SCIENCE THEATER CARD SET

EXPLORE 1D LESSON 19

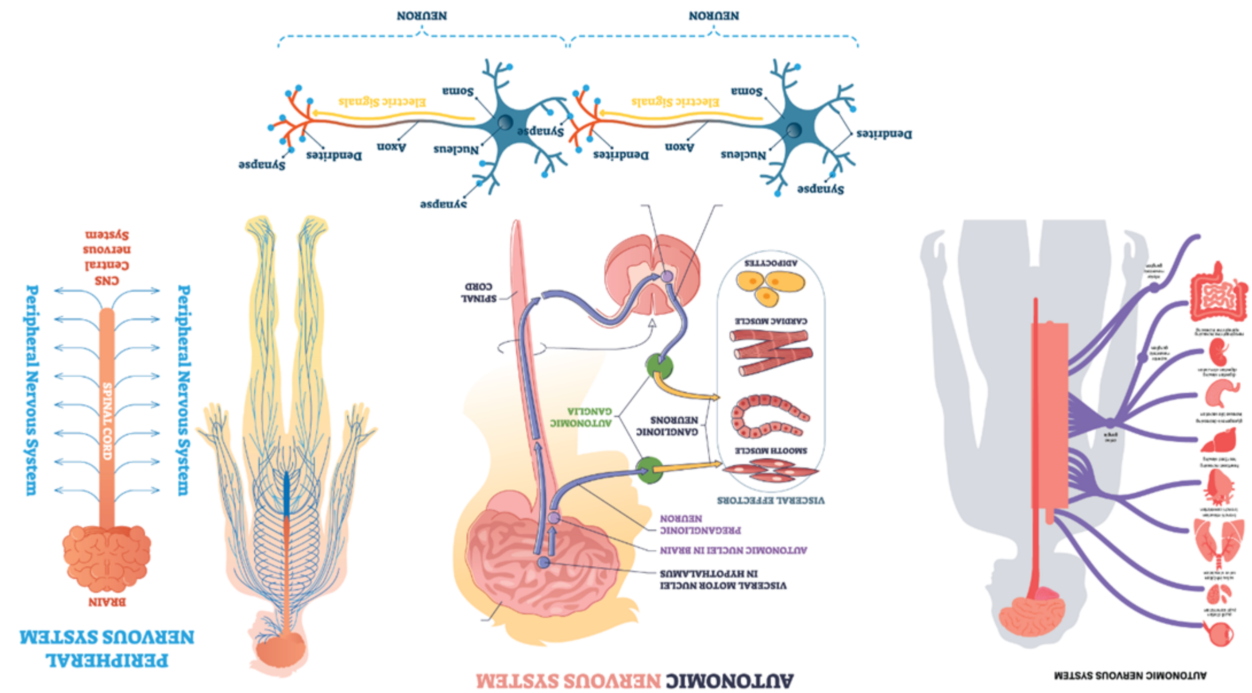
Materials

Materials included on the following pages include:

- **Table Tents** for each organ (or, in some cases, grouping of organs) represented in the model (Pages 2-9)
- **Tokens** for each represent relevant nutrients, stimuli, and responses represented in the model (Pages 10-23)
- **Role Cards** for each organ, including any specialized cells (Pages 24-41)

Instructions for printing and preparing materials:

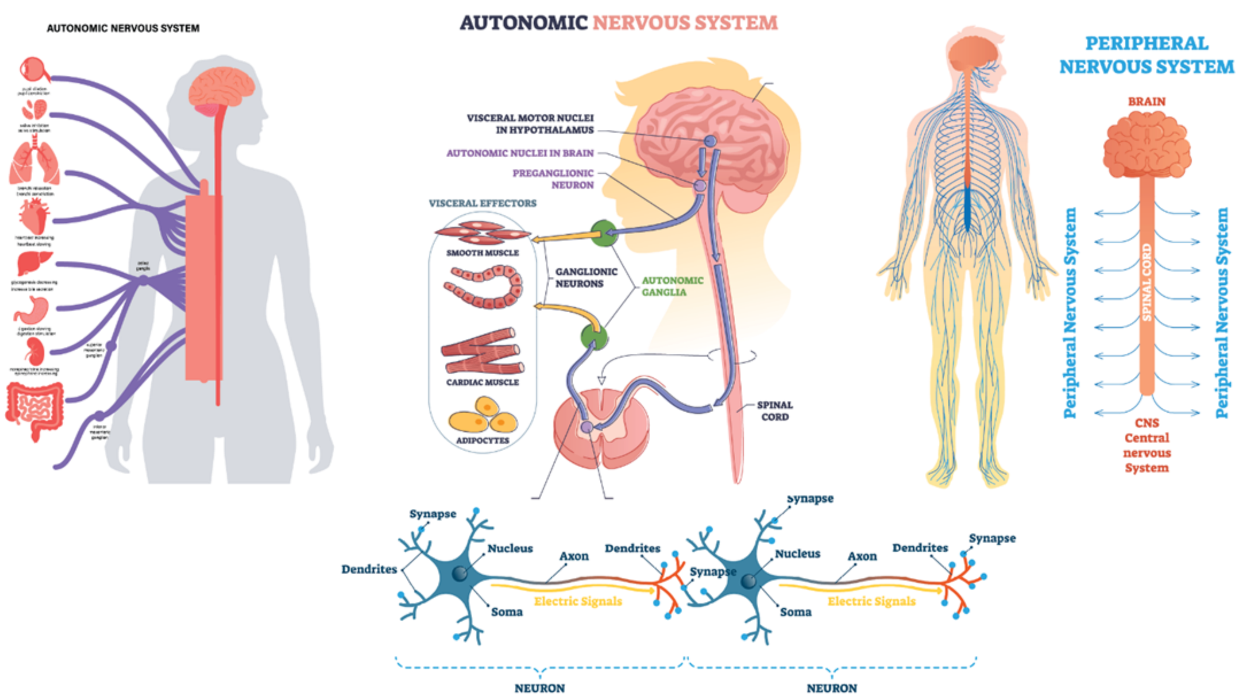
- Print one copy of the materials on the following pages (printing on cardstock weight is suggested)
- Cut along dotted lines
- Fold along solid lines marked "FOLD."

