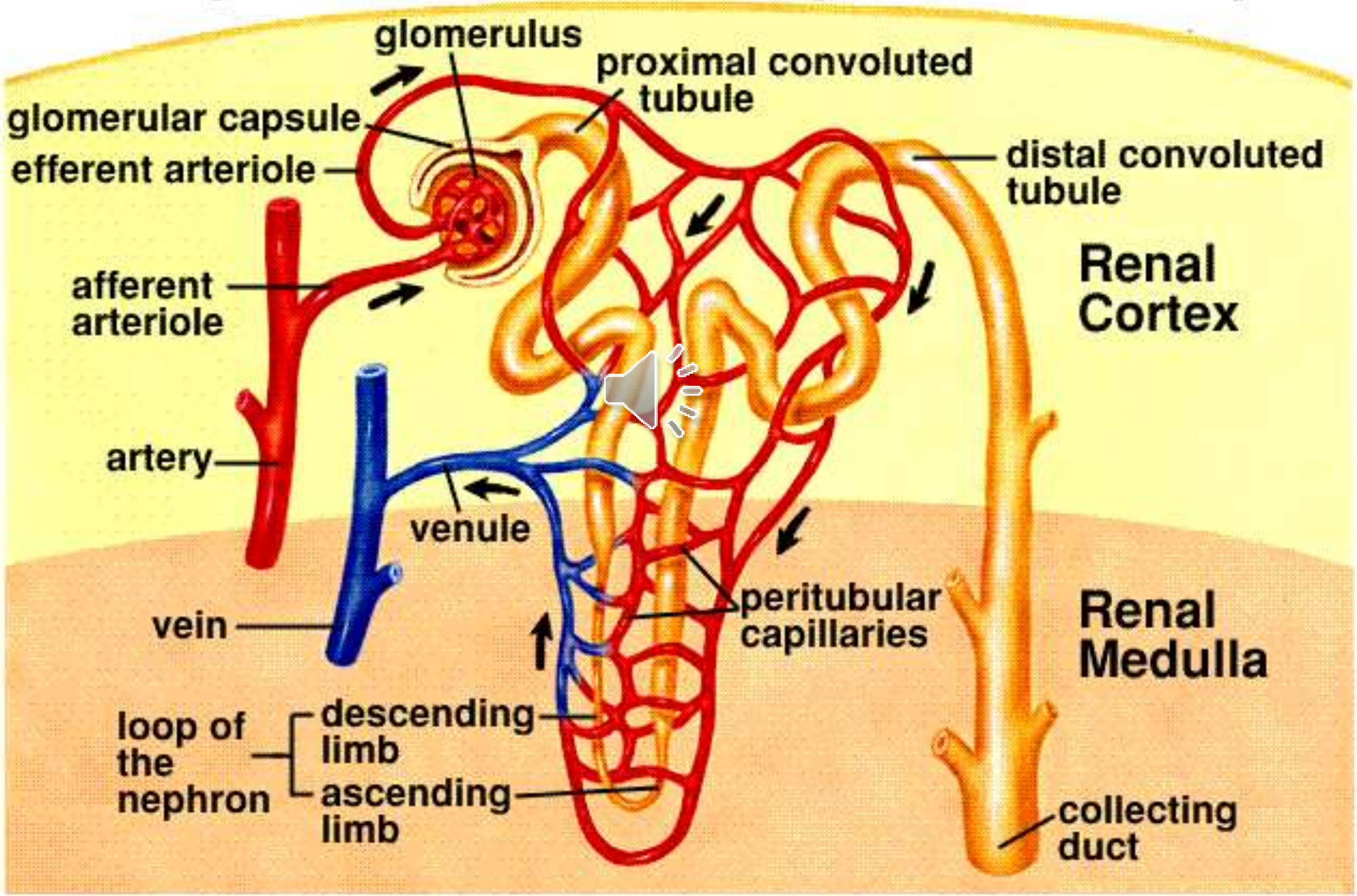
Blood Supply of Kidney



Anatomy of a Nephron

Each nephron has its own blood supply including two capillary regions . From the renal artery, an afferent arteriole transports blood to the **glomerulus,** a knot of capillaries inside the glomerular capsule. Blood leaving the glomerulus is carried away by the efferent arteriole. Blood pressure is higher in the glomerulus because the efferent arteriole is narrower than the afferent arteriole. The efferent arteriole divides and forms the **peritubular capillary network,** which surrounds the rest of the nephron. Blood from the efferent arteriole travels through the peritubular capillary network. Then the blood goes into a venule that carries blood into the renal vein

Nephron Macroscopic Anatomy



Parts of a Nephron

Each nephron is made up of several parts . Some functions are shared by all parts of the nephron. However, the specific structure of each part is especially suited to a particular function.

First, the closed end of the nephron is pushed in on itself to form a cuplike structure called the **glomerular capsule** (Bowman's capsule). The outer layer of the glomerular capsule is composed of squamous epithelial cells. The inner layer is made up of podocytes that have long cytoplasmic extensions. The podocytes cling to the capillary walls of the glomerulus and leave pores that allow easy passage of small molecules from the glomerulus to the inside of the glomerular capsule. This process, called glomerular filtration, produces a filtrate of the blood.

