The nucleus and ribosomes help make proteins

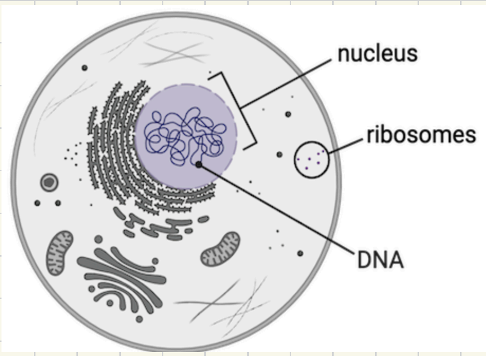
Proteins are biomolecules that are vital for nearly all cell functions. In eukaryotic cells, protein synthesis (building) involves several key structures, including the nucleus and ribosomes.

- The nucleus is a membrane-bound organelle that contains the cell's genetic material. This genetic material is in the form of DNA molecules, which are organized into linear structures called chromosomes.

- Ribosomes are cell parts that build protein molecules. Ribosomes can either be found suspended in the cytosol, or attached to the rough endoplasmic reticulum.

→ determine the cell's structure & function chromosomes

protein synthesis — associated with straight DNA strands in eukaroyitic cells. They are built by ribosomes.



A eukaryotic cell diagram. The diagram highlights the nucleus, ribosomes, and DNA in purple.

How do these cell parts work together?

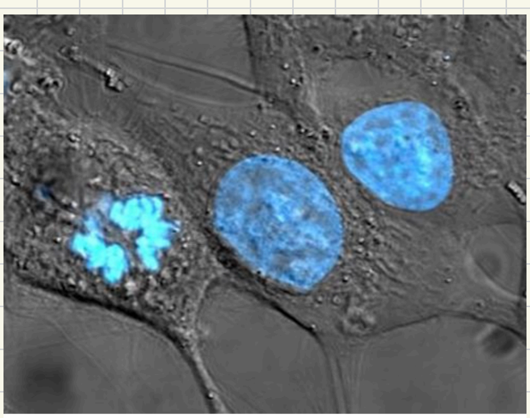
The process of protein synthesis begins in the nucleus with DNA, which encodes the genetic instructions for making proteins. These instructions are used to build intermediate molecules called messenger RNAs (mRNAs), which travel outside the nucleus to the ribosomes. The ribosomes then use the mRNA molecules as blueprints for assembling protein molecules.

1. building protein begins in nucleus
2. DNA: encodes the genetic instructions for making proteins.
3. These instructions are used to build mRNAs: which travels outside the nucleus to the ribosomes. 4. Then, ribosomes use the mRNAs as blueprints for assembling protein molecules

How are these cell parts related to cell specialization?

Eukaryotic cells in multicellular organisms are specialized to carry out specific functions. A cell's structure and function is largely determined by its proteins. So, differences in which proteins are made (i.e., differences in protein expression) are key to how cells take on specialized roles.

As such, the process of protein synthesis is highly regulated in cells. Many factors affect which proteins are made in a cell at any given time, including signals from the cell's environment.



A fluorescence micrograph showing the nuclei of three cells. Each nucleus appears as a bright blue circle inside the cell.

proteins

they determine the function & structure — affected by signals, time of production, etc....

Me

The endoplasmic reticulum, Golgi body, and vesicles make, modify, and transport molecules

Molecules are built and modified via chemical reactions in the cell, and then transported to the locations where they are needed. Some molecules are used inside the cell, while other molecules are secreted (transported out of the cell). The organelles most closely associated with these processes are the rough and smooth endoplasmic reticulum, the Golgi body, and vesicles.

- The rough endoplasmic reticulum (rough ER) is a series of connected membranes with ribosomes attached to the outer surface. Proteins made by these ribosomes are fed into the rough ER where they receive chemical modifications.

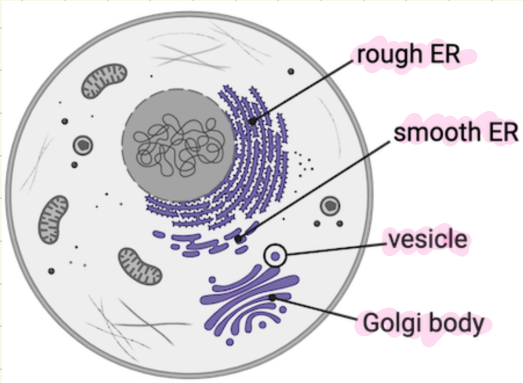
  • Rough ER: membranes + ribosomes

- The smooth endoplasmic reticulum (smooth ER) is similar to the rough ER in appearance, but without the attached ribosomes. The smooth ER helps build a variety of lipid (fat) molecules. It also helps detoxify drugs and poisons through chemical modification of these compounds.

  • Smooth ER: just membranes

- The Golgi body is a set of disc-shaped, membrane-bound sacs that receive molecules from the rough and smooth ER. Here, the molecules are chemically modified, and other molecules are made.

- Vesicles are small, membrane-enclosed sacs that bud off from the membranes of the ER, Golgi body, and plasma membrane. Vesicles carry substances between these cell parts, and play a key role in transporting substances within and out of the cell.



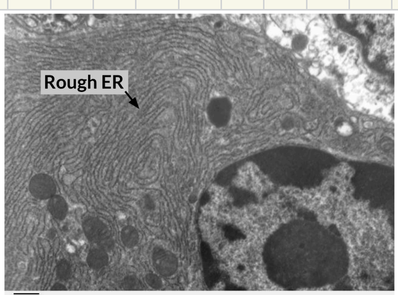
A eukaryotic cell diagram. The diagram highlights the rough and smooth ER, the Golgi body, and a vesicle in purple. Created with Biorender.com.

How do these cell parts work together?

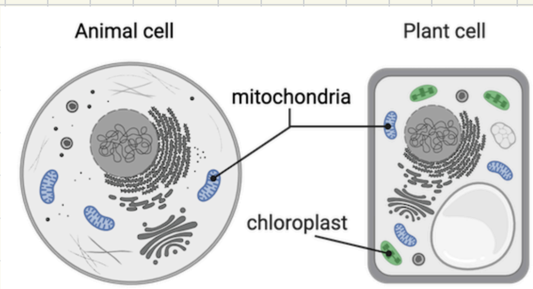
One important way that these organelles work together is in protein modification and transport. Proteins modified in the rough ER are transported via vesicles to the Golgi body. The Golgi body further modifies these proteins and sorts them for transport. The proteins are then transported via vesicles to their final destinations. These destinations can be inside the cell, within the plasma membrane, or outside the cell.

How are these cell parts related to cell specialization?

Eukaryotic cells in multicellular organisms are specialized to carry out specific functions. A cell's functions are often reflected in the make-up of its organelles. For example, cells that function primarily in protein or lipid secretion tend to have extensive ER membranes. Lung cells, like the one shown below, secrete many proteins the help protect the lining of the airways, and are therefore rich in rough ER.



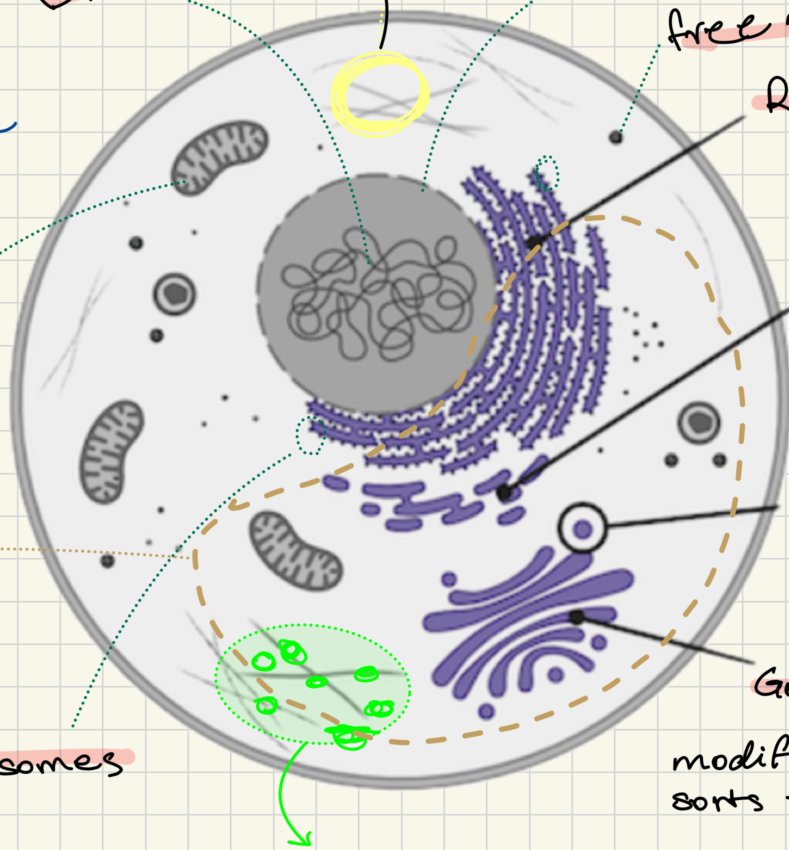
A TEM micrograph showing a section through a mammalian lung cell. This cell type secretes molecules that protect the lining of the airway, and so is rich in rough ER. The cell's nucleus can be seen on the bottom right, and the rough ER is the wavy-looking structure outside of the nucleus. Image credit: modified from "Clara cell lung - TEM" by Louisa Howard, Public domain.