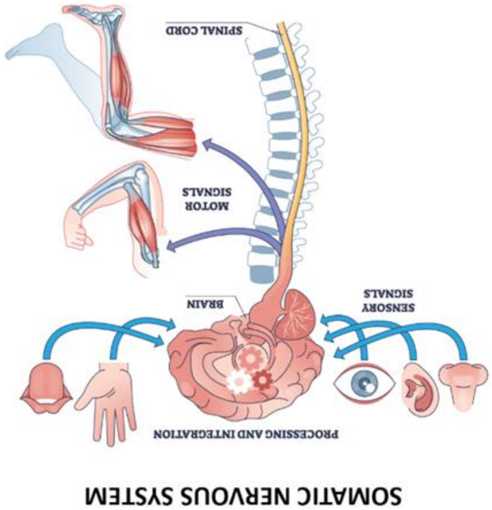


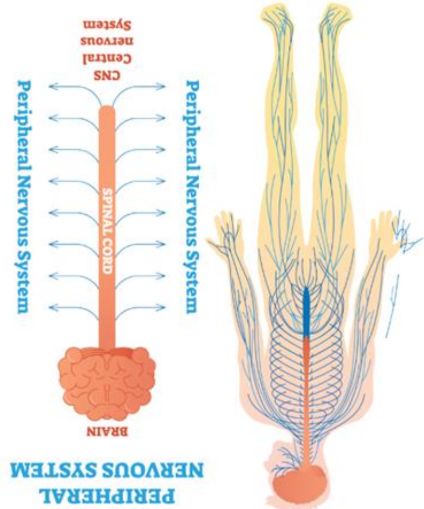
Brain & Autonomic Nerves: Neurons

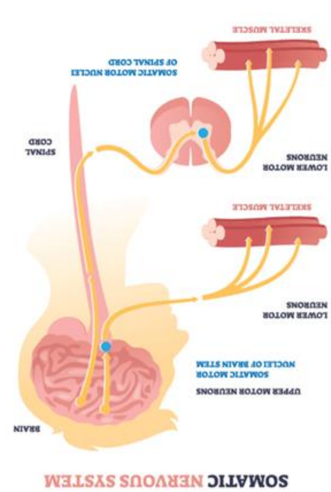
FOLD

Brain & Autonomic Nerves: Neurons





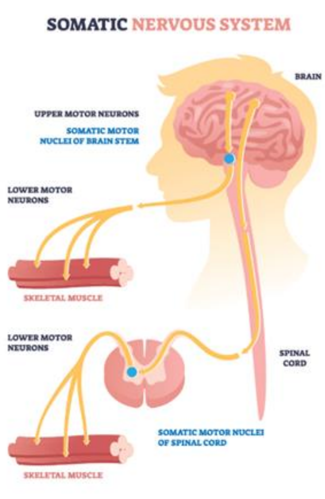


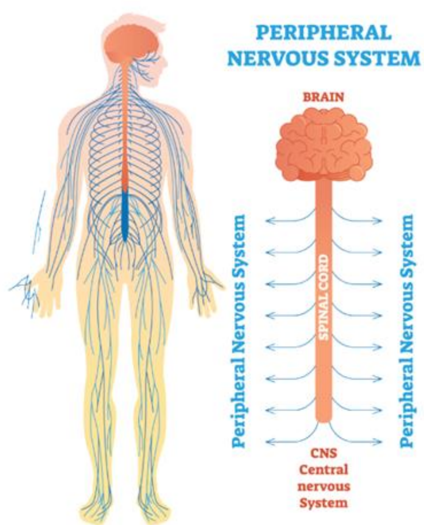


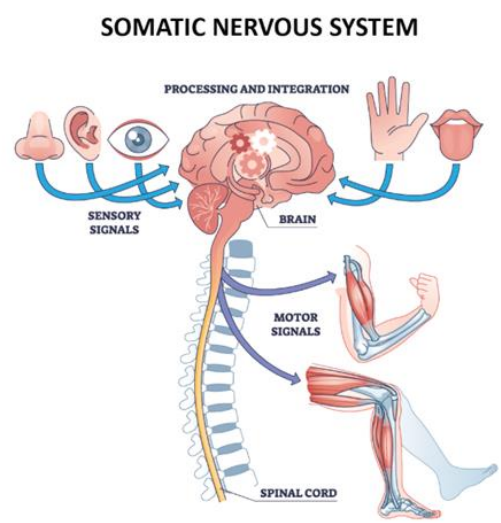
Brain & Somatic Nerves: Motor Neurons

FOLD

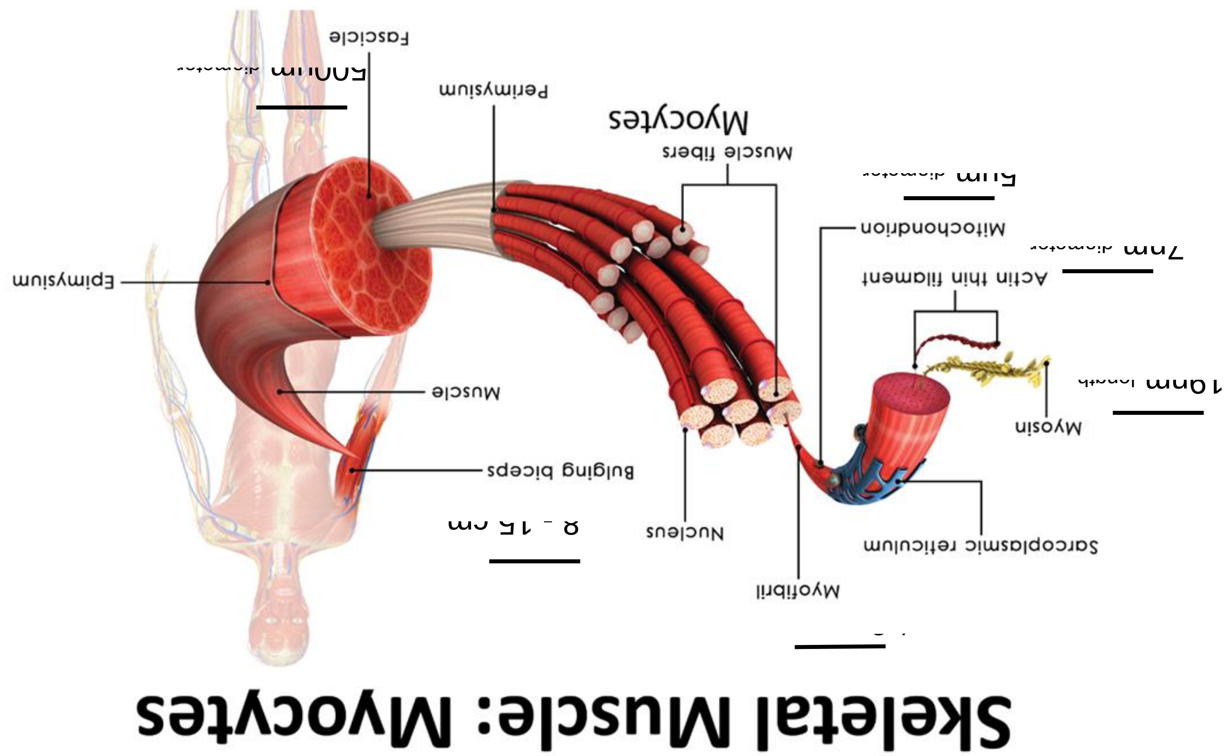
Brain & Somatic Nerves: Motor Neurons



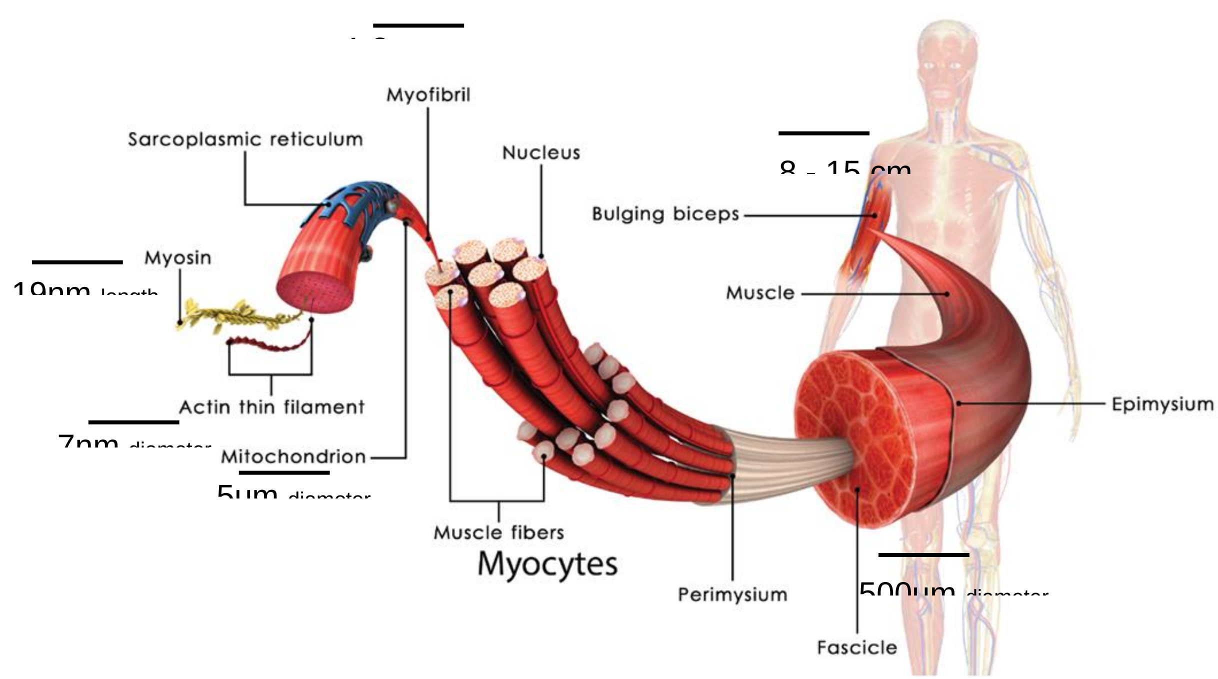




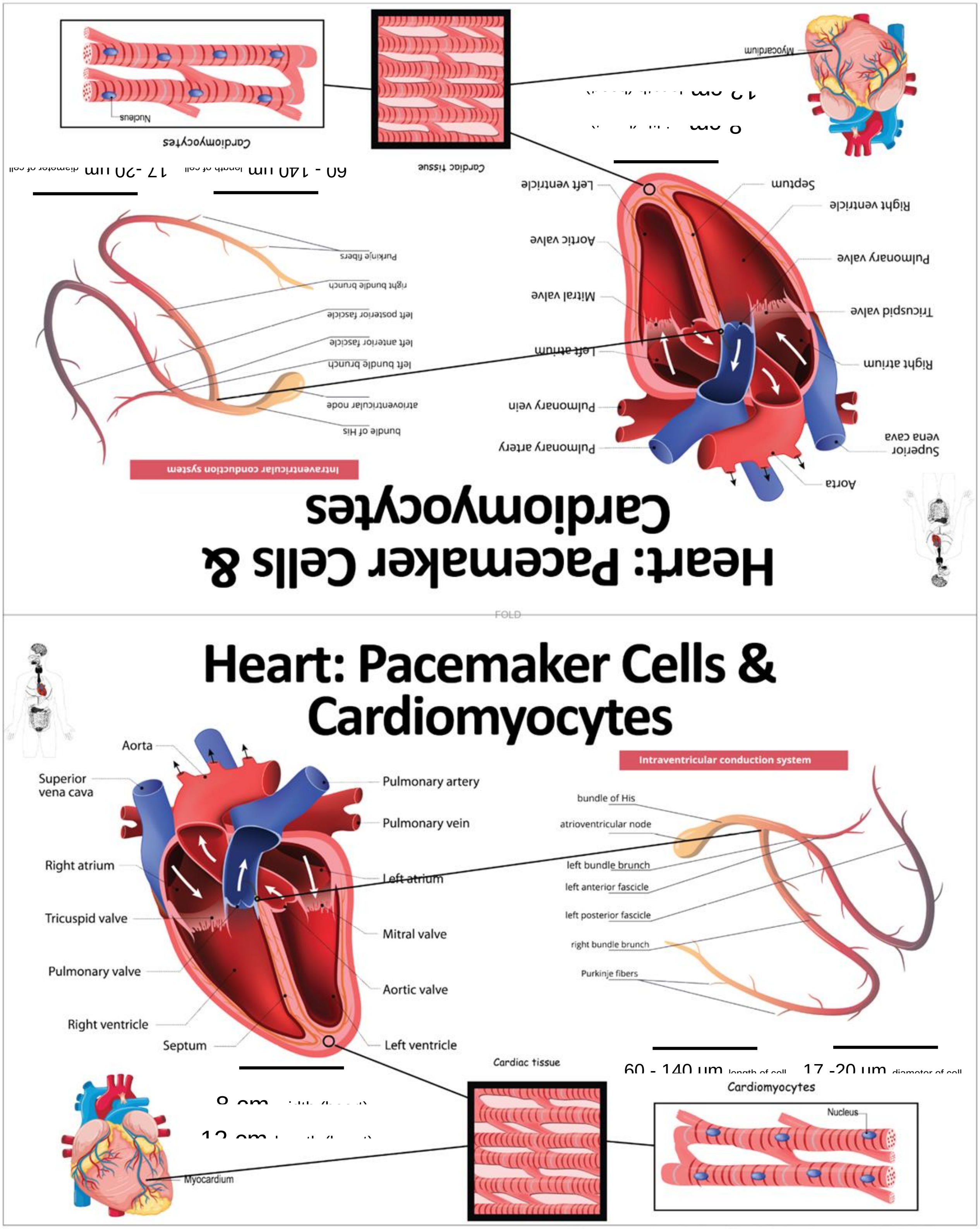
Postgame Analysis - Module 1 - Lesson 4: Table Tents



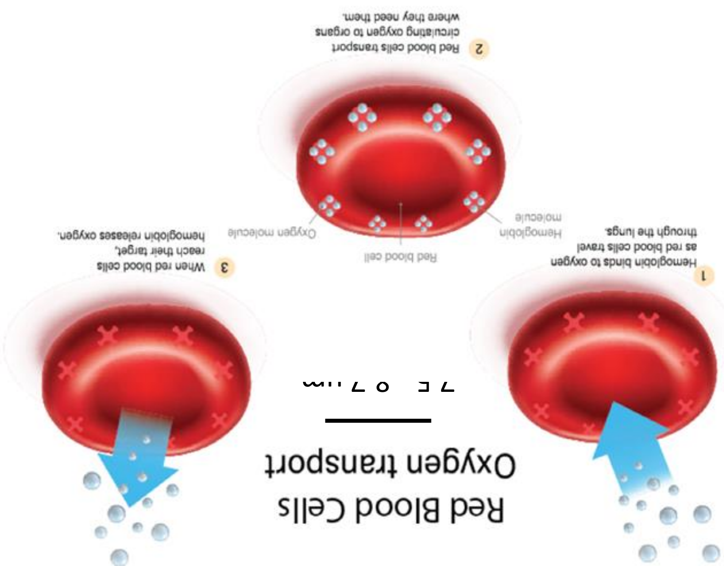
Skeletal Muscle: Myocytes

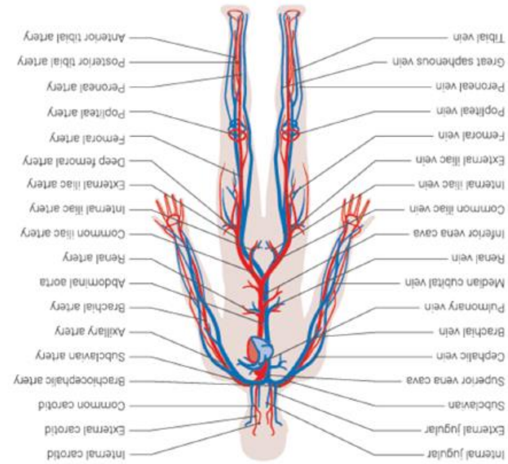


Postgame Analysis -Module 2 - Lesson 9: Table Tents *This work is licensed under a Creative Commons Attribution 4.0 License*