Next, there is a **proximal convoluted tubule.** The cuboidal epithelial cells lining this part of the nephron have numerous microvilli, about 1 μm in length, that are tightly packed and form a brush border . A brush border greatly increases the surface area for the tubular reabsorption of filtrate components. Each cell also has many mitochondria, which can supply energy for active transport of molecules from the lumen to the peritubular capillary network.

Simple squamous epithelium appears as the tube narrows and makes a U-turn called the **loop of the nephron** (loop of Henle). Each loop consists of a descending limb and an ascending limb. The descending limb of the loop allows water to diffuse into tissue surrounding the nephron. The ascending limb actively transports salt from its lumen to interstitial tissue. As we shall see, this activity facilitates the reabsorption of water by the nephron and collecting duct. The cuboidal epithelial cells of the **distal convoluted tubule** have numerous mitochondria, but they lack microvilli. This means that the distal convoluted tubule is not specialized for reabsorption. Instead, its primary function is ion exchange. During ion exchange, cells reabsorb certain ions returning them to the blood. Other ions are secreted from the blood into the tubule. The distal convoluted tubules of several nephrons enter one collecting duct. Many **collecting ducts** carry urine to the renal pelvis.

the glomerular capsule and the convoluted tubules always lie within the renal cortex. The loop of the nephron dips down into the renal medulla. A few nephrons have a very long loop of the nephron, which penetrates deep into the renal medulla. Collecting ducts are also located in the renal medulla, and together they give the renal pyramids their appearance.

Glomerular Filtration

Glomerular filtration occurs when whole blood enters the glomerulus by way of the afferent arteriole. Due to glomerular blood pressure, water and small molecules move from the glomerulus to the inside of the glomerular capsule. This is a filtration process because large molecules and formed elements are unable to pass through the capillary wall. In effect, then, blood in the glomerulus has two portions: the filterable components and the nonfilterable components

The nonfilterable components leave the glomerulus by way of the efferent arteriole. The **glomerular filtrate** inside the glomerular capsule now contains the filterable blood components in approximately the same concentration as plasma.