Animal and plant cell diagrams showing mitochondria (colored blue, in both the plant and animal cell) and chloroplasts (colored green, in the plant cell only). Created with Biorender.com.

All membrane bound organelles

A eukaryotic cell diagram



• notes •

- In a eukaryotic cell, the genetics information, the DNAs, are in a membrane called nucleus.
  ↳ contains cell's genetic material
- The nucleus has holes that are connected to endoplasmic reticulum, which are layers of membranes that have ribosomes attached to them.
  - protein synthesis
- Some ribosomes are free__ called free ribosome.
- The parts of the endoplasmic reticulum that have ribosomes attache are called rough endoplasmic reticulum.
  ↳ a site of protein synthesis & modification
- The parts of the endoplasmic reticulum that don't have ribosomes attache are called smooth endoplasmic reticulum.
  ↳ a site of lipid synthesis

- Golgi Body — Similar structure as E.R. but different function

↳ pronunciation: /Golji/ ↳ modifies and sorts molecules for transport

- mitochondria — the most famous membrane bound organelle outside the nucleus that is the power house of the cell.

/maytokondria/

↳ generates useable energy for the cell

it has its own DNA, and it comes from the mother in humans, which make mitochondria essential for tracing the maternal lineage.

- chloroplast — in plants/algea. they help with photosynthesis, and they have thylakoids inside.

↳ carries out photosynthesis

- vacuole — a less famous membrane-bound organelle in a cell that are very big, function as storage units storing water and enzymes (e.g. enzymes for digestion), and etc.

- lysosome — associated with animal cells but has been seen in some plant cell as well. It's a compartment containing a whole series of enzymes in it, that are useful for lysing — breaking down either waste products as the cell lives, or even foreign substances that might not be helpful for the cel

- cytosol — makes up the cell's internal environment

- vesicle — transports molecules within the cell

- ribosome — builds the cell's protein

- cytoskeleton — maintains cell structure and internal organization

- DNA — encodes the cell's genetic information

- plasma membrane — regulates what enters and exits the cell

- Palisade Cells in Mesophyll likely have an abundance of chlorophyl compared to other plant cells.

Mitochondria and chloroplasts help capture and release energy

All organisms need energy to survive. In eukaryotic organisms, the organelles that help organisms harness and generate useful forms of energy are the chloroplasts and mitochondria.

- Chloroplasts are the sites of photosynthesis, which is the process that converts energy from sunlight into chemical energy stored in sugar molecules. These sugars can then be stored and used by the cell to power cellular functions. Chloroplasts are found only in plant cells and some protists.

- Mitochondria are the sites of cellular respiration, which is the process that releases chemical energy stored in food molecules (including sugars) in order to generate usable energy for the cell. Mitochondria are found in nearly all eukaryotic cells.

How do these cell parts work together?

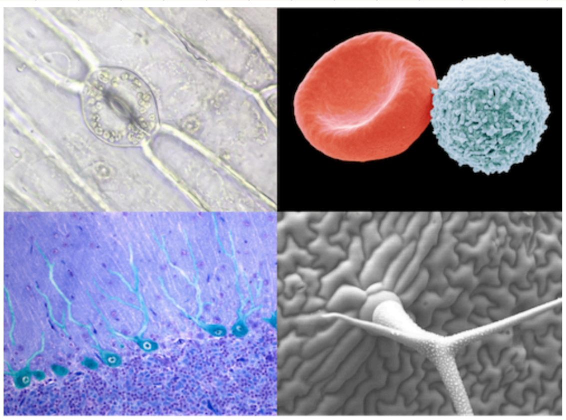
In plants, chloroplasts use photosynthesis to make energy-rich sugar molecules. These sugars can then be used by mitochondria in the same cell for cellular respiration, generating energy that the cell can use to carry out all the functions of life.

How are these cell parts related to cell specialization?

Eukaryotic cells in multicellular organisms are specialized to carry out specific functions. A cell's functions are often reflected in the make-up of its organelles. For example, muscle cells have large numbers of mitochondria in order to generate enough energy for movement. Similarly, plant cells that are exposed to sunlight (such as leaf surface cells) have many more chloroplasts than cells that are not exposed to sunlight (such as root cells).

Multicellular organisms are made up of specialized cells

Multicellular organisms are made up of various types of specialized cells, such as muscle, nerve, and skin cells. Each type of specialized cell has a unique structure and function. This allows each cell type to carry out a specific set of tasks needed for the survival, growth, and reproduction of the organism.



*Four examples of specialized cells, clockwise from top left: plant leaf guard cells, human red blood cell (left) and white blood cell (right), a single-celled plant leaf trichome, and human nerve cells. Image credits: "Leaf epithelium..." by Emilio Ermini, CC BY 4.0, "Arabidopsis..." by Emmanuel Boutet, CC BY-SA 2.5.

Specialized cells come from stem cells

The cells of multicellular organisms don't start out in their specialized forms. Instead, unspecialized cells are transformed into specialized cells through a highly regulated process called cellular differentiation.

The unspecialized cells that undergo differentiation are called stem cells. Stem cells have two defining characteristics:

- Potency describes the ability of stem cells to differentiate into specialized cells.

- Self-renewal describes the fact that stem cells can divide many times while remaining unspecialized.

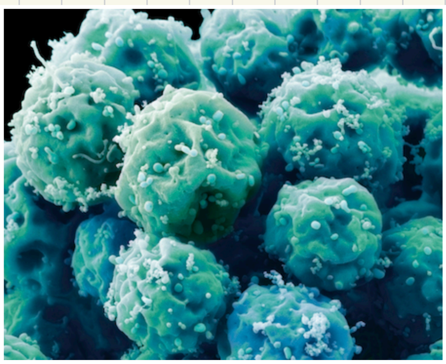
Stem cells are found in embryos, which are organisms in the early stages of development. For example, after 5-6 days of development, a human embryo is a mass of embryonic stem cells. Each cell has the ability to divide and differentiate into all the specialized cells of the body.

Stem cells are also found in several adult tissues, including in the lungs, intestines, and skin. The cells in these tissues are often damaged, so stem cells are needed for cell regrowth and tissue repair.

Stem cells are categorized based on their level of potency

Stem cells are grouped as totipotent, pluripotent, or multipotent based on their ability to differentiate into different cell types.

- Totipotent stem cells can give rise to all of the specialized cell types of an organism. Examples of totipotent stem cells include a fertilized human egg and the cells of its first few divisions, as well as the cells in the meristems (root and shoot tips) of plants.
- Pluripotent stem cells can differentiate into all of the body's cell types, except for the tissues surrounding the embryo. Embryonic stem cells are pluripotent.
- Multipotent stem cells are more limited in their potency. These stem cells, which include adult stem cells, can only become the cell types within a specific tissue. For example, intestinal stem cells can only differentiate to replace cells in the lining of the intestines.



SEM micrograph of embryonic stem cells

All cells in an organism have the same genetic material

Every cell in the body of a multicellular organism contains the same genetic information. This means that cell specialization does not involve gaining or losing genes from the nucleus. Instead, cells specialize by using only a subset of their genes both during and after differentiation. In other words, only certain genes are expressed, or used to make proteins, in a given cell type.

Stem cells in medicine

Stem cells are a key part of regenerative medicine—a field that utilizes medical techniques to generate healthy cells which can be used to replace diseased or injured cells. Researchers in this field are exploring ways of getting lab-grown stem cells to differentiate and grow into specific types of healthy tissues. These cells and tissues can then be transplanted into patients in need. Research into stem cell therapies have shown promise in treating conditions such as vision loss, spinal cord injuries, and heart disease.