Postgame Analysis - Module 1 - Lesson 4: Table Tents





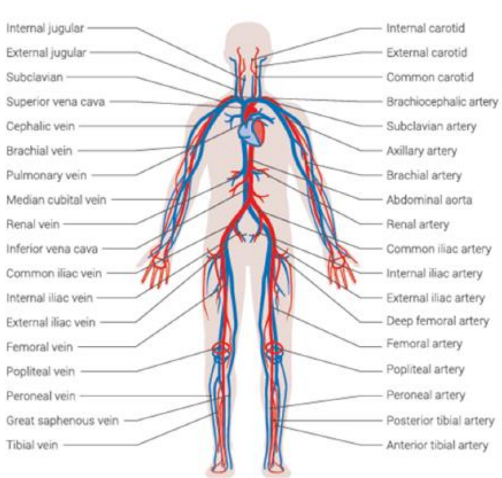
Blood Vessels

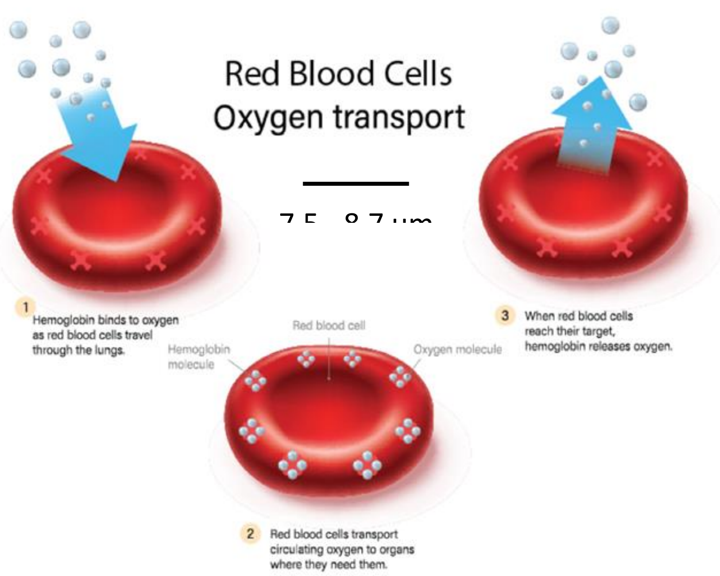
Blood Vessels: Red Blood Cells

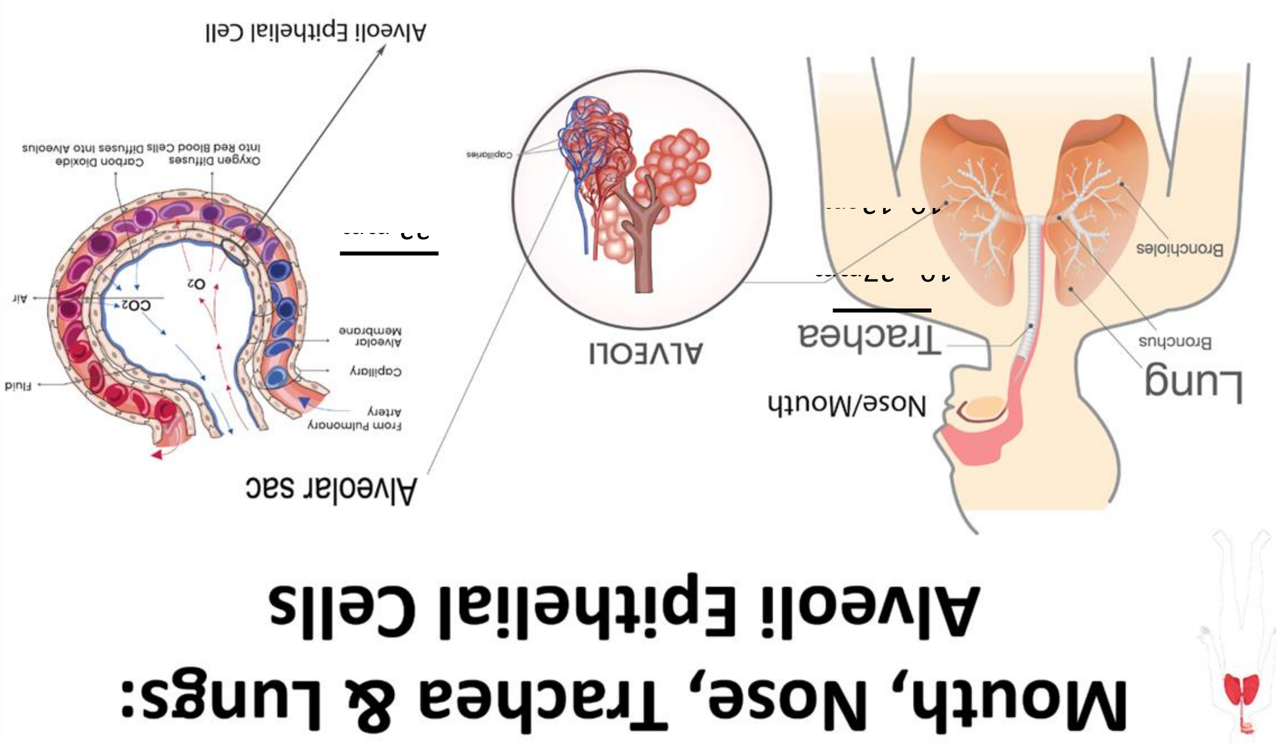
FOLD

Blood Vessels: Red Blood Cells

Blood Vessels







Mouth, Nose, Trachea & Lungs:
Alveoli Epithelial Cells

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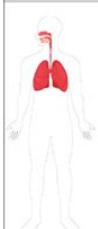
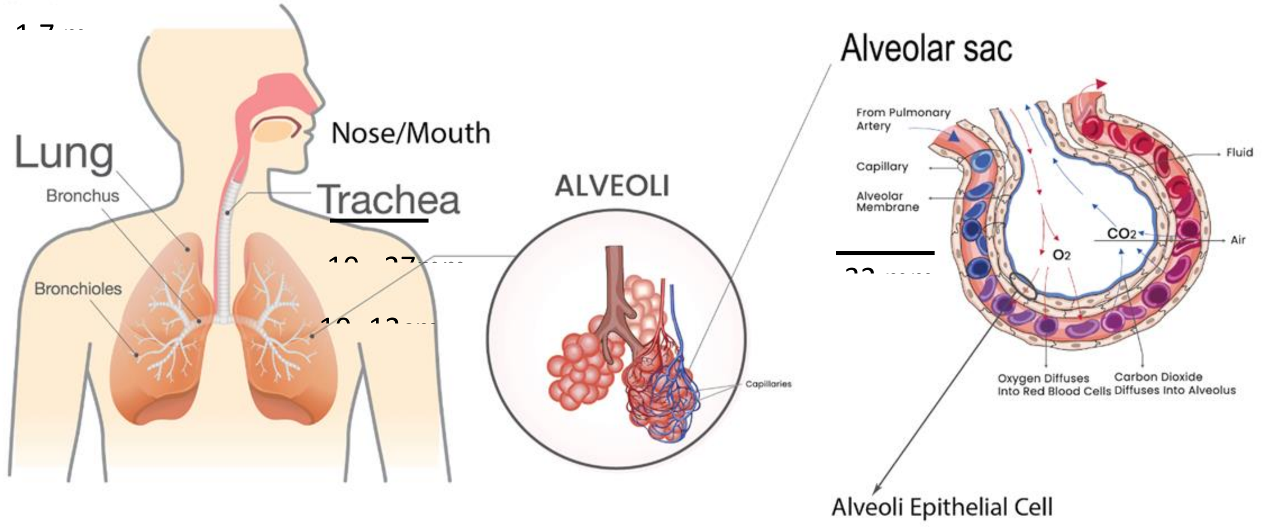
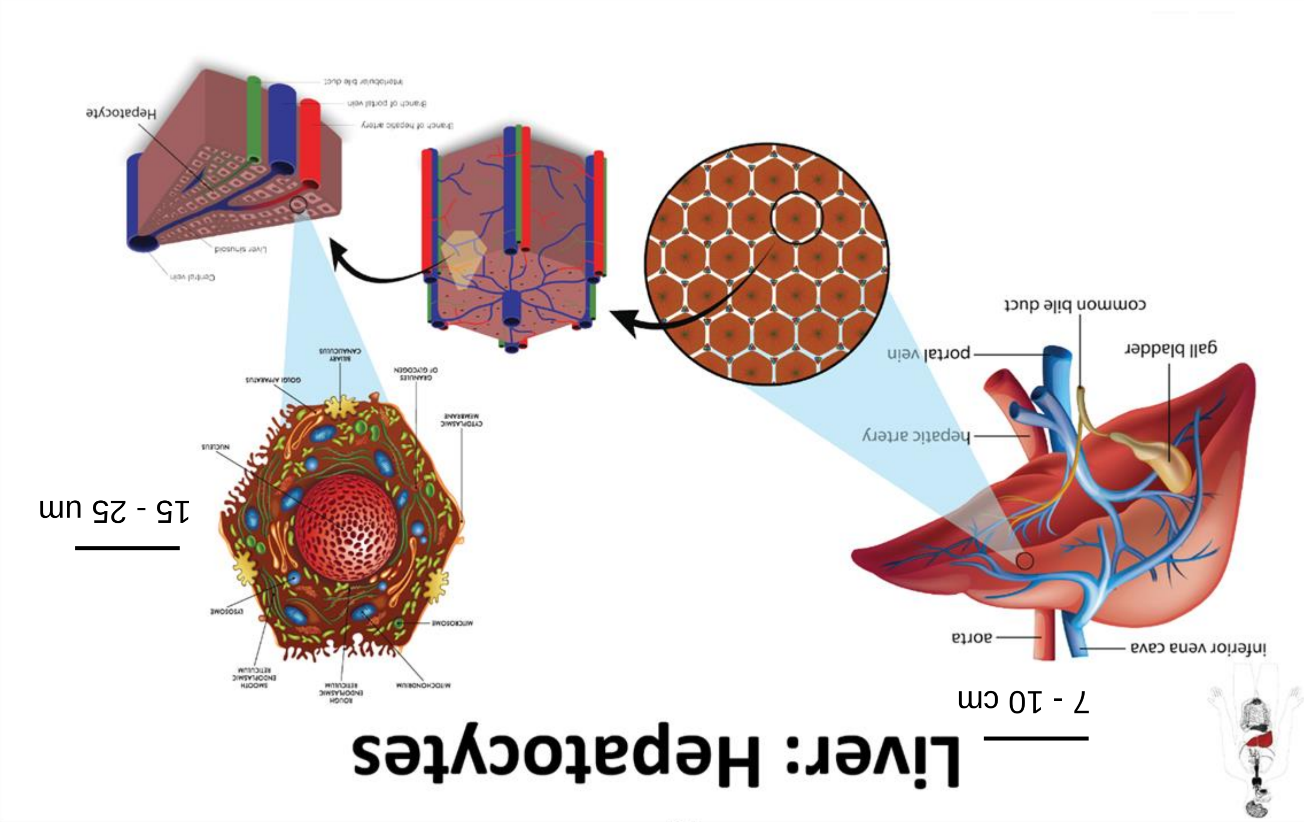