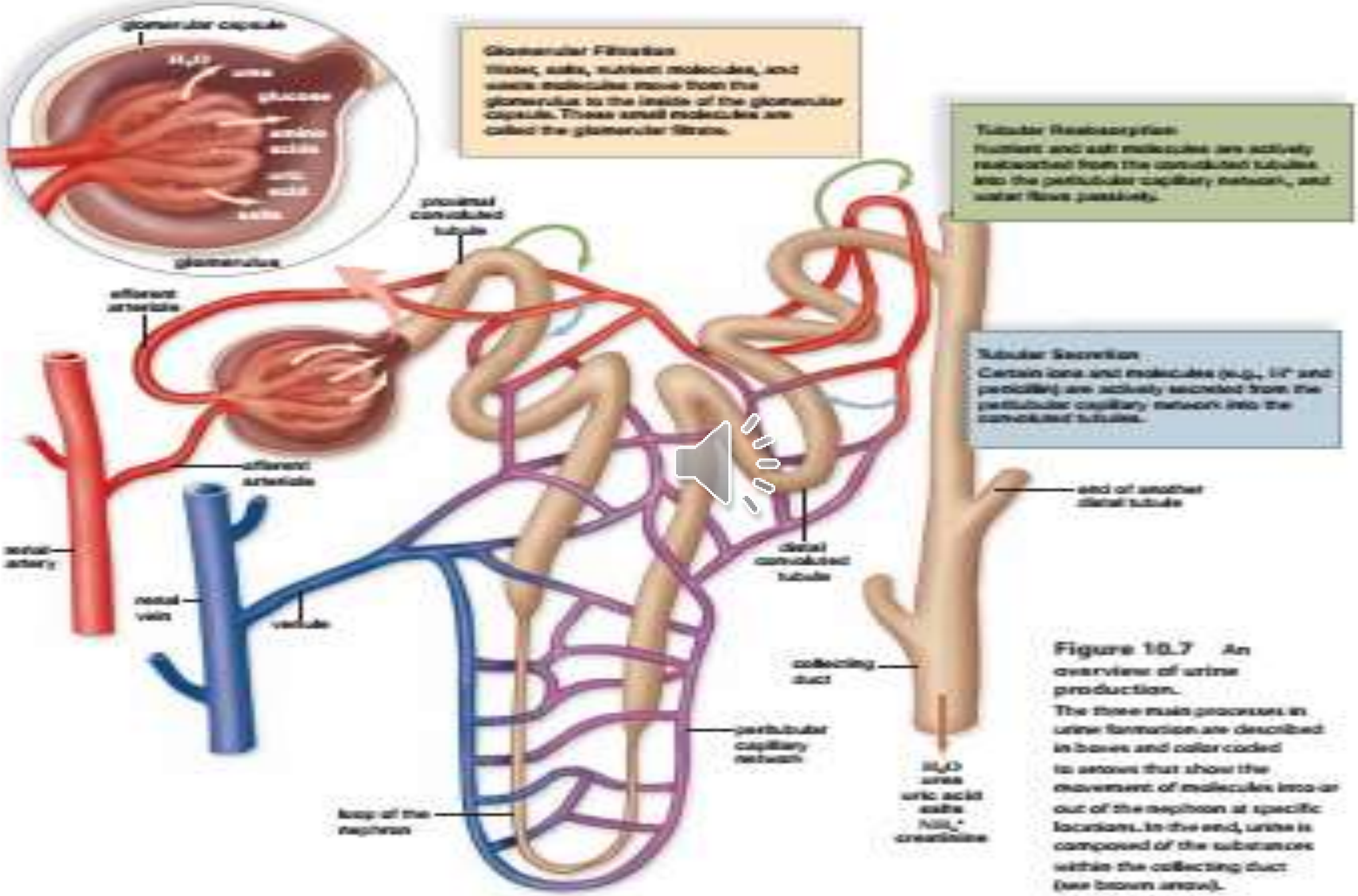
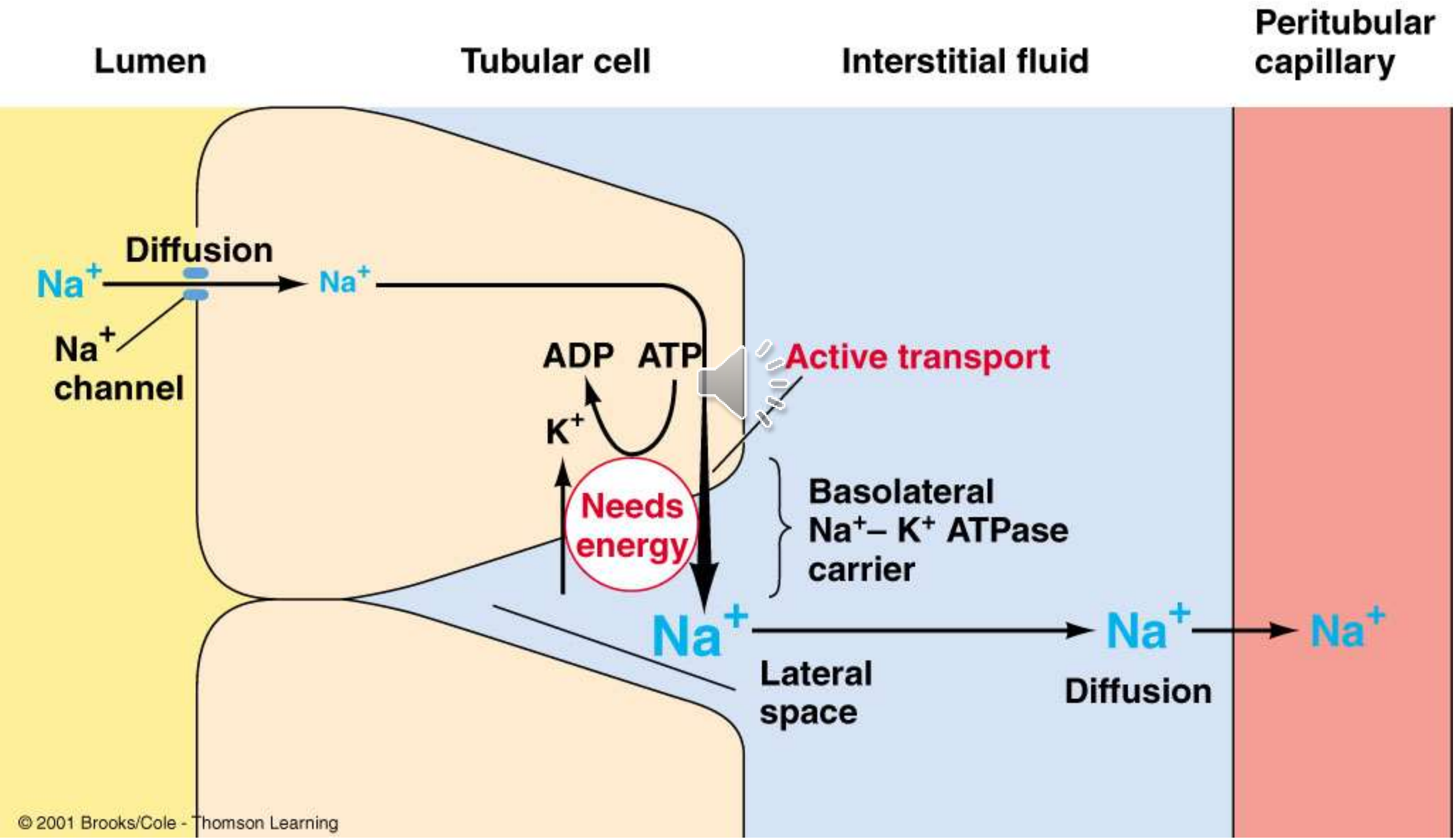


Figure 10.7 An overview of urine production.
The three main processes in urine formation are described in boxes and color coded to arrows that show the movement of molecules into or out of the nephron at specific locations. In the end, urine is composed of the substances within the collecting duct (see brown arrow).