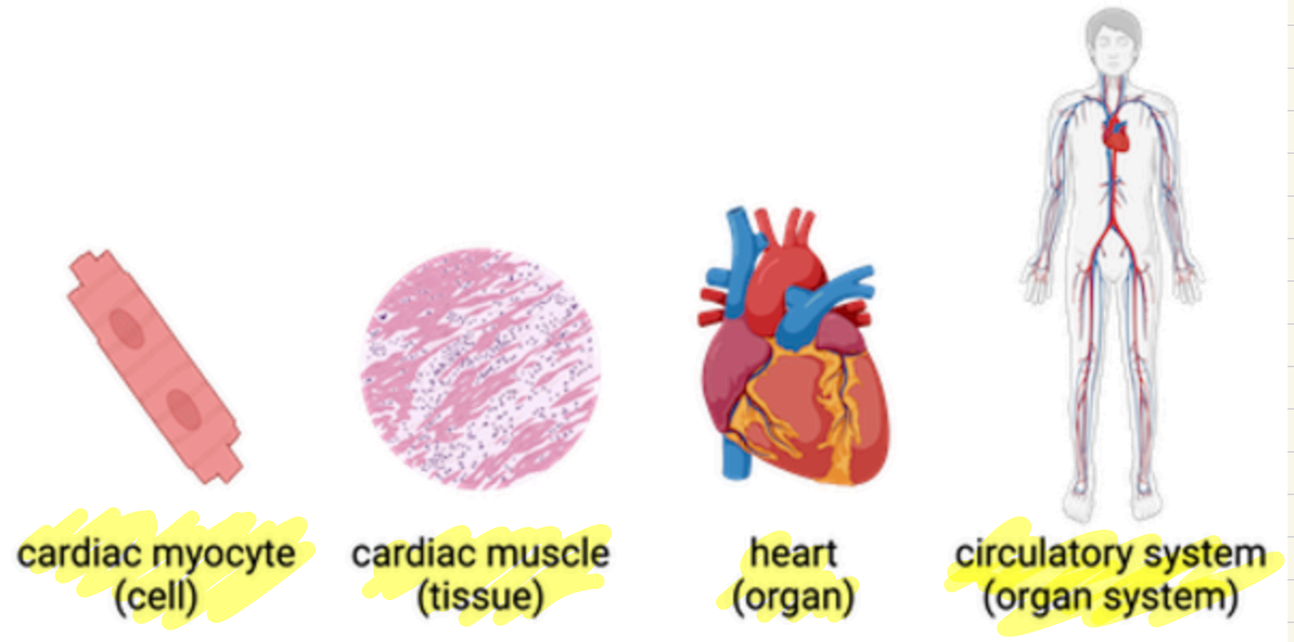
One stem cell therapy that is currently available is a bone marrow transplant. During this procedure, doctors harvest stem cells from a donor's bone marrow. These stem cells are then infused into a patient's body. Once inside the patient's body, the stem cells differentiate into various types of blood cells. This treatment can restore healthy blood cells to patients with blood cancer (such as leukemia) or other blood disorders.

Multicellular organisms have a nested organization

Humans and other complex multicellular organisms are made up of nested, interacting systems:

- Specialized cells make up tissues.
- Tissues make up organs.
- Organs make up organ systems.

Because of the way these different levels build on each other, we say that multicellular organisms have a hierarchical organization.



Four levels of organization in the human body: cardiac cells help make up cardiac muscle tissue, which helps make up the heart, which is part of the circulatory system. Created with Biorender.com.

Specialized cells make up tissues

In multicellular organisms, specialized cells come together to form tissues. A tissue is a group of similar cells that work together to carry out a specific function. There are four types of tissue in the human body: muscle, nervous, epithelial, and connective.

- Muscle tissue can contract (or shorten) and relax, which allows it to power nearly all types of movement in the body. Muscle tissue is made up of muscle cells, which are often called muscle fibers.

- Nervous tissue is involved in sensing stimuli (external or internal cues). It is also responsible for processing and transmitting information. Nervous tissue is made up of nerve cells (neurons) and support cells called glia.

- Epithelial tissue helps protect the body from pathogens, injury, and water loss. It consists of tightly packed sheets of cells that cover surfaces and line body cavities. For example, the outer layer of the skin and the lining of the intestine are epithelial tissues. Epithelial tissue is made up of epithelial cells, which have a polarized structure.

- Connective tissue supports and connects other tissues. It consists of cells suspended in an extracellular matrix, which is a network of proteins and other molecules that surround and support cells. Bone, cartilage, adipose (fat) tissue, and blood are all examples of connective tissue.

Tissues make up organs

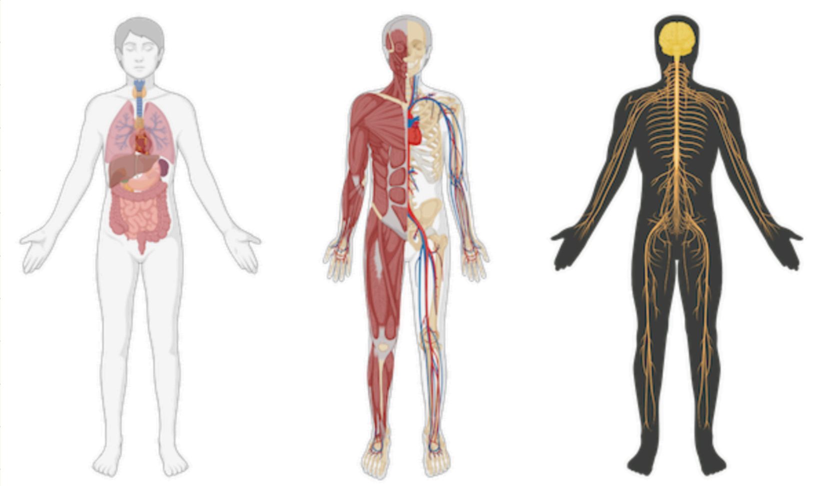
An organ is a structure made up of two or more tissues that work together to carry out a particular function. Examples of organs include the heart, which pumps blood, and the stomach, which helps digest food.

Organs make up organ systems

An organ system is a group of related organs that work together to carry out complex tasks in an organism. There are several major organ systems in the body, including the muscular, skeletal, respiratory, digestive, circulatory, and nervous systems.

Organ systems work together to carry out organism-level functions

Organ systems interact in complex ways to allow the body to carry out organism-level functions. These functions include taking in and getting energy from food, reproducing, and moving in response to environmental cues.



The body is made up of multiple organ systems that work together to carry out organism-level functions. The digestive and respiratory systems (left) help cells get the nutrients and oxygen they need. The skeletal and muscular systems (center left) allow an organism to move, while the circulatory system (center right) brings the muscles the oxygen they need for energy. The nervous system (right) helps an organism sense and respond to its environment. Created with Biorender.com.

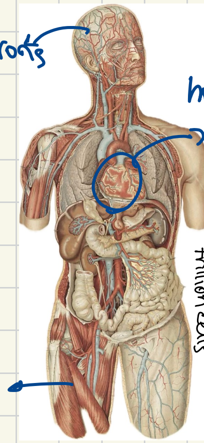
notes

o y-o

toti potent → (only one cell!)

fertilized egg

normal adult



neurons

heart cells

bone cell

around 30-40 trillion cells

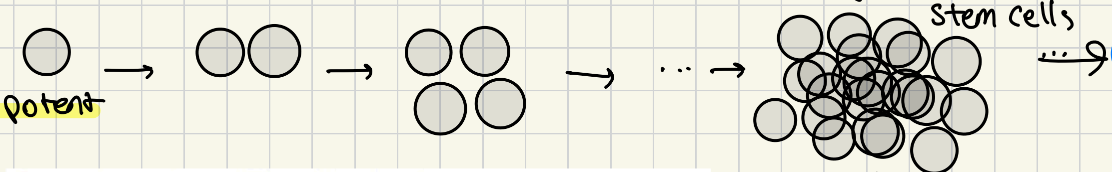
- we all started as a fertilized egg!
- how did we come from 1 egg? →
  ↳ this boils down to Stem Cells

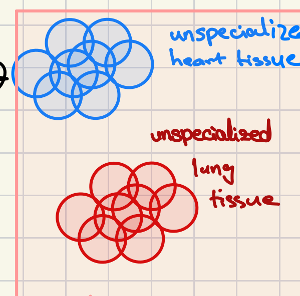
- Stem cells have the ability to differentiate into specialized cells, but also have self-renewal; that they divide as many times while remaining unspecialized

- fertilized egg cell

toti potent

Embryonic stem cells





called multi potent

They have the ability to become more differentiated and specialized

Stem cells can have different levels of potency.