Mouth, Nose, Trachea & Lungs: Alveoli Epithelial Cells



 Postgame Analysis - Module 1 - Lesson 4: Table Tents



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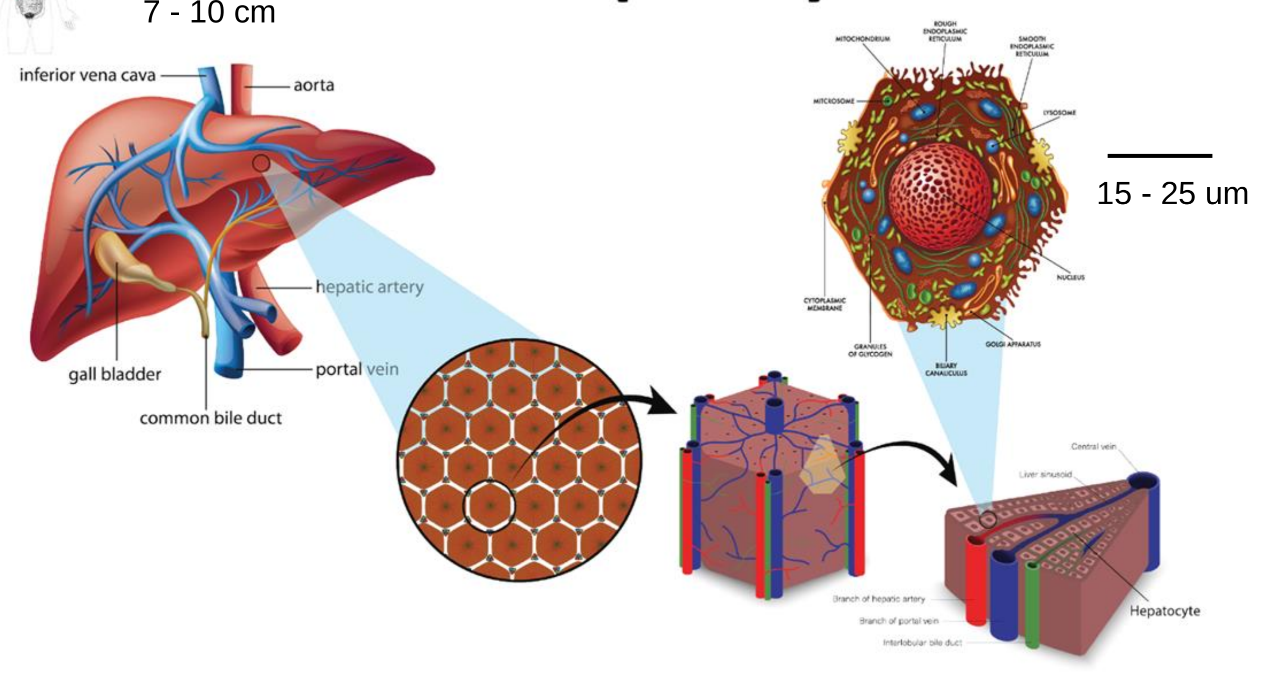
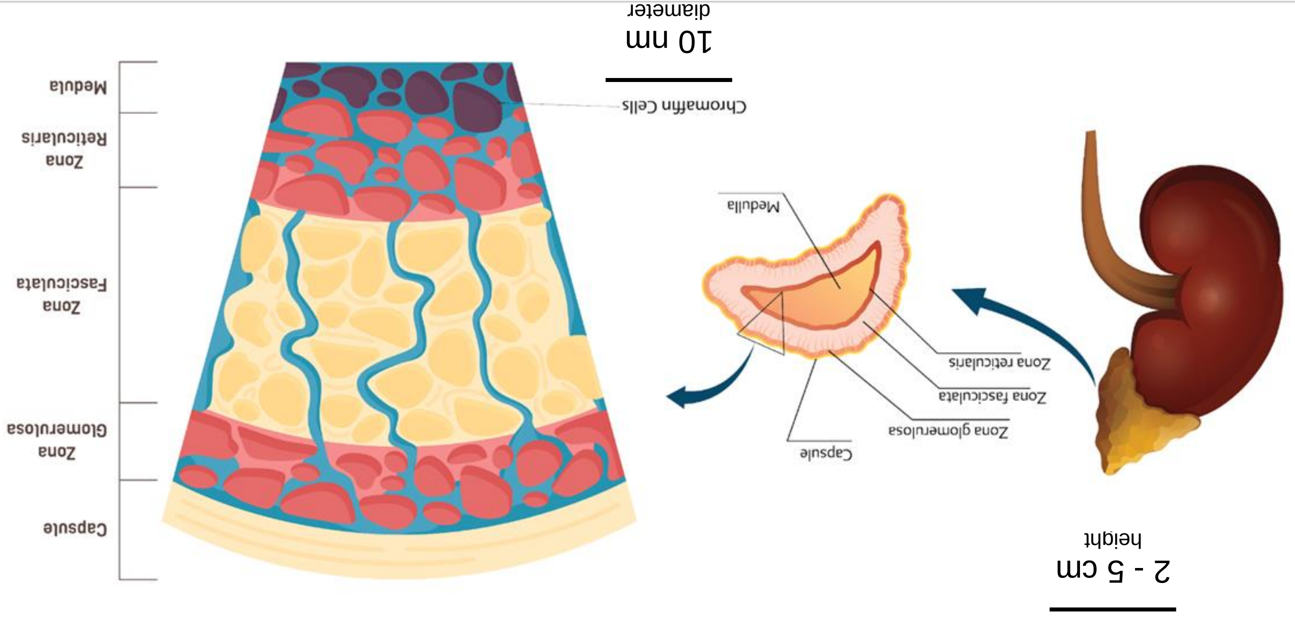
Liver: Hepatocytes





Adrenal Gland: Chromaffin Cells

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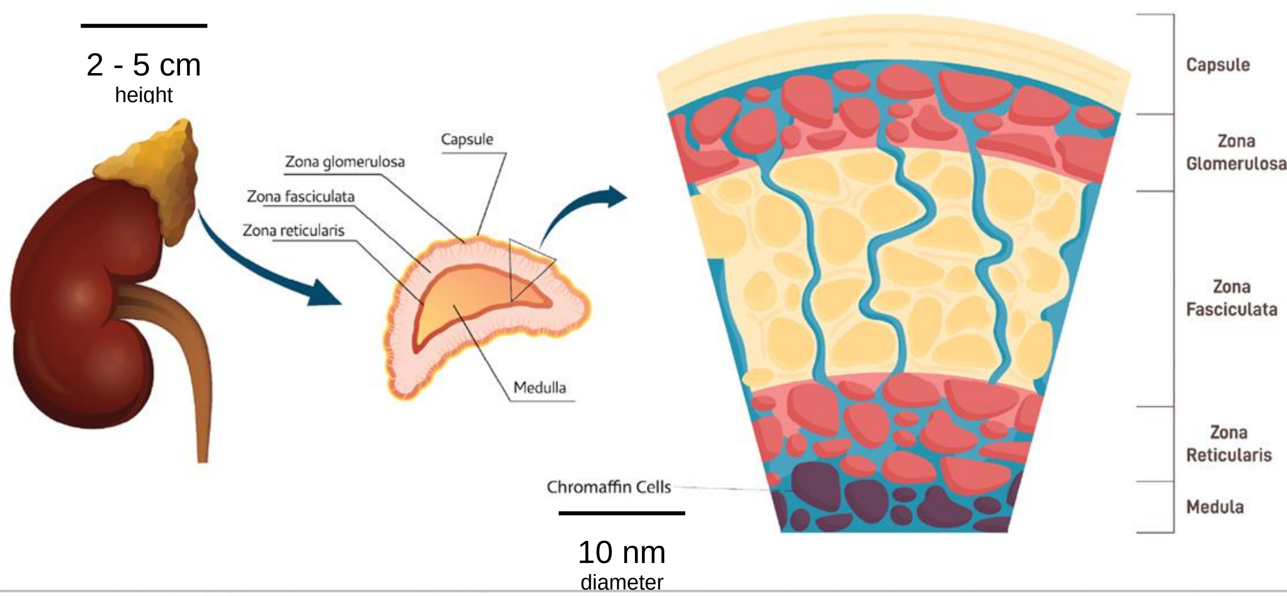
Adrenal Gland: Chromaffin Cells



Increased breathing rate

Starting Location: Mouth/Nose/Trachea/Lungs

Increased heart rate

Starting Location: Heart - Cardio

Increased blood flow

Starting Location: Blood Vessels

Produce epinephrine

Starting Location: Adrenal Glands - Chromaffin Cells

Glycogenolysis (breakdown of glycogen to glucose)

Starting Location: Skeletal Muscle - Myocytes

Glycogenolysis (breakdown of glycogen to glucose)

Starting Location: Liver - Hepatocytes

Decreasing pH

(due to buildup of H+ ions)

Starting Location: Skeletal Muscles

Anaerobic cellular respiration

Starting Location: Skeletal Muscle - Myocyte

Anaerobic cellular respiration

Starting Location: Skeletal Muscle - Myocytes

Anaerobic cellular respiration

Starting Location: Skeletal Muscle - Myocytes

Anaerobic cellular respiration

Starting Location: Skeletal Muscle - Myocytes

End anaerobic respiration

Starting Location: Skeletal Muscle - Myocytes

Aerobic cellular respiration

Starting Location: Skeletal Muscles - Myocytes

Movement

Starting Location: Skeletal Muscles - Myocytes

Slow and stop movement

Starting Location: Skeletal Muscles - Myocytes

Epinephrine

Starting Location: Adrenal Glands - Chromaffin Cells

Epinephrine

Starting Location: Adrenal Glands - Chromaffin Cells)