Tubular reabsorption occurs as molecules and ions are passively and actively reabsorbed from the nephron into the blood of the peritubular capillary network. The osmolarity of the blood is maintained by the presence of plasma proteins and salt. When sodium ions (Na+) are actively reabsorbed, chloride ions (Cl–) follow passively. The reabsorption of salt (NaCl) increases the osmolarity of the blood compared with the filtrate. Therefore, water moves passively from the tubule into the blood. About 65% of Na+ is reabsorbed at the proximal convoluted tubule.

Nutrients such as glucose and amino acids return to the peritubular capillaries almost exclusively at the proximal convoluted tubule. This is a selective process because only molecules recognized by carrier proteins are actively reabsorbed. Glucose is an example of a molecule that ordinarily is completely reabsorbed because there is a plentiful supply of carrier proteins for it.

Saving Sodium



Tubular Secretion

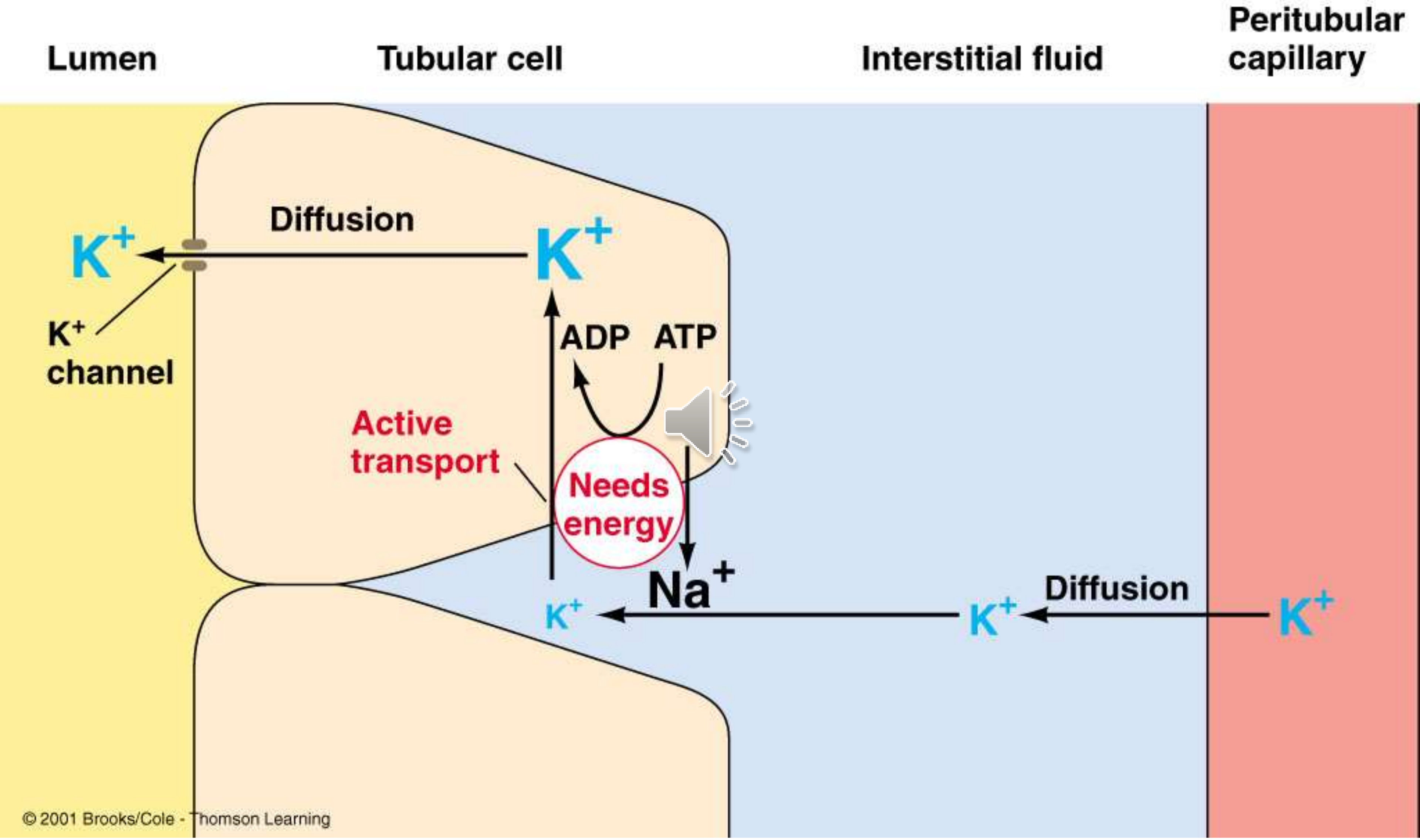
Tubular secretion is a second way by which substances are removed from blood and added to the tubular fluid.