Potency describes a stem cell's ability to differentiate into different cell types. Some stem cells (such as pluripotent stem cells) have the ability to differentiate into more cell types than other types of stem cells (such as multipotent stem cells).

pluri potent

They can differentiate to all body cell type, except for the embryonic stem cells.

Question: How these cells become different types of specialized cells?

- All cells have DNA, and the same DNA, but cells show different types of combination of them.

- specialized cells _ the unit block of any living organism

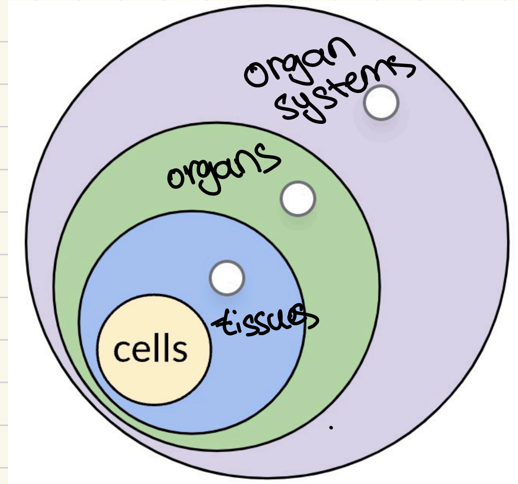
cells → tissue → organ → system → organism

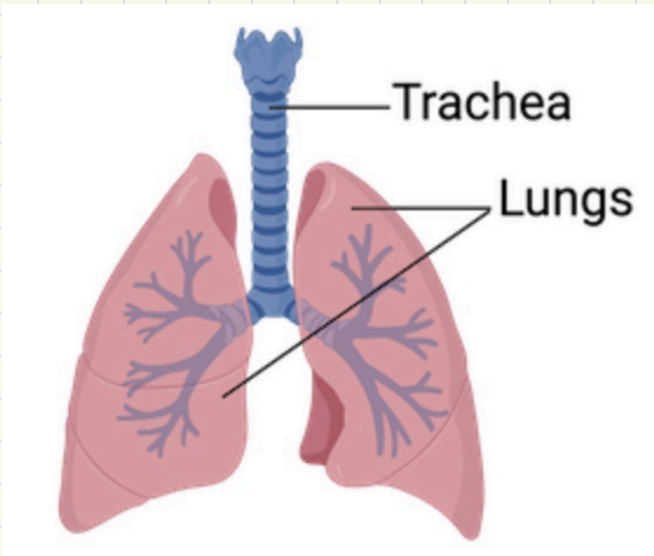
- cells ↳ basic building block
- tissue ↳ Combination of specialized cells
- organ ↳ groups of tissues
- system ↳ organs together with the same mission
- organism ↳ the whole living organism

example: neuron (or nerves) cells → neuron tissue → brain → nervous system → human body

So, the systems correctly ordered from least to most complex (starting from the top) are: cell, tissue, organ, organ system, and organism.

Tissue	Function
muscle	contraction and movement
nervous	sensing, processing, and transmitting information
connective	supporting and connecting other tissues
epithelial	protection from pathogens, injury, and water loss





The lungs and trachea are both organs of the respiratory system. When a person breathes in, air flows into the trachea. The air then moves through increasingly smaller airways into the lungs where gas exchange occurs.
The functions of these organs are aided by their structures: the trachea contains cartilage, which helps it maintain its shape. The airways in the lungs contain smooth muscle and elastic fibers, allowing them to expand and contract when a person breathes. The airways are lined with tightly packed, mucus-producing cells. Blood vessels run throughout the lungs, allowing for gas exchange.
Nerves are also found throughout the lungs, which allows the breath to be regulated by the nervous system.

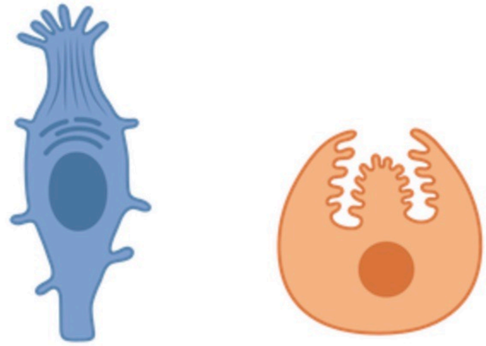
Q: Based on the passage, which type of tissue produces mucus in the airways of the lungs?

A: epithelial tissue

The mucus-producing cells are described as tightly packed and lining the airways in the lungs. This describes epithelial tissue.

Q: The parts of the body listed below are involved in breaking down and absorbing nutrients from food.

A: Multicellular organisms have a nested organization—they are made up of interacting parts that build on one another. With each successive level of organization, complexity increases.
The most foundational level of organization in an organism is its cells. So, parietal cell is the least complex part of the body listed above.
Cells make up tissues, so the next most complex part of the body listed above is epithelial tissue.
Tissues make up organs. So, the next most complex part of the body listed above is the stomach, which is an organ in the digestive system.
The digestive system is made up of multiple organs, and so is the most complex part of the body listed above.
The parts correctly ordered from least to most complex (starting from the top) are: parietal cell, epithelial tissue, stomach, and digestive system.



a tuft cell (left) and a parietal cell (right)

Statement	True or false?
Both the tuft cell and the parietal cell arose from stem cells.	true
The tuft cell and the parietal cell likely carry out different functions for the organism.	true
Both the tuft cell and the parietal cell express the same set of proteins.	false

---

Key terms - The circulatory system

Circulatory system: The body system responsible for carrying blood, nutrients, and waste throughout the body
Cardiac: Related to the heart
Pulmonary: Related to the lungs
Artery: Blood vessel that moves blood away from the heart
Vein: Blood vessel that moves blood toward the heart
Aorta: Major artery that carries blood to the systemic circulatory system
Capillary: Small blood vessel that allows nutrient exchange
Atrium: Upper chamber of the heart
Ventricle: Lower chamber of the heart

The circulatory system

→ A system responsible for carrying blood, nutrient, & waste throughout the body.

The circulatory system is a network consisting of blood, blood vessels, and the heart. This network supplies tissues in the body with oxygen and other nutrients, transports hormones, and removes unnecessary waste products.

The heart

specialized cell → cardiac tissue → heart → circulatory system

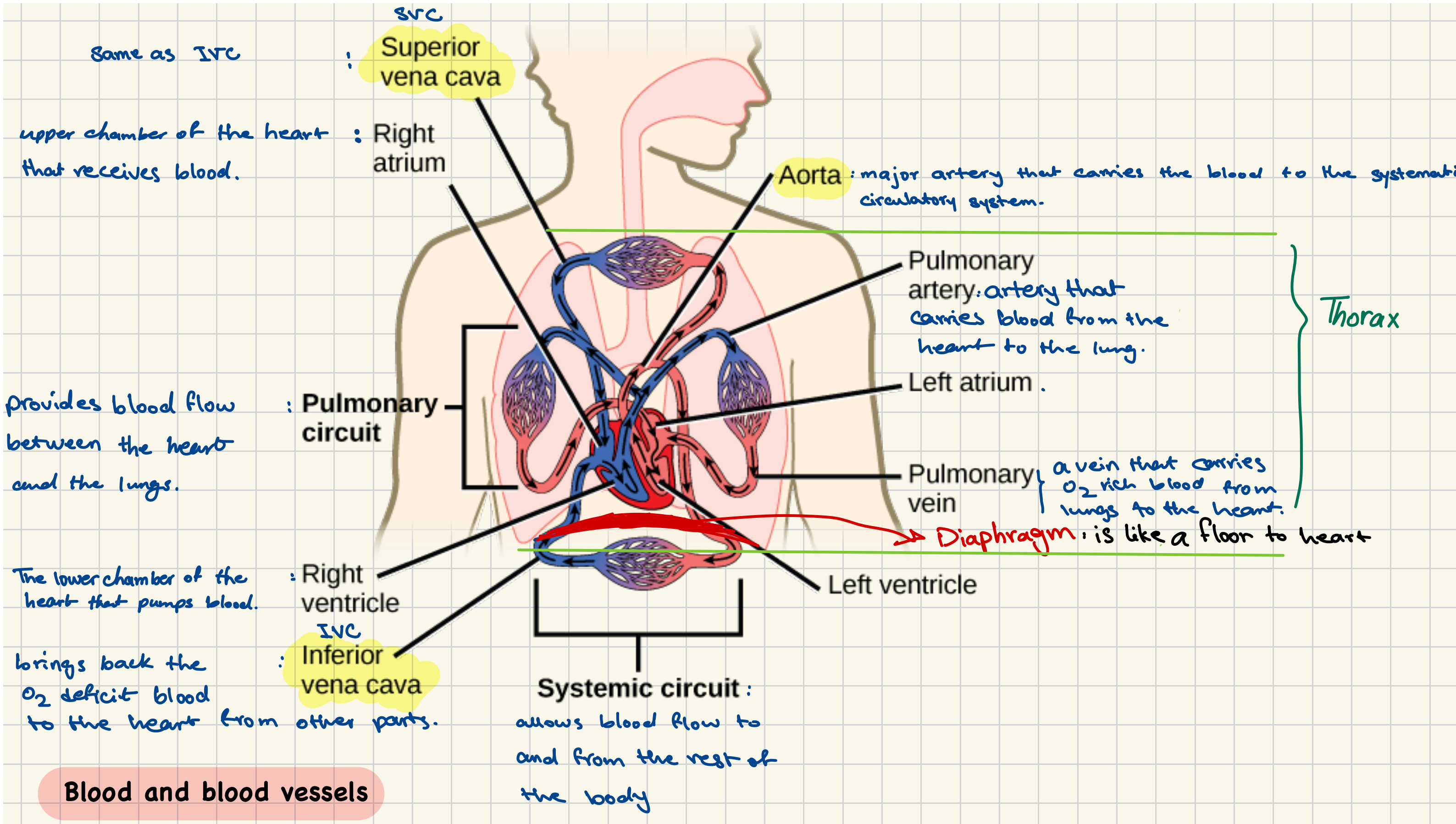
The heart is made of specialized cardiac muscle tissue that allows it to act as a pump within the circulatory system.