Epinephrine

Starting Location: Adrenal Glands - Chromaffin Cells

Epinephrine

Starting Location: Adrenal Glands - Chromaffin Cells

Starting Location: Skeletal Muscles - Myocytes

Glycogen
(1 molecule)

Glucose
(lots of molecules)

Starting Location: Skeletal Muscles - Myocytes

Starting Location: Liver - Hepatocytes

Glycogen

(1 molecule)

Glucose

(lots of molecules)

Starting Location: Liver - Hepatocytes

Lactate
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

Carbon Dioxide
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

ATP
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

H+ ions
(2 ions)

Starting Location: Skeletal Muscles - Myocytes

Lactate
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

Carbon Dioxide
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

ATP
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

H+ ions
(2 ions)

Starting Location: Skeletal Muscles - Myocytes

Carbon Dioxide
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

H+ ions
(2 ions)

Starting Location: Skeletal Muscles - Myocytes

Lactate
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

ATP
(2 molecules)

Starting Location: Skeletal Muscles - Myocytes

Glucose
(1 molecule)

Starting Location: Skeletal Muscles - Myocytes

Glucose
(1 molecule)

Starting Location: Blood Vessels - Red Blood Cells

Glucose
(1 molecule)

Starting Location: Skeletal Muscles - Myocytes

Water

(6 molecules)

Starting Location: Skeletal Muscles - Myocytes

Carbon Dioxide

(6 molecules)

Starting Location: Skeletal Muslces - Myocytes

ATP

(38 molecules)

Starting Location: Skeletal Muscles - Myocytes

Oxygen

(6 molecules)

Starting Location: Nose/Mouth/Trachea/Lungs

Sensory Input
(detecting potentially dangerous situation)

Starting Location: Brain - Somatic Nerves

Electrical Signal
(like fight-or-flight)

Starting Location: Autonomic Nervous System - Nerves

Detect decreasing pH

Starting Location: Skeletal Muscle

Electrical signal decreasing

Starting Location: Skeletal Muscle

Electrical pain signal

Starting Location: Brain- Somatic Motor Neurons

Electrical signal
(to initiate movement)

Starting Location: Brain - Somatic Motor Neurons

Intense exercise begins

Starting Location: Facilitator

Exercise Ends

Starting Location: Facilitator

Electrical signal
(to continue movement)

Starting Location: Brain - Somatic Motor Neurons

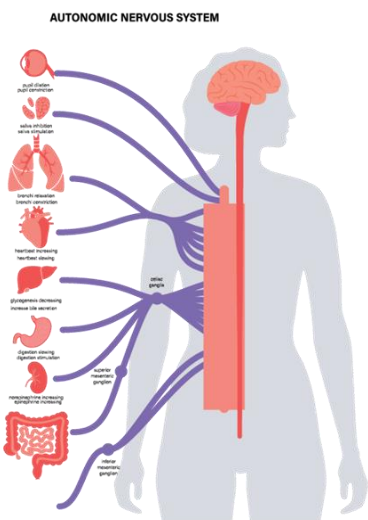
Electrical signal
(to continue movement)

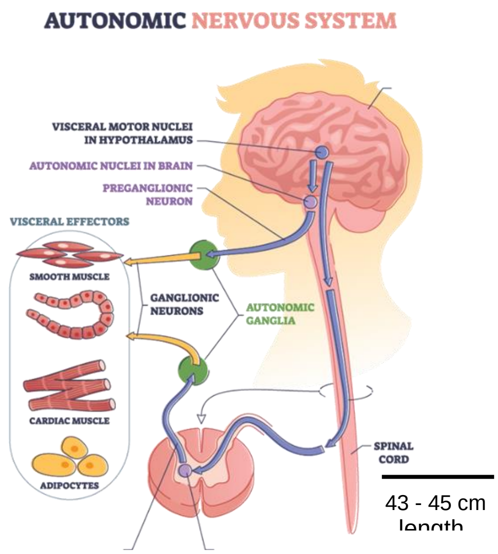
Starting Location: Brain - Somatic Motor Neurons

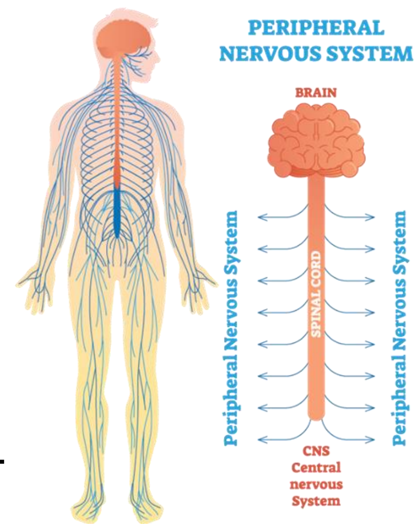
Brain & Autonomic Nervous System

The brain is the central organ of the human nervous system. It consists of billions of cells called neurons that communicate through complex networks of electrical signals. Ultimately, the brain is responsible for processing information, controlling bodily functions, and enabling cognitive functions such as perception, thought, and memory.

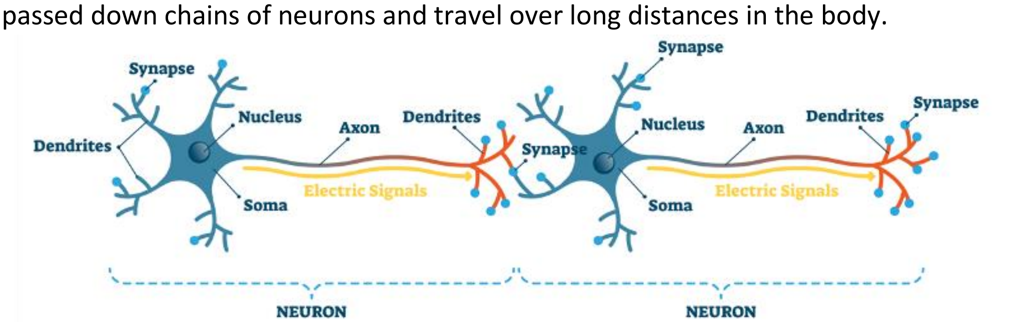
To send and receive signals, the brain relies on the spinal cord and nerves that extend from the spinal cord and out to the other organs and tissues throughout the body. There are two main sets of nerves that the brain uses to receive and send signals to control the body: the autonomic nerves and the somatic nerves. The autonomic nervous system mediates unconscious activities such as breathing, heartbeat, and digestion. It consists of nerves that connect the brain and spinal cord to core organs such as the heart, lungs, stomach, and intestines. The autonomic nervous system is regulated by the hypothalamus.







The brainstem and spinal cord are the central parts of the autonomic nervous system. The fibers/nerves in the spinal cord extend to the core internal organs in the body. Nerves that relay signals from the core organs to the autonomic centers of the brain are sensory nerves/fibers. The nerves/fibers that carry the responsive signals from the brainstem and out the core organs are called motor neurons. Neurons function by sending an electrical signal from one end of the cell to another and then a chemical signal from one neuron to the next. Signals can, therefore, be passed down chains of neurons and travel over long distances in the body.



Science Theater Actions: Brain & Autonomic Nervous System

Act 1: Exercise Begins	Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase
None	The brain detects that the body is in a potentially stressful situation: exercise. It sends a signal via the somatic neurons to the adrenal glands, telling them to release epinephrine, also known as adrenaline. ● Send an Electrical Signal token to the adrenal glands.

Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
The brain continues to send a signal to the adrenal glands to release epinephrine. ● Do not complete any actions in this Act. The brain and nerves continue the same functions as from the previous act, but for simplicity, you will not carry them out a second time.	The brain decides that the body has completed exercise. It stops sending a signal to the adrenal glands, telling them to stop releasing epinephrine. ● Tell the adrenal glands you are not sending them anymore signals.

Brain & Somatic Nervous System

The brain is the central organ of the human nervous system, responsible for processing information, controlling bodily functions, and enabling cognitive functions such as perception, thought, and memory. To send and receive signals, the brain relies on the spinal cord and nerves that extend from the spinal cord and out to the other organs and tissues throughout the body. There are two main sets of nerves that the brain uses to receive and send signals to control the body: the autonomic and the somatic.

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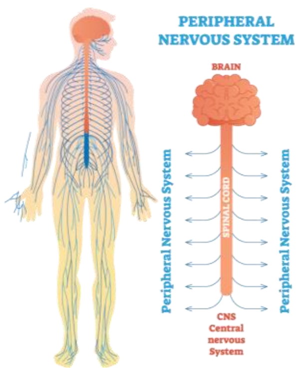
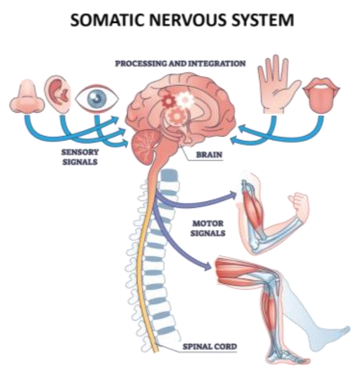
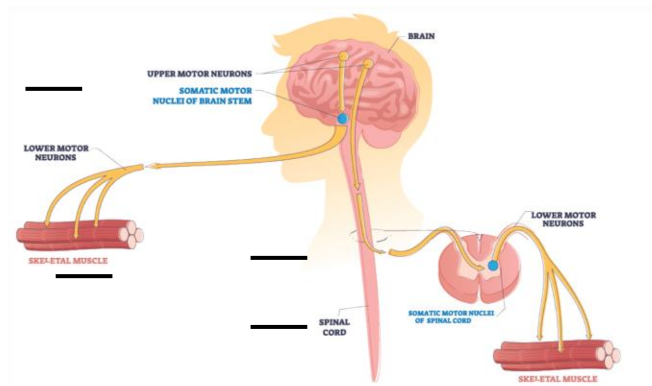






The brain is structurally divided into several regions, including the cerebrum, cerebellum, and brainstem. The cerebrum, with its cerebral cortex, is responsible for higher cognitive functions such as thinking, memory, and perception. The cerebellum coordinates motor movements, while the brainstem regulates essential functions like breathing and heart rate.

The brain controls two sets of nerves that run throughout the body. The somatic nervous system consists of nerves that go to the skin and muscles and is involved in conscious activities. Motor neurons are nerve cells connected directly to muscle fibers and control their movement. The autonomic nervous system consists of nerves that connect the brain and spinal cord to the organs such as the heart, stomach, and intestines. The autonomic nervous system mediates unconscious activities such as breathing, heartbeat, and digestion.