Hydrogen ions (H+), creatinine, and drugs such as penicillin are some of the substances moved by active transport from blood into the kidney tubule. In the end, urine contains substances that have undergone glomerular filtration but have not been reabsorbed and substances that have undergone tubular secretion.

Tubular secretion is now known to occur along the length of the kidney tubule.

Water–Salt Balance

Most of the water found in the filtrate is reabsorbed into the blood before urine leaves the body. All parts of a nephron and the collecting duct participate in the reabsorption of water. The reabsorption of salt always precedes the reabsorption of water. In other words, water is returned to the blood by the process of osmosis. During the process of reabsorption, water passes through water channels, called **aquaporins**, within a plasma membrane protein. Sodium ions (Na^+) are important in plasma. Usually more than 99% of the Na^+ filtered at the glomerulus is returned to the blood. The kidneys also excrete or reabsorb other ions, such as potassium ions (K^+), bicarbonate ions (HCO_3^-), and magnesium ions (Mg^{2+}) as needed.


Lumen
Tubular cell
Interstitial fluid
Peritubular capillary
Diffusion
K+
K+
K+ channel
ADP
ATP
Active transport
Needs energy
Na+
K+
Diffusion
K+
K+
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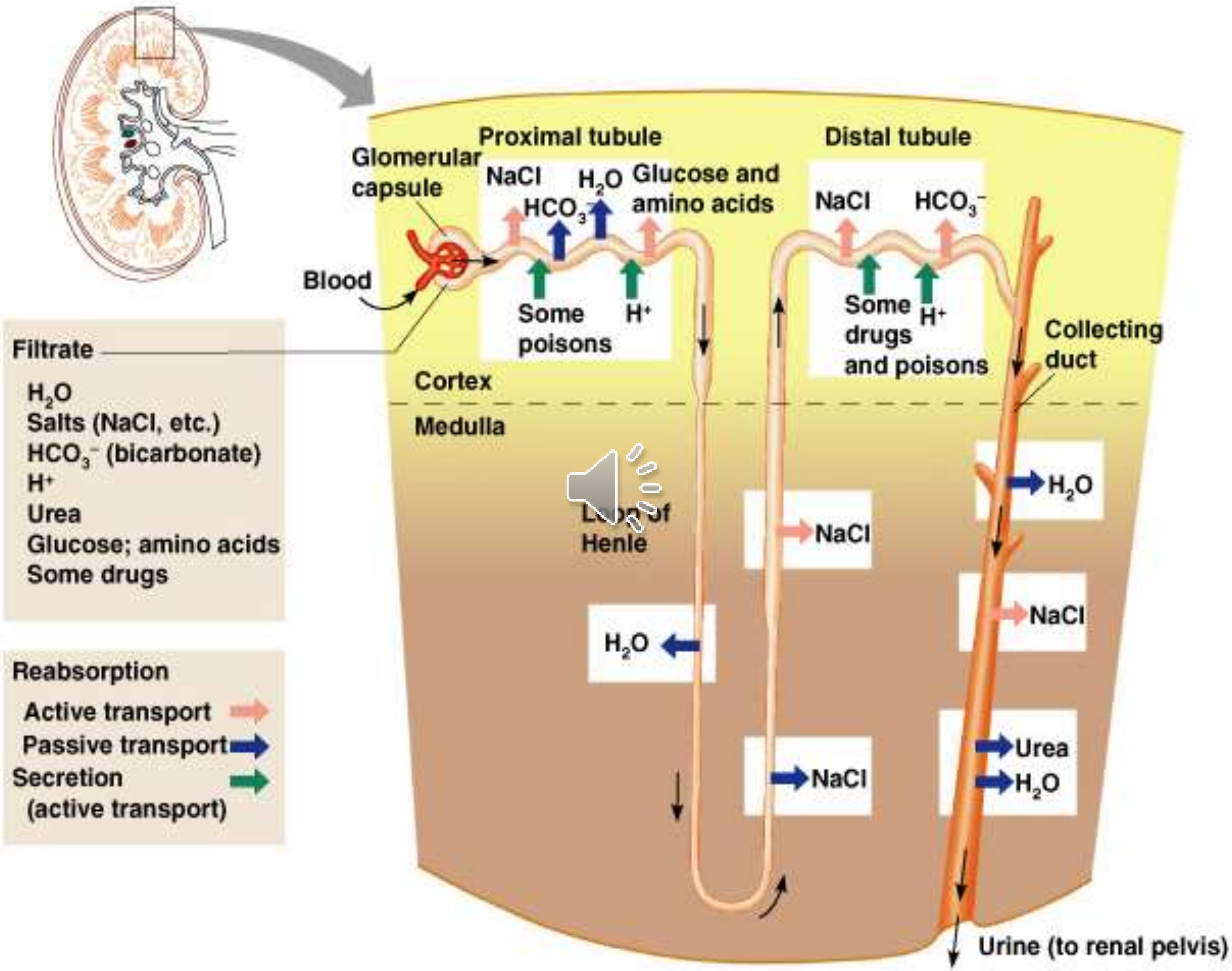
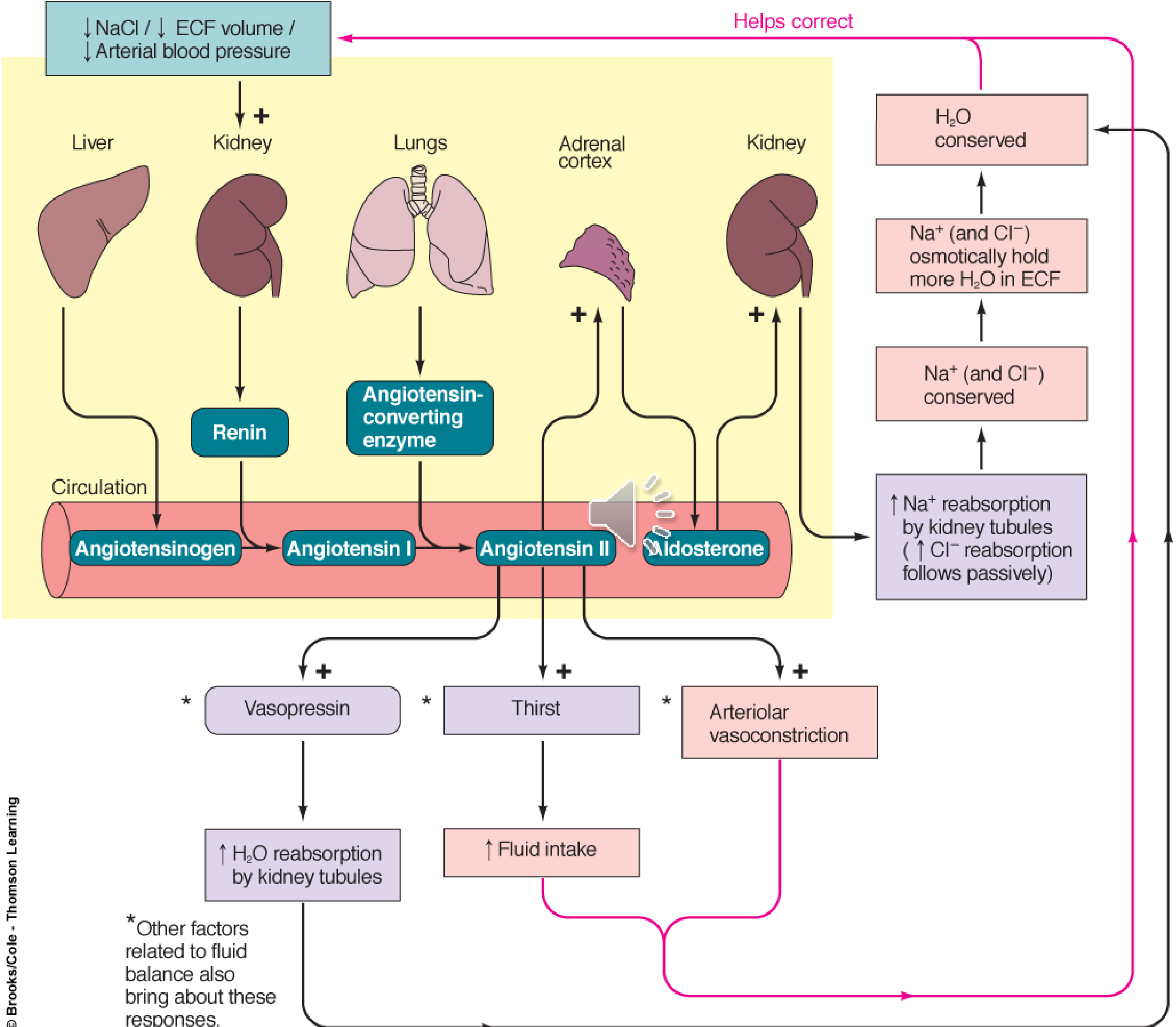