The human heart is divided into four chambers. There are one atrium and one ventricle on each side of the heart. The atria receive blood and the ventricles pump blood.

There are one atrium and one ventricle on each side of the heart
Atrium: receives blood, ventricle: pumps blood

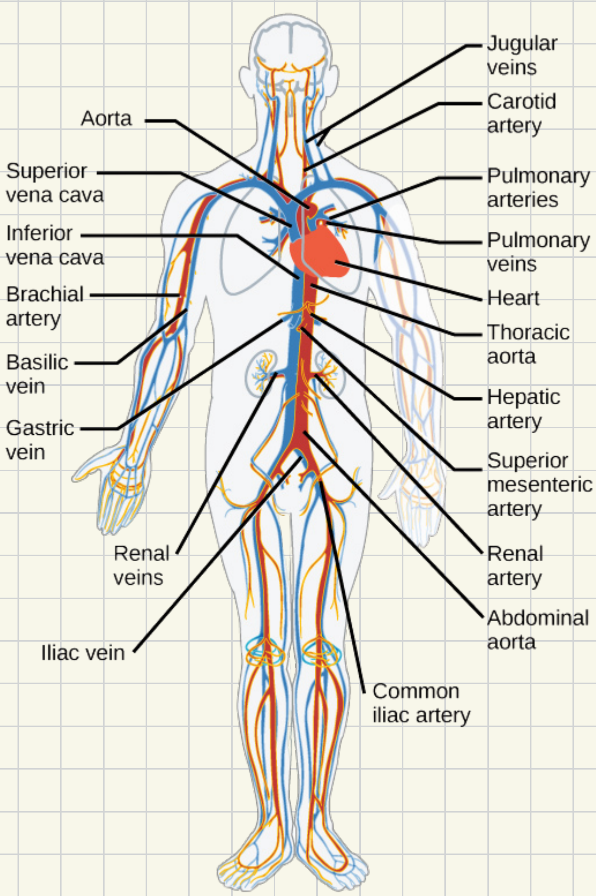
The human circulatory system consists of several circuits:

- The pulmonary circuit provides blood flow between the heart and lungs.
- The systemic circuit allows blood to flow to and from the rest of the body.
- The coronary circuit strictly provides blood to the heart (not pictured in the figure below).

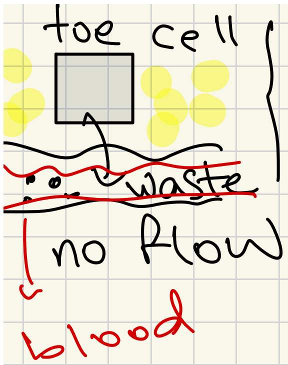


Blood and blood vessels

Blood from the heart is pumped throughout the body using blood vessels. Arteries carry blood away from the heart and into capillaries, providing oxygen (and other nutrients) to tissue and cells. Once oxygen is removed, the blood travels back to the lungs, where it is reoxygenated and returned by veins to the heart.



The main artery of the systemic circuit is the aorta which branches out into other arteries, carrying blood to different parts of the body.



- O_2
- nutrient

they need

- CO_2

they produce

↳ - Blood brings in O_2 & nutrient
- Blood takes away waste

The flow needs a strong pump → heart

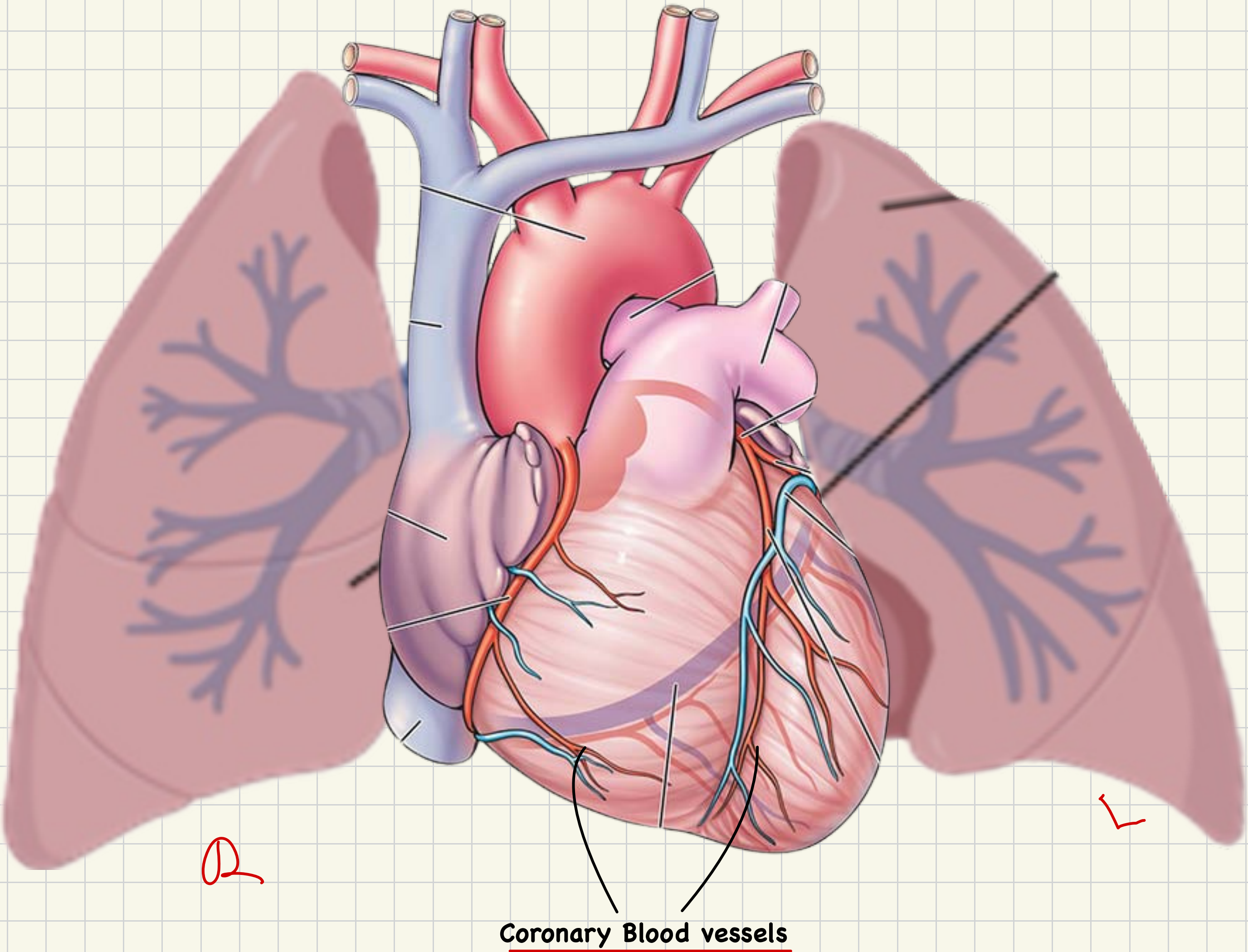
Heart's Job

1. Systemic Flow
2. Pulmonary Flow

- we know that cells need oxygen. And that they have a lot of CO_2 waste. cells need blood + O_2, if just blood flows, not gonna be useful → lungs come in. heart sends the blood to the left lung and right lung, and blood comes back, pushed back to the heart, squeeze through the aorta.