Neurons function by sending an electrical signal from one end of the cell to another and then a chemical signal from one neuron to the next. Signals can, therefore, be passed down chains of neurons and travel over long distances in the body.

Science Theater Actions: Brain & Somatic Nervous System

Act 1: Exercise Begins	Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase
The brain sends a signal to the muscle cells via the motor neurons to initiate movement. ● Send the electrical signal to initiate movement token to the myocytes via the motor neurons.	The brain continues to send a signal to motor neurons to continue movement. ● Do not complete any actions in this Act. The brain and nerves continue the same functions as from the previous act, but for simplicity, you will not carry them out a second time.

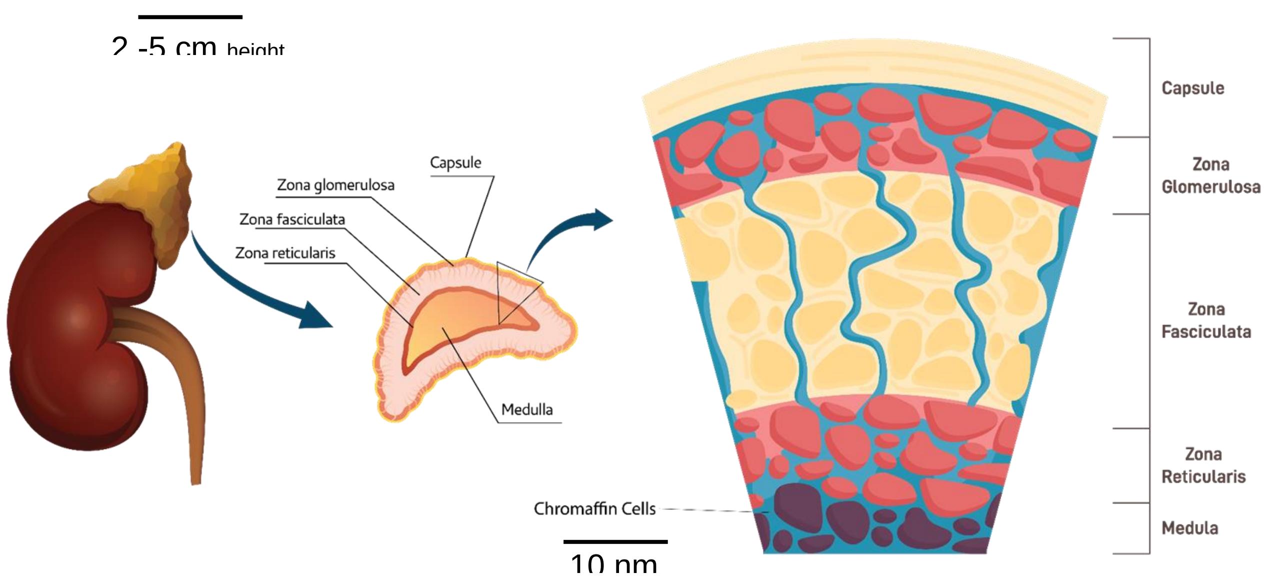
Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
The brain continues to send a signal to motor neurons to continue movement. ● Do not complete any actions in this Act. The brain and nerves continue the same functions as from the previous act, but for simplicity, you will not carry them out a second time.	A signal is received from the muscles via nociceptors that detect pain, alerting the brain that the pH in the skeletal muscles is decreasing. The brain produces a burning sensation in the exercising skeletal muscle. ● Receive the signal of Decreasing pH Due to Buildup of H^+ Ions token from the Myocytes. ● Activate Muscle Burn & Fatigue token. The brain responds to the pain by sending a signal that travels along the motor neurons back to the active skeletal muscle. The signal encourages the skeletal muscle to slow down or stop exercising so that the muscles can clear the increased H^+ ions and restore homeostasis of pH in the muscles. ● Send an Electrical Signal token to the Myocytes.

Adrenal Glands - Chromaffin Cells

The adrenal glands are part of the endocrine system; they are considered both a gland and an organ. They sit on top of each kidney. The role of the adrenal glands is to produce and secrete some of the key hormones. Two of those hormones are epinephrine (commonly called adrenalin) and norepinephrine (commonly known as noradrenaline). Typically, the brain sends electrical signals to the adrenal glands to release specific kinds of hormones in response to different signals the brain receives from sensory nerves. In response to the stimuli that the brain detects, the adrenal glands secrete hormones that control blood pressure, heart rate, sexual traits, and emotions.

The adrenal glands are roughly shaped like a pyramid. If you were to take a cross-section of the pyramid, you would see layers and zones beginning at the center of the gland and expanding outward. At the center is a layer called the medulla, which is surrounded by the zona reticularis. Further out is the zona fasciculata, then the zona glomerulosa, which is surrounded by the outermost layer of the gland called the capsule. The cells in the adrenal gland are surrounded by a lot of arterial and venous capillaries. Hormones produced by the adrenal glands are delivered to organs via the bloodstream.

Each layer and/or zone produces different types of hormones. The medulla, in the center, is where epinephrine and norepinephrine hormones are produced by specialized cells called chromaffin cells. Chromaffin cells that produce epinephrine are called E-type chromaffin cells, and those that produce norepinephrine are called N-type. Both of these hormones act on several organs, including the heart, lungs, blood vessels, lungs, and brain.



Science Theater Actions: Adrenal Glands - Chromaffin Cells

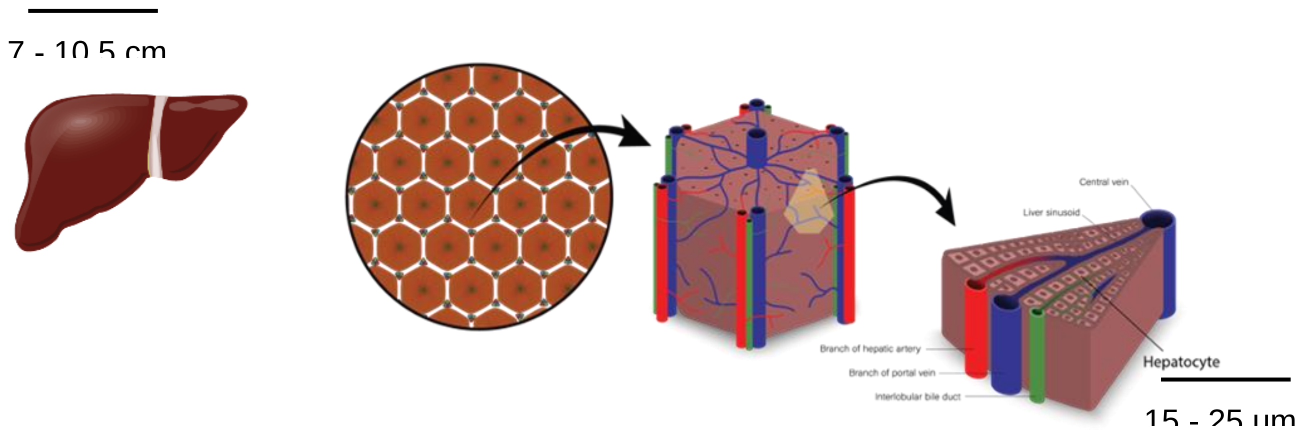
Act 1: Exercise Begins	Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase
None	When signaled by the brain via the autonomic neurons, Chromaffin cells in the adrenal glands produce the hormone epinephrine into the bloodstream. ● Receive the Nerve Signal token from the Brain & Autonomic Nerves. ● Activate the Produce Epinephrine token. ● Release 4 Epinephrine tokens into the Bloodstream.

Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
The adrenal glands continue to release epinephrine as the individual continues to exercise. ● Do not complete any actions in this Act. The adrenal glands continue the same functions as from the previous act, but for simplicity, you will not carry them out a second time.	The adrenal glands stop production of epinephrine after the individual slows and stops exercise. ● Deactivate the Produce Epinephrine token *(turn it over)*.

Liver - Hepatocytes

The liver is one of the primary metabolic organs of the body and has numerous functions. It plays critical roles in digestion by secreting enzymes and bile, and it plays a role in filtering out potentially harmful waste products, microbes, and drugs from the blood. The liver regulates the amounts of glucose, fatty acids, and amino acids in the bloodstream and assembles specific proteins, such as hemoglobin, that help cells in the blood transport gasses and nutrient molecules.

When it comes to energy, the liver can be compared to a rechargeable battery; it stores, releases, and recycles molecules that the cells of the body use for energy. When there is an excess of nutrient molecules in the bloodstream and energy demands are low, it stores energy for use later by holding on to excess food molecules. For example, it will store excess glucose in the form of glycogen. When the energy demand on the body is high, the liver is able to release the stored molecules, such as by converting stored glycogen into glucose, into the bloodstream to be used by the other cells of the body to be converted into chemical energy during cellular respiration.



Eighty percent of the cells in the liver are called hepatocytes. These cells are organized into small bundles called lobules. Arteries and veins flow through the lobules, allowing hepatocytes to be in constant contact with blood. This structural organization supports the function of the liver and makes it easy for the hepatocytes to move various molecules into the blood and filter other molecules out of the blood.

When exercising, the hepatocytes receive the epinephrine signal from the adrenal glands. The cell membranes of the hepatocytes have specialized receptors for hormones such as epinephrine. When epinephrine binds to its specific receptor on the membrane of a hepatocyte, it triggers the activation of a specific enzyme that breaks down glycogen to release glucose into the bloodstream to increase blood glucose levels. This process is called glycogenolysis.