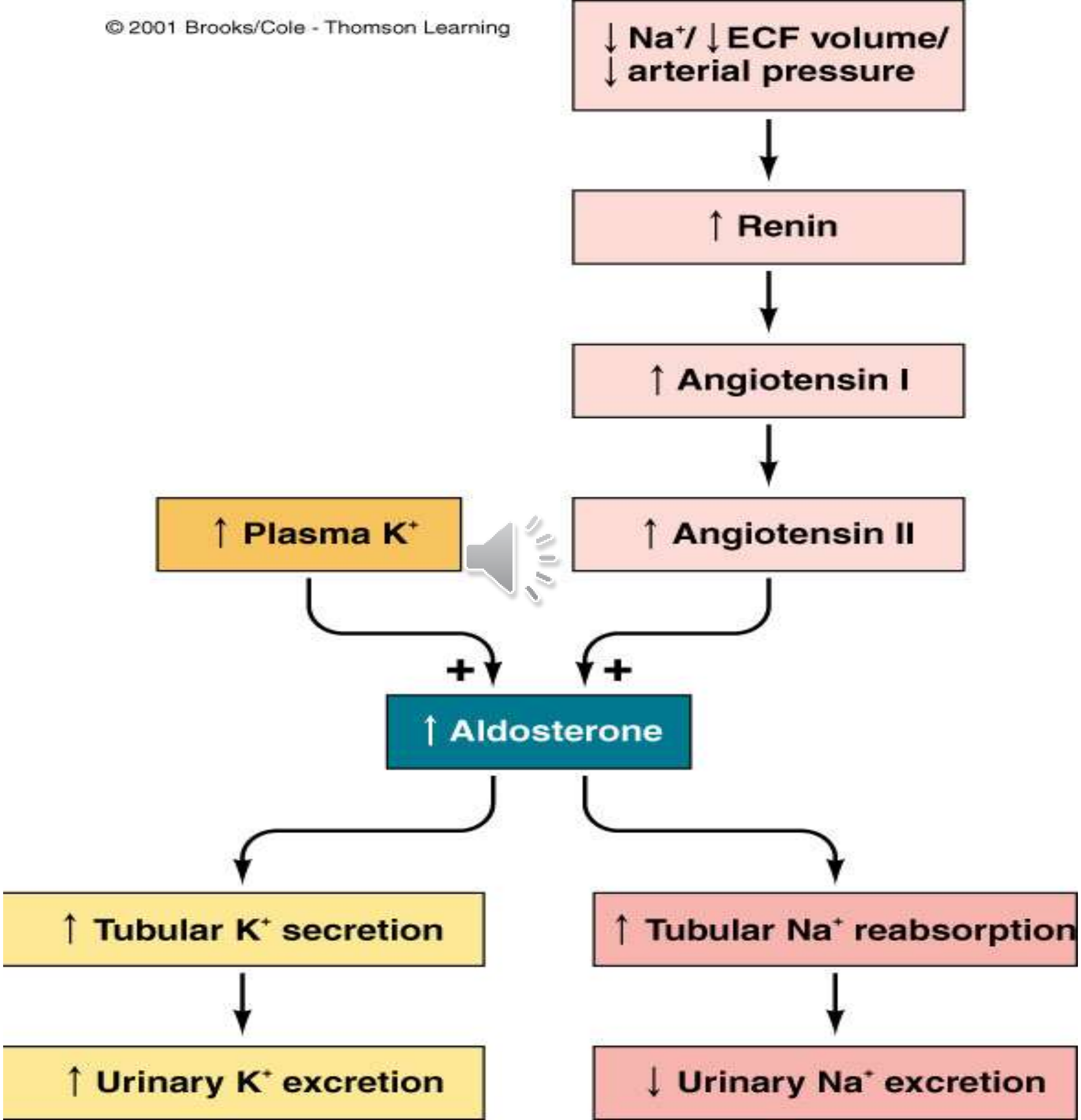
Proximal tubule
Distal tubule
Glomerular capsule
NaCl
H_2O
HCO_3^-
Glucose and amino acids
NaCl
HCO_3^-
Blood
Some poisons
H^+
Some drugs and poisons
H^+
Collecting duct
Filtrate
H_2O
Salts (NaCl, etc.)
HCO_3^- (bicarbonate)
H^+
Urea
Glucose; amino acids
Some drugs
Cortex
Medulla
Henle
NaCl
H_2O
H_2O
NaCl
NaCl
Urea
H_2O
Reabsorption
Active transport
Passive transport
Secretion (active transport)
Urine (to renal pelvis)