---

blood going to lungs and coming back → pulmonary flow



Systemic Flow

Common mistakes and misconceptions

Incorrect: Arteries always carry oxygenated blood and veins always carry deoxygenated blood.
Correct: It is true most of the time arteries carry oxygenated blood and veins carry deoxygenated blood. However, the pulmonary arteries and veins are an exception to this rule. Pulmonary veins carry oxygenated blood towards the heart and the pulmonary arteries carry deoxygenated blood away from the heart.

Incorrect: Blood can be red or blue, depending on its oxygenation status.
Correct: Blood is always red. Veins can appear blue as we see them through our skin, leading some people to believe that deoxygenated blood is blue. However, this is not the case! Blood only appears blue because of the way tissues absorb light and our eyes see color. Although oxygen does have an effect on the brightness of the blood (more oxygen makes a brighter red, less makes it darker), blood is never actually blue.

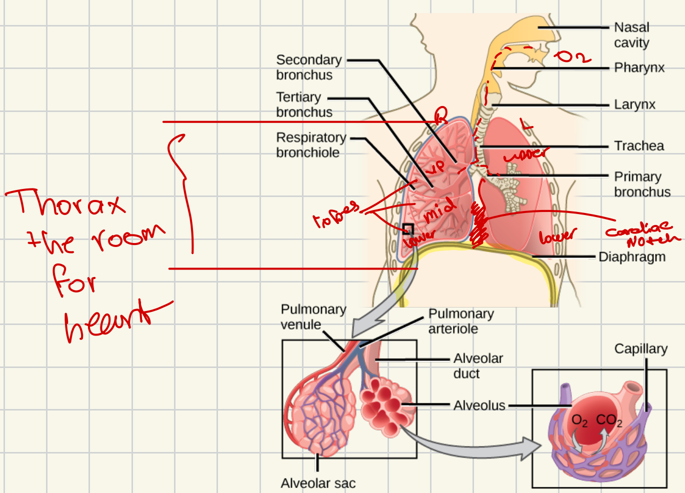
Key terms - The raspiratory system

Respiratory system: The body system responsible for gas exchange between the body and the external environment
Pharynx (throat): Tube connected the nose/mouth to the esophagus
Larynx (voice box): Tube forming a passage between the pharynx and trachea
Trachea: Tube connecting the larynx to the bronchi of the lungs
Bronchi: Branches of tissue stemming from the trachea
Bronchiole: Airway that extends from the bronchus
Alveoli: Structures of the lung where gas exchange occurs
Diaphragm: Thoracic muscle that lays beneath the lungs and aids in inhalation/exhalation

The respiratory system

The process of physiological respiration includes two major parts: external respiration and internal respiration. External respiration, also known as breathing, involves both bringing air into the lungs (inhalation) and releasing air to the atmosphere (exhalation). During internal respiration, oxygen and carbon dioxide are exchanged between the cells and blood vessels.

Respiration begins at the nose or mouth, where oxygenated air is brought in before moving down the pharynx, larynx, and the trachea. The trachea branches into two bronchi, each leading into a lung. Each bronchus divides into smaller bronchi, and again into even smaller tubes called bronchioles. At the end of the bronchioles are air sacs called alveoli, and this is where gas exchange occurs.



An important structure of respiration is the diaphragm. When the diaphragm contracts, it flattens and the lungs expand, drawing air into the lungs. When it relaxes, air flows out, allowing the lungs to deflate.

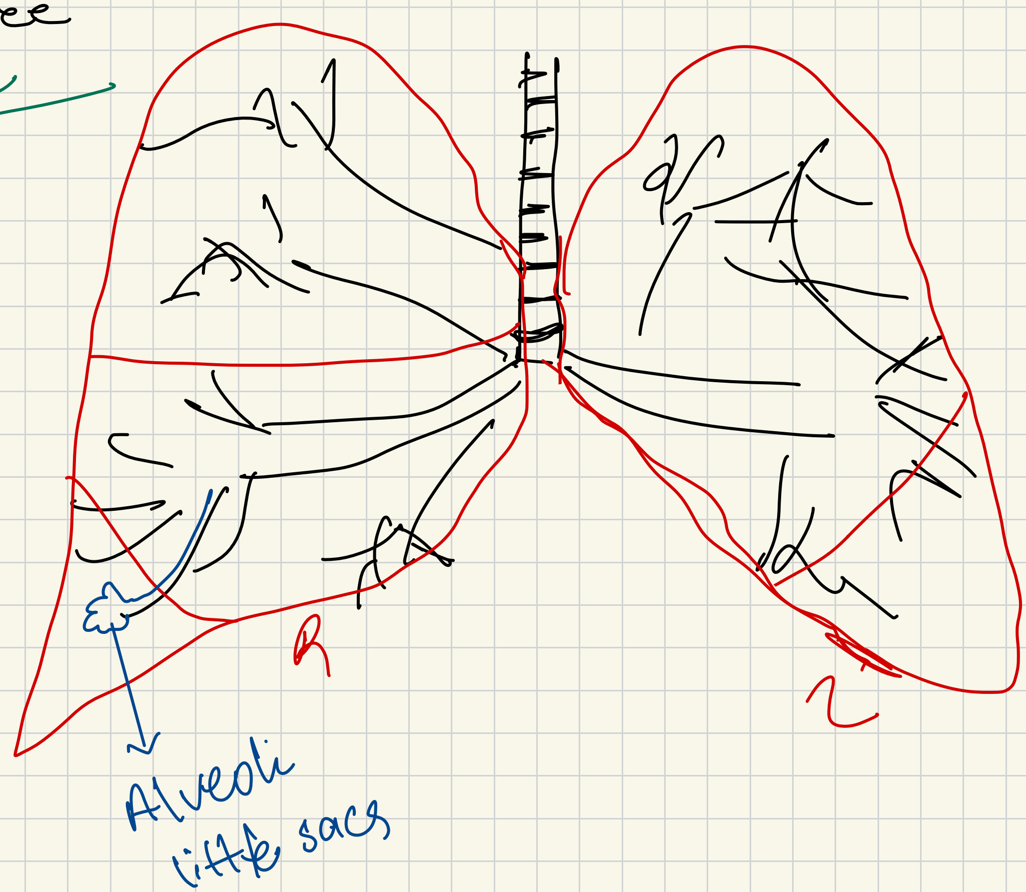
Common mistakes and misconceptions

Incorrect: Physiological respiration and cellular respiration are the same thing.
Correct: People sometimes use the word "respiration" to refer to the process of cellular respiration, which is a cellular process in which carbohydrates are used to generate usable energy. Physiological respiration and cellular respiration are related processes, but they are not the same.

Incorrect: We breathe in only oxygen and breathe out only carbon dioxide.
Correct: Often the terms "oxygen" and "air" are used interchangeably. It is true that the air we breathe in haas more oxygen than the air we breathe out, and the air we breathe out has more carbon dioxide than the air that we breathe in. However, oxygen is just one of the gases found in the air we breathe. (In fact, the air has more nitrogen than oxygen!)

Incorrect: The respiratory system works alone in transporting oxygen through the body.
Correct: The respiratory system works directly with the circulatory system to provide oxygen to the body. Oxygen taken in from the respiratory system moves into blood vessels that then circulate oxygen-rich blood to tissues and cells.