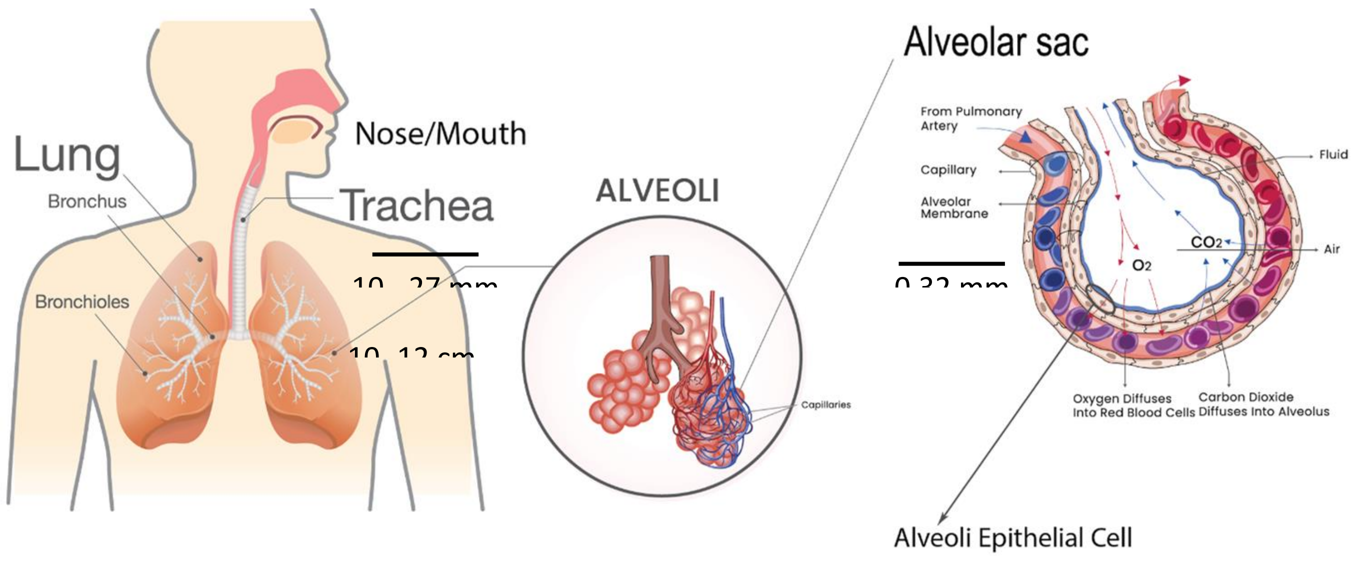
Science Theater Actions: Liver - Hepatocytes

<table>
<tr><td>Act 1: Exercise Begins</td><td>Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase</td></tr>
<tr><td>None</td><td>Epinephrine from the bloodstream binds to receptors on the cell membrane of the hepatocytes in the liver, triggering the activation of an enzyme to break down the glycogen in the hepatocytes into glucose molecules. This increases the amount of glucose available in the bloodstream.
Receive the Epinephrine token from the Bloodstream.
Use the Epinephrine token to activate the Glycogenolysis token—(glycogen broken down to glucose molecules by enzyme)
Replace the Glycogen (one molecule) token by flipping it over to the Glucose (lots of molecules) token. Pass the free glucose molecules to the bloodstream.</td></tr>
</table>

<table>
<tr><td>Act 3: Continued Exercise</td><td>Act 4: Muscle Burn & Fatigue</td></tr>
<tr><td>The liver continues to release glucose as the individual continues to exercise.
Do not complete any actions in this Act. The liver continues the same functions as from the previous act, but for simplicity, you will not carry them out a second time.</td><td>The liver stops producing glucose from glycogen after the individual slows and stops exercise.
Deactivate the Glycogenolysis token (by turning it over).</td></tr>
</table>

Lungs – Alveoli Epithelial Cells

The mouth, nose, trachea, and lungs are organs of the respiratory system. The nose and mouth allow entry of air into the body. All of these organs are lined with mucous cells to secrete mucus, which acts like a filter to trap unwanted particles in the air before the air moves into the trachea and lungs. Air enters the mouth and nose, then moves to the trachea. The trachea is often called the windpipe, and it connects the mouth and nose to the lungs. Air moves from the trachea to the lungs, which provide a large space filled with small structures called alveoli to collect air.



The function of these organs is to exchange oxygen and carbon dioxide between the interior of the lungs and the bloodstream. In the lungs, when breathing in, oxygen-rich air enters millions of small, sack-like structures called alveoli. Here, it encounters the alveolar epithelial cells that line the alveoli. These cells allow oxygen from the interior of the lung to diffuse through them and into the capillaries and red blood cells that surround the alveoli. They also provide a layer of protection from any unwanted substances, such as microbes or pollutants, from entering the bloodstream and, therefore, the rest of the body.

When breathing out, carbon dioxide in the red blood cells of the bloodstream also diffuses through the epithelial cells and into the alveoli in the interior of the lung. Here, it accumulates until it is exhaled out of the lungs, through the trachea, and out of the nose or mouth.

Science Theater Actions: Lungs – Alveoli Epithelial Cells

Act 1: Exercise Begins	Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase
Breathing rate at the start of exercise is normal. No actions.	Epinephrine increases the breathing rate in anticipation of the need to expel higher amounts of carbon dioxide and supply muscle cells with more oxygen to produce energy. ● Receive the Epinephrine token from Bloodstream ● Activate the Increased Breathing Rate token. As blood passes through the capillaries surrounding the alveoli, the higher concentration of carbon dioxide in the blood means the CO_2 can diffuse out of the capillaries and through the epithelial cells, where it can be expelled by traveling up the trachea and out the nose/mouth while exhaling. ● Accept the Carbon Dioxide (2 molecules) token from the Bloodstream ● Pass the Carbon Dioxide tokens out of the body. ● Pass the Oxygen (6 molecules) token to the Bloodstream.

Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
The lungs continue to breathe at an increased rate as the individual continues to exercise. ● Do not complete any actions in this Act. The lungs continue the same functions as from the previous act, but for simplicity, you will not carry them out a second time.	The lungs decrease their breathing rate after the individual slows and stops exercise. ● Deactivate the Increased Breathing Rate token *(turn it over)*.

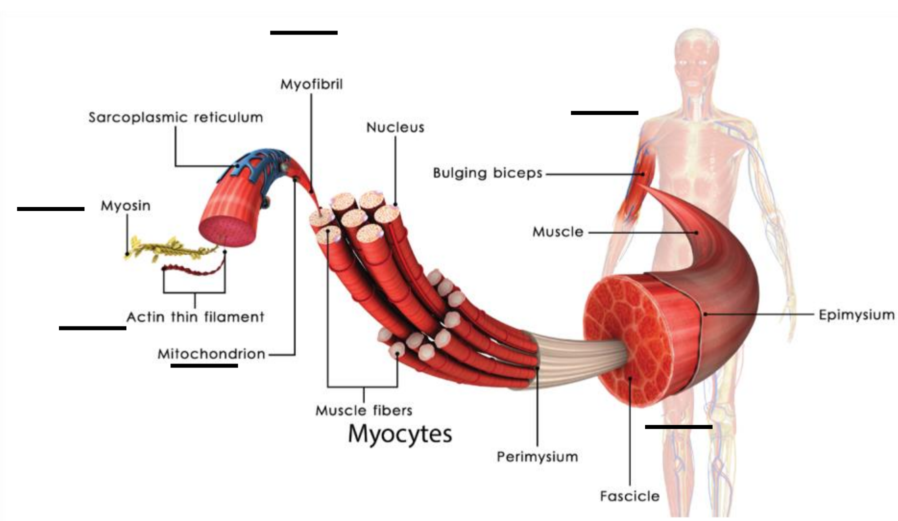
Skeletal Muscles - Myocytes

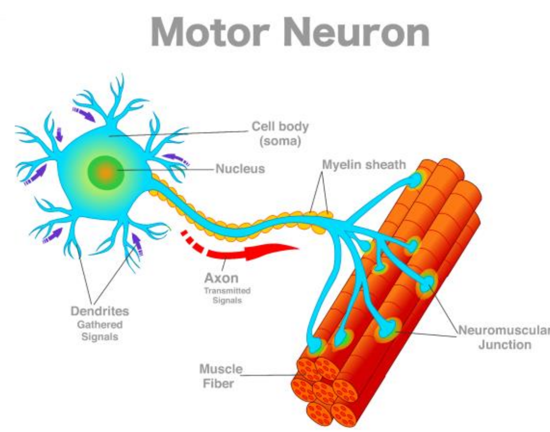
Skeletal muscles are voluntary muscles attached to the bones by tendons, responsible for movement and maintaining posture. They work in pairs, contracting and relaxing to facilitate coordinated and controlled motions in response to signals from the nervous system.

Skeletal muscles are made of long, thin fibers that are tightly packed together. Muscle tissue can be stimulated by nerve signals from the brain. Motor neurons from the brain attach directly to the muscle cells, allowing a nerve signal to directly stimulate myocytes. When muscle cells receive this nerve signal, they contract to shorten the length of the muscle tissue, which results in movement.

Muscle cells require a large amount of cellular energy to expand and contract rapidly during exercise. During strenuous exercise, for example, the rate of energy use in skeletal muscles can increase by more than 100-fold almost instantly. To meet this energy demand, muscle cells produce their own cellular energy using a series of chemical reactions that transfer energy in food molecules, such as glucose, to a form of energy that muscle cells can use. In the mitochondria of the muscle cell, two different energy pathways are used to transfer energy in food molecules to cellular energy, also known as adenosine triphosphate or ATP.

First, in high-intensity exercise, when oxygen is not yet available, the muscle cells use an energy transfer process called anaerobic respiration. This process occurs in the absence of oxygen and uses a chemical reaction to convert one molecule of glucose to two molecules of lactate. This process also produces hydrogen ions and carbon dioxide as byproducts. Second, when oxygen later becomes available, the mitochondria use a different energy transfer process called aerobic respiration to convert one molecule of glucose and six molecules of oxygen to six molecules of carbon dioxide, six molecules of water, and 38 molecules of ATP. The ATP produced from both of these processes is used by muscle cells to undergo contractions and move the muscle fibers to move the body.





Science Theater Actions: Skeletal Muscles - Myocytes

Act 1: Exercise Begins	Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase
Oxygen has not yet been delivered to the muscles. Muscles detect the lack of oxygen and begin anaerobic respiration to generate cellular energy (ATP) that is used by the muscles for muscle cell contraction and, thus, movement. The inputs of anaerobic cellular respiration are glucose, and the byproducts include H^+ ions, lactate, and carbon dioxide. ● Receive the Electrical signal to initiate movement from the Brain & Somatic Nerves. ● Activate the Anaerobic Respiration token. Exchange glucose molecule (1) for ATP (2 molecules) ATP and lactate (2 molecules). ● Activate carbon dioxide (2 molecules) and H^+ (2 ions) tokens as byproducts of this process. Pass the carbon dioxide (2 molecules) to the blood vessels. Keep the H+ (2 ions) in the muscle. ● Use and deactivate the 2 ATP token *(by turning it over)* to activate the Movement token.	Anaerobic respiration continues in the myocytes. Glucose molecules in the myocyte are used for anaerobic respiration to generate ATP so that the muscle can continue contracting. ● Receive a glucose molecule from the bloodstream. ● Continue to generate ATP using the Anaerobic Respiration token. Exchange glucose molecule (1) for ATP (2 molecules) ATP and lactate (2 molecules). ● Activate carbon dioxide (2 molecules) and H^+ (2 ions) tokens as byproducts of this process. Pass the carbon dioxide (2 molecules) to the blood vessels. Keep the H+ (2 ions) in the muscle. The myocytes receive the epinephrine signal from the bloodstream, which triggers them to make more glucose available to support the energy needs of intense exercise. Muscle cells convert their glycogen to glucose. ● Activate the Glycogenolysis token. Replace the Glycogen token *(by flipping it over)* to the Glucose (several molecules) token. ● Use another molecule of Glucose (formerly glycogen) to undergo anaerobic respiration once again. (Exchange all the proper molecules including the ATP, carbon dioxide, lactate, and H+ ions.)