Hormones regulate the reabsorption of sodium and water in the distal convoluted tubule.

Aldosterone is a hormone secreted by the adrenal glands, which sit atop the kidneys. This hormone promotes ion exchange at the distal convoluted tubule. Potassium ions (K+) are excreted, and sodium ions (Na+) are reabsorbed into the blood. The release of aldosterone is set into motion by the kidneys.

The **juxtaglomerular apparatus** is a region of contact between the afferent arteriole and the distal convoluted tubule . When blood volume (and,therefore, blood pressure) falls too low for filtration to occur, the juxtaglomerular apparatus can respond to the decrease by secreting **renin.** Renin is an enzyme that ultimately leads to secretion of aldosterone by the adrenal glands. Thus, reabsorption of excess salt and water—might contribute to high blood pressure. Aquaporins are not always open in the distal convoluted tubule.


↓NaCl / ↓ ECF volume /
↓Arterial blood pressure
Helps correct
Liver
Kidney
Lungs
Adrenal cortex
Kidney
H2O conserved
Na+ (and Cl−) osmotically hold more H2O in ECF
Na+ (and Cl−) conserved
Renin
Angiotensin-converting enzyme
Circulation
Angiotensinogen
Angiotensin I
Angiotensin II
Aldosterone
↑Na+ reabsorption by kidney tubules (↑Cl− reabsorption follows passively)
* Vasopressin
* Thirst
* Arteriolar vasoconstriction
↑H2O reabsorption by kidney tubules
↑Fluid intake
*Other factors related to fluid balance also bring about these responses.