- if we look at the lungs and vessels, they look like an upside down tree → the vessels are called Bronchial Tree



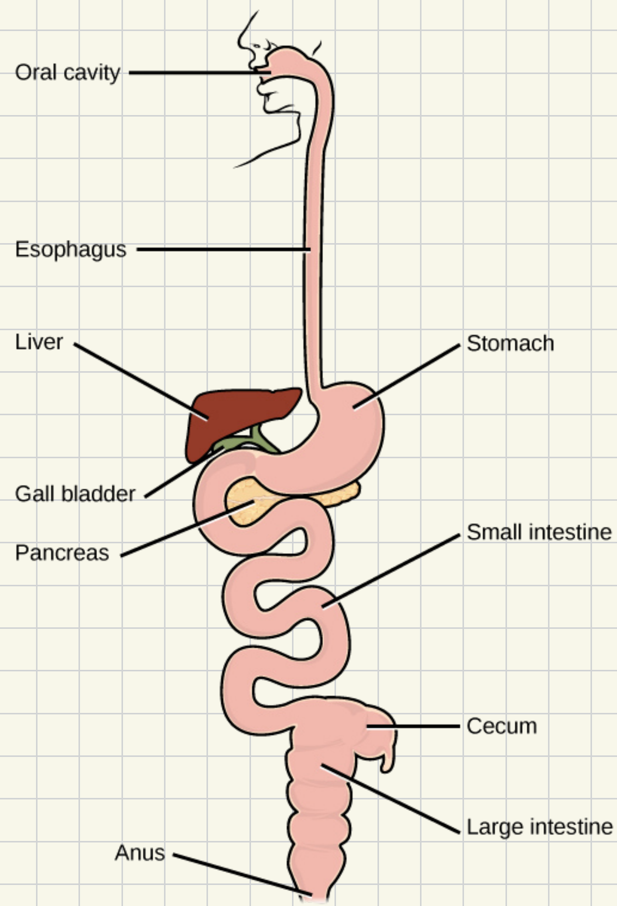
Key terms - The digestive system

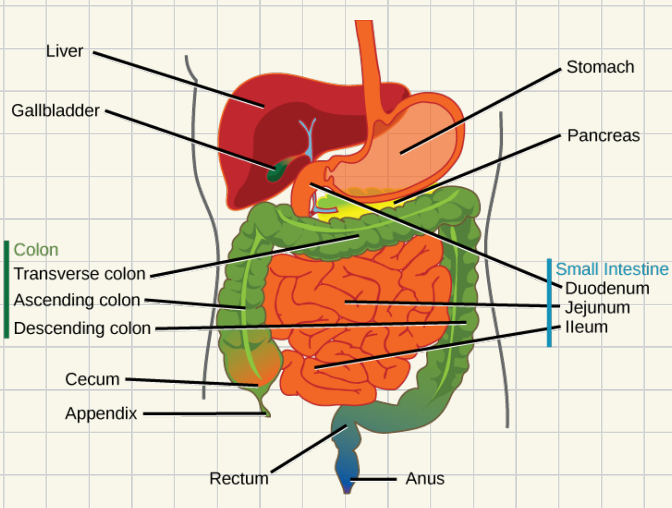
Digestive system: The body system that converts food into energy and nutrients to fuel the body
Chemical digestion: The breaking down of food using chemical agents, such as enzymes and bile
Mechanical digestion: The breaking down of food by physical means, such as chewing
Absorption: The process by which nutrients pass through the walls of the digestive system into the blood
Excretory system: The body system that removes metabolic wastes from the body
Excretion: The process of removing wastes and excess water from the body

The digestive system

The human digestive system breaks food down into small molecules that can be used by cells in the body.

Digestion begins when food enters the mouth (oral cavity). Both mechanical and chemical digestion occur in the mouth. Teeth grind and break up food (mechanical), while an enzyme in saliva called amylase begins to break down carbohydrates (chemical).
After it is swallowed, the chewed food (now called a bolus) moves down the esophagus. The esophagus acts as a connection between the mouth and the stomach, but no digestion occurs here.
The bolus then reaches the stomach, where more mechanical and chemical digestion take place. The muscles in the stomach walls churn the bolus (mechanical), allowing it to mix with digestive enzymes and gastric acids (chemical). This process converts the bolus into a liquid called chyme.
Digestion continues in the stomach for several hours. During this time, an enzyme called pepsin breaks down most of the protein in the food.





The chyme is slowly transported into the small intestine, where most chemical digestion takes place. Bile, which is made in the liver, is released from the gallbladder to help digest fats. In addition, enzymes from the pancreas and intestinal walls combine with the chyme to start the final part of digestion.

Most nutrient absorption occurs in the small intestine. Nutrients are absorbed through its walls into the circulatory system and by the time the chyme exits the small intestine, only water and indigestible substances are left behind.

The chyme then enters the large intestine. Here, water is removed and bacteria break down some indigestible materials, producing important compounds (such as vitamin K). The concentrated waste material that remains is called feces, which is passed into the rectum and eliminated from the body through the anus.

Accessory organs

Accessory organs help with digestion but are not part of the digestive tract. These include:

- Salivary glands: moisten food and begin chemical digestion of starches.
- Liver: creates bile for fat digestion, detoxifies blood, processes absorbed vitamins
- Gallbladder: stores bile produced by the liver
- Pancreas: secretes pancreatic juices to help digestion of proteins and carbohydrates

The excretory system

The excretory system removes metabolic wastes from the body.

The major organs of excretion are the kidneys, a pair of bean-shaped organs located below the liver. The kidneys filter blood and regulate water balance in the body.

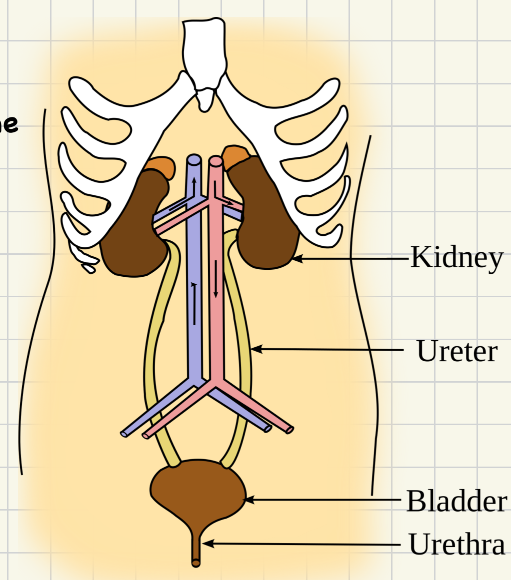
There are several other organs that are also involved in excretion, including:

- the skin, which removes excess water and salt via sweat,
- the lungs, which exhale carbon dioxide, and
- the liver, which breaks down toxic substances in the blood and convert nitrogenous waste into urea

Urinary tract

The urinary tract is a major part of the excretory system. It filters wastes and water from the blood, and eliminates them from the body.

The kidneys produce a waste product called urine using special functional units called nephrons. The urine is then excreted from the body. This process takes place in three steps:



1. Filtration: Blood enters a nephron, which filters out impurities.
2. Reabsorption: The impurities move through tubules, while the rest of the blood is reabsorbed through capillary walls into the blood.
3. Excretion: Urine is transported from the kidneys through the ureters and into the urinary bladder. It remains stored in the bladder until it is released through the urethra.

Common mistakes and misconceptions

Incorrect: Digestion begins in the stomach.
Correct: While some digestion occurs in the stomach, the process actually begins in the mouth, where chewing and salivary amylase act on the food.

Incorrect: The digestive system produces urine.
Correct: Some people think that the digestive system has two outlets—one for feces and one for urine. However, urine is a product of the excretory system, not the digestive system.

Incorrect: The small intestine is shorter than the large intestine.
Correct: The small intestine is actually longer than the large intestine. In fact, at approximately 20 feet in length, the small intestine is nearly four times as long as the large intestine (5 feet long)! However, the intestines are named for their diameters, not their lengths. The large intestine has a diameter of about 3 inches compared to the small intestine, with a diameter of about 1 inch.

Key terms - The nervous system

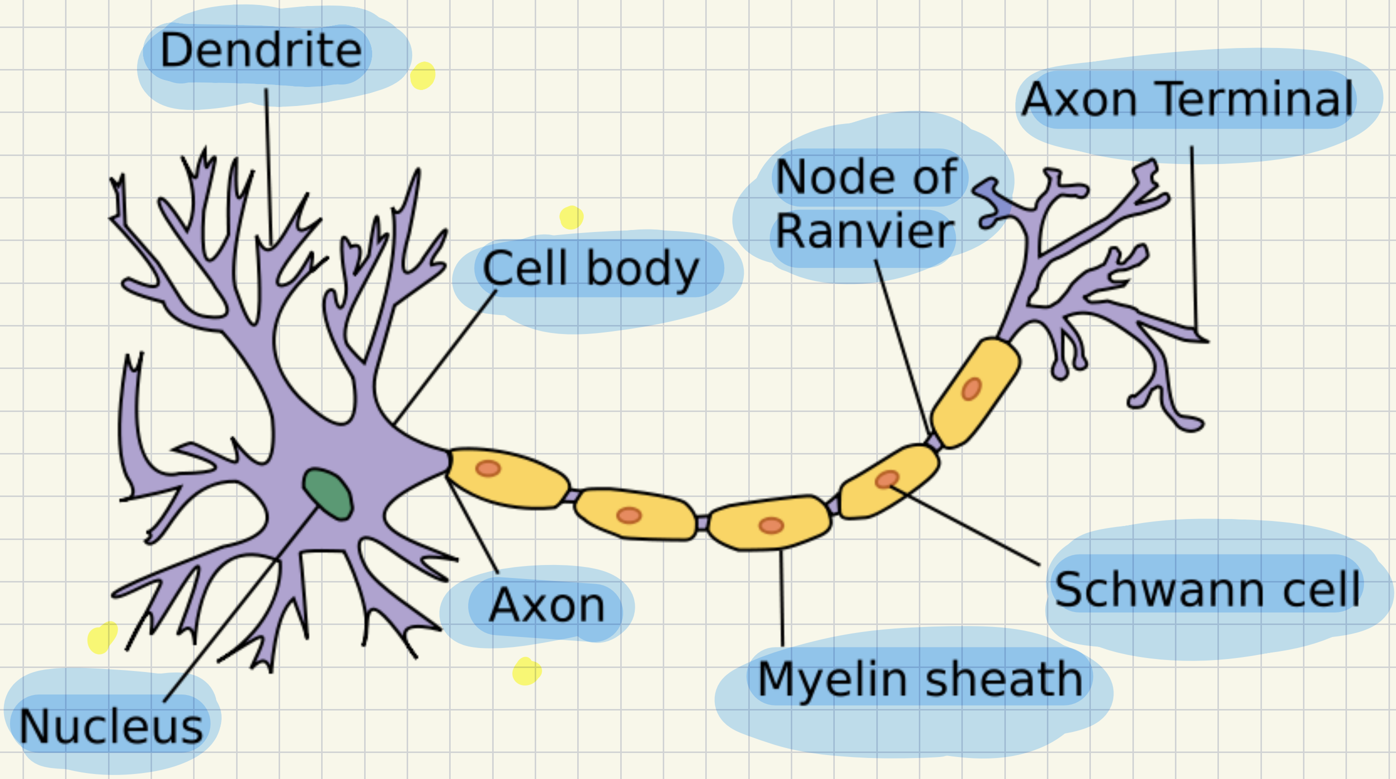
Nervous system: The body system that collects, processes, and responds to information using electrical signals
Neuron: A nerve cell; the basic unit of the nervous system neuron → nerve tissue → brain → nervous system
Glial cell: A cell that supports and protects neurons
Central nervous system: Part of the nervous system containing the brain and spinal cord
Peripheral nervous system: Part of the nervous system containing associated nerves that are not part of the brain or spinal cord
Endocrine system: The body system that regulates cells and organs using chemical substances called hormones
Hormone: Chemical messenger that acts as a regulatory substance
Gland: Organ that secretes chemical substances, such as hormones

The nervous system

The nervous system uses electrical impulses to collect, process and respond to information about the environment.

Nervous system cells

The unique structure of neurons makes them specialized for receiving and transmitting electrical impulses throughout the body. Neurons are supported by glial cells, which surround, protect, and insulate them.



All neurons have several features in common, including a cell body, dendrites, and an axon. These structures are important for transmitting neural impulses, electrical signals that allow neurons to communicate with one another.

Neurons are specialized, depending on their required functions:

- Sensory neurons carry impulses from sense organs, such as the eyes or ears.
- Motor neurons carry impulses to muscles and glands.
- Interneurons transfer signals between sensory and motor neurons, as well as in between other interneurons.

In a resting neuron, there is a separation of ions in the cell regulated by sodium-potassium pumps. If a neuron receives a large enough signal, the resting potential changes, producing an electrical impulse called an action potential. Once an impulse begins, it moves down the axon until it reaches the axon terminal.

Parts of the nervous system

The nervous system is made up of two parts: the central nervous system (CNS) and the peripheral nervous system (PNS).

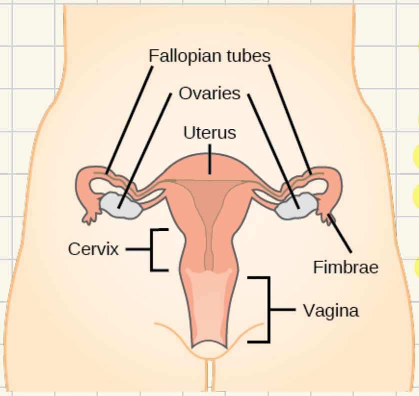
brain and spinal cord

all other neurons that are not a part of brain and spinal cord.

Key terms - Reproductive Systems

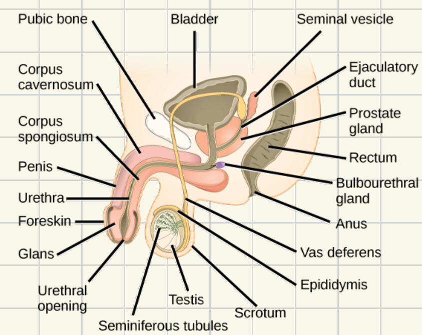
Gamete: A reproductive (sex) cell. In males, sperm; in females, eggs
Puberty: Process during which adolescents reach sexual and reproductive maturity
Testes: Male reproductive gland that produces sperm and male hormones
Ovaries: Female reproductive gland that produces eggs and female hormones
Menstrual cycle: Pattern of events in females involving the development and release of an egg
Fertilization: The process in sexual reproduction in which a male gamete and female gamete fuse to form a new cell

The female reproductive system



Ovaries: Produces and develops eggs
Fallopian tubes (oviducts): Transports egg to uterus, acts as site of fertilization
Uterus: Supports a developing embryo
Cervix: Allows passage between the uterus and the vagina
Vagina: Receives penis during intercourse, acts as birth canal, passes menstrual flow
Breasts: Produce and deliver milk

During puberty, the hypothalamus signals the pituitary gland to produce two hormones, follicle-stimulating hormone (FSH) and luteinizing hormone (LH). In females, FSH and LH stimulate the ovaries to produce the female sex hormones, estrogen and progesterone. This results in the development of secondary sex characteristics (such as breasts), and causes the ovaries to begin producing mature eggs.
Egg release (ovulation) occurs approximately every 28 days, and is part of a larger process called the menstrual cycle. If an egg is fertilized after ovulation, it attaches to the wall of the uterus and embryonic development begins.
If an egg is not fertilized (or a fertilized egg does not attach to the wall of the uterus), the egg and the lining of the uterus are discharged from the body.



The male reproductive system

Testes: Produce sperm and male hormones
Scrotum: Supports testes and regulates their temperature
Seminal vesicle: Contribute fluids to semen production
Prostate gland: Secretes prostate fluid (component of semen), aids in ejaculation
Epididymis: Stores mature sperm
Vas deferens: Transports sperm from epididymis
Penis: Transfers sperm into female

Puberty begins the same way in males as it does in females: the hypothalamus signals the pituitary gland to produce FSH and LH.

In males, LH stimulates the testes to produce testosterone, and with FSH, causes sperm development to occur. Testosterone is also responsible for the development of secondary male sex characteristics, such as a deepened voice and growth of body hair.

Common mistakes and misconceptions

Incorrect: Fertilization occurs in the uterus or vagina.
Correct: Fertilization occurs in the fallopian tube (oviduct) of the female reproductive system. Once fertilized, the egg attaches to the lining of the uterus. It becomes a ball of cells over time, then develops in the uterus of the female to become a baby.

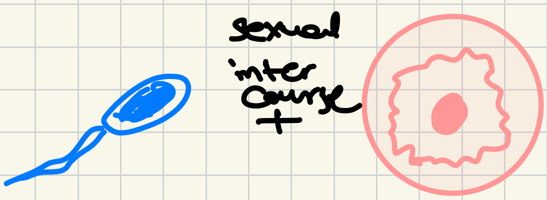
Incorrect: Both males and females are born with reproductive sex cells.
Correct: Only females are born with reproductive sex cells. Females are born with immature eggs already in their ovaries. When puberty occurs, the eggs mature and are released by the ovaries. Males only produce sperm after reaching puberty.

Incorrect: Females urinate through the vagina.
Correct: In men, both semen and urine pass through the urethra, a passageway that terminates at the end of the penis. Females urinate through a urethra as well, but it is not connected to their vaginal opening. The female urethra is located above the vagina and urine may pass over or around the opening, but the two passageways are not connected.

•NOTES•

Reproductive system – system that includes sex organs and some parts of our brain.

Combining Genetic materials – making babies



Pregnancy

1. sperm + egg ⟶ zygote : the first cell that has genetic materials from both mom & dad.
2. implants into the uterus
3. gestation : the developments of the fetus into a baby and its organs

sex Organs

male

Testes : produce sperm

Penis : delivers sperm

female

ovary : produce eggs (x2)

Uterus : where babies develop