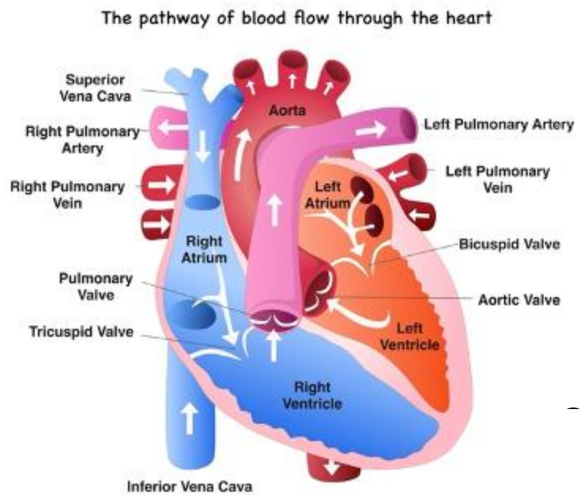
Science Theater Actions: Skeletal Muscles - Myocytes (continued)

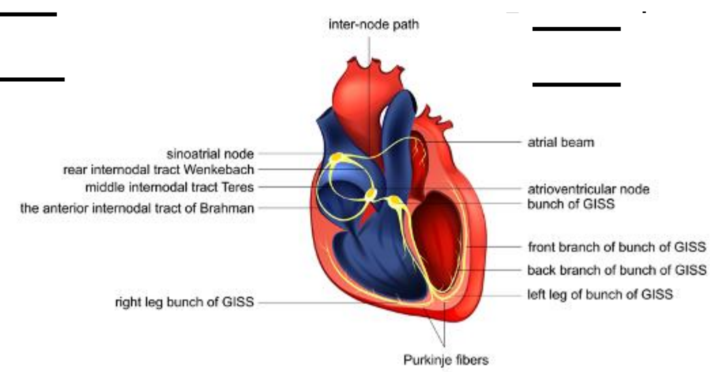
Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
As time has passed during the workout, oxygen has been passed from the lungs to the bloodstream and to the myocytes. As a result, myocytes shift from undergoing Anaerobic Respiration and instead now	As a result of anaerobic respiration, a buildup of H^+ ions is present in the skeletal muscle. This is detected by nociceptors/pain receptors in the skeletal muscle. ● Activate the Decreasing pH due to buildup of

engage in Aerobic Respiration, which produces even more ATP for cellular energy that can be used by the myocytes for movement. ● Receive an additional Glucose token and the Oxygen (6 molecules) token from the bloodstream. ● Activate the Aerobic Cellular Respiration token. ● Undergo aerobic cellular respiration. Deactivate the Glucose token and six Oxygen tokens *(by turning them over)*, and activate six Carbon Dioxide, six Water tokens, and 38 ATP token. ● Pass the six Carbon Dioxide tokens and the six Water tokens to the Bloodstream.	H^+ Ions token. The pain response travels along the motor neurons back to the active skeletal muscle. The pain is felt in the muscle to encourage the skeletal muscle to slow down or stop exercising so that the muscles can clear the increased H^+ ions and restore homeostasis of pH in the muscles. ● Receive an Electrical Signal token from the Brain and Somatic Neurons. ● Activate the Slow and Stop Movement token.

Heart – Pacemaker Cells & Cardiomyocytes

The heart is an organ in the chest that is essentially a special muscle made of heart muscle cells (cardiomyocytes) that are similar to those in muscle (myocytes). The heart is responsible for pumping blood through the blood vessels that run throughout the body. The heart can pump harder and faster or slower depending on the needs of the body.





The heart consists of four chambers. The right atrium takes in all the oxygen-poor blood from your body and passes it to the right ventricle. The right ventricle pumps this blood into the pulmonary arteries and out to your lungs. Oxygen-rich blood returns from the lungs into the left atrium and then moves into the left ventricle. The left ventricle actively pumps the blood throughout your body. Incredibly, this process repeats with every heartbeat.

Cardiomyocytes are contractile, excitable heart cells that contract rhythmically without rest to produce the heartbeat. The cardiomyocyte is the cell responsible for the contraction of the heart. Each cardiomyocyte uses an intricate network of contractile proteins and electrical signals to continually contract and relax. During exercise, the heart can receive an epinephrine signal that will stimulate the cardiomyocytes to increase their rates of contraction, which leads to an increased heart rate.

Science Theater Actions: Heart – Pacemaker Cells & Cardiomyocytes

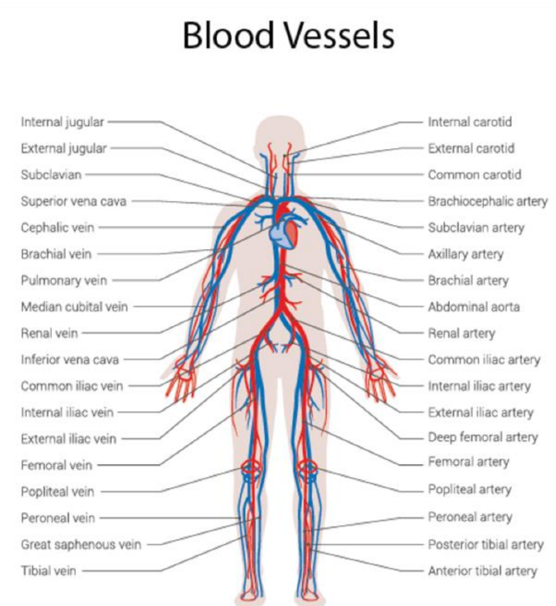
Act 1: Exercise Begins	Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase
Heart rate at the start of exercise is normal. No actions.	Epinephrine binds to the receptors on the pacemaker cells and increases heart rate in anticipation of needing to pump more blood, deliver nutrients and oxygen throughout the body, and remove carbon dioxide faster during intense exercise. ● Receive the Epinephrine token from the bloodstream. ● Activate the Increased Heart Rate token. ● Activate the Increase in Blood Flow token.

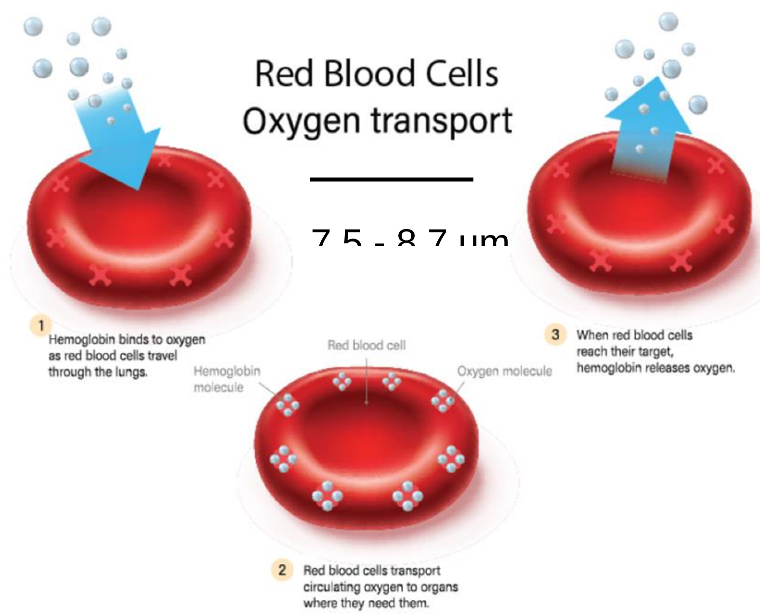
Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
The heart continues to beat at an increased rate as the individual continues to exercise. ● Do not complete any actions in this Act. The heart continues the same functions as from the previous act, but for simplicity, you will not carry them out a second time.	Heart rate slows down after the individual slows and stops exercise. ● Deactivate the Increased Heart Rate token *(by turning it over)*. ● Deactivate the Increased Blood Flow token *(by turning it over)*.

Blood Vessels - Red Blood Cells

Blood vessels are a complex network of structures, including arteries, veins, and capillaries, that transport blood throughout the body. Blood vessels facilitate the delivery of oxygen, nutrients, and hormones to cells and organs while removing waste products, playing a crucial role in maintaining the body's internal balance and supporting various physiological functions.

The heart, a muscular organ, pumps blood through two main pathways: the pulmonary blood vessels, where blood is oxygenated in the lungs, and the systemic vessels, where oxygenated blood is distributed to the body. Arteries carry blood away from the heart, veins return it, and capillaries facilitate the exchange of nutrients and gasses with tissues throughout the body. In this process, red blood cells act as the carrier of oxygen. When blood passes through the alveoli of the lungs, oxygen binds to a molecule called hemoglobin in the red blood cell. Red blood cells carry this oxygen throughout the body and deliver it to the rest of the cells of the body. Red blood cells also pick up carbon dioxide from the cells of the body and transport it back to the lungs, where it is exhaled.





Science Theater Actions: Blood Vessels - Red Blood Cells

<table>
<tr><th>Act 1: Exercise Begins</th><th>Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase</th></tr>
<tr><td>None</td><td>The Adrenal Glands send epinephrine throughout the body to prepare the body’s organs to respond to strenuous exercise.
Receive four Epinephrine tokens from the Adrenal Glands
Deliver one Epinephrine token to the Liver, one to the Lungs, one to the Heart, and one to the Muscle Cells.
An increase in breathing rate allows more oxygen to enter the lungs and diffuse into the bloodstream. The red blood cells bind to oxygen and carry it throughout the body, particularly to muscle cells.
Receive X Oxygen tokens from the Lungs.
Deliver these tokens to the Muscles.
An increase in anaerobic respiration produces an increase in carbon dioxide that must be transported to the lungs via the bloodstream so that it can be exhaled out of the body.
Receive the X Carbon Dioxide tokens from the Skeletal Muscles
Deliver the Carbon Dioxide tokens to the lungs.
The liver converts glycogen to glucose to provide muscles with additional glucose for anaerobic respiration. It sends the glucose through the bloodstream to the muscles.
Receive the Glucose tokens from the Liver.
Deliver the Glucose tokens to the Myocytes.</td></tr>
</table>

Act 3: Continued Exercise	Act 4: Muscle Burn & Fatigue
The bloodstream continues to provide nutrients to the muscles as the individual continues to exercise. ● Do not complete any actions in this Act. The	The bloodstream continues to provide nutrients to the muscles as the individual continues to exercise. ● Do not complete any actions in this Act.

bloodstream continues the same functions as from the previous act, but for simplicity, you will not carry them out a second time.	