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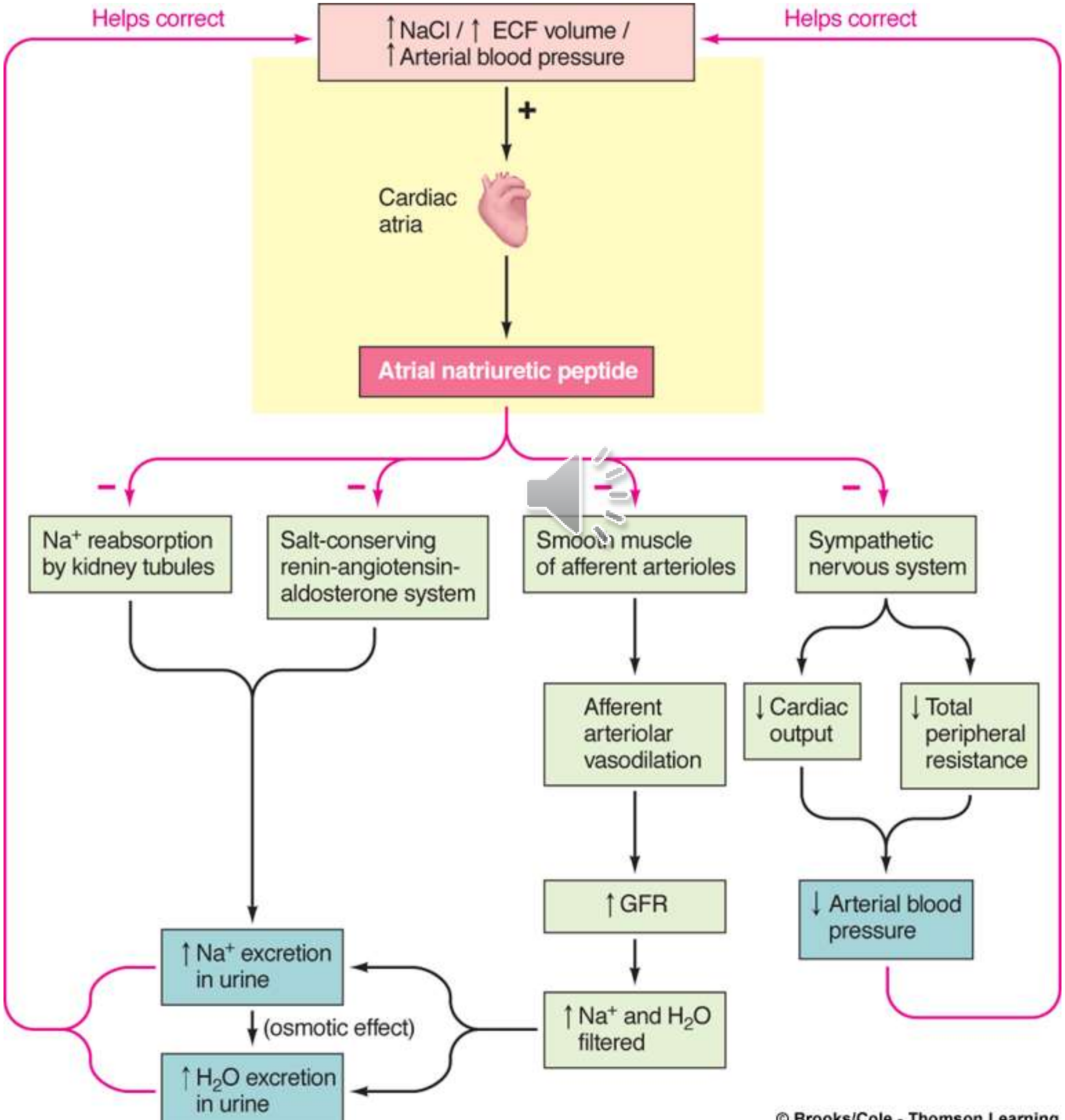
↓ Na+/ ↓ ECF volume/ ↓ arterial pressure
↑ Renin
↑ Angiotensin I
↑ Plasma K+
↑ Angiotensin II
+
+
↑ Aldosterone
↑ Tubular K+ secretion
↑ Tubular Na+ reabsorption
↑ Urinary K+ excretion
↓ Urinary Na+ excretion

antidiuretic hormone (**ADH**). ADH is produced by the hypothalamus and secreted by the posterior pituitary according to the osmolarity of the blood. If our intake of water has been low, ADH is secreted by the posterior pituitary. Water moves from the distal convoluted tubule and the collecting duct into the blood.

Atrial natriuretic hormone (**ANH**) is a hormone secreted by the atria of the heart when cardiac cells are stretched due to increased blood volume. ANH inhibits the secretion of renin by the juxtaglomerular apparatus and the secretion of aldosterone by the adrenal glands. Its effect, therefore, is to promote the excretion of sodium ions (Na+), called natriuresis. Normally, salt reabsorption creates an osmotic gradient that causes water to be reabsorbed. Thus, by causing salt excretion, ANH causes water excretion, too. If ANH is present, less water will be reabsorbed, even if ADH is also present.

Losing Sodium



Thank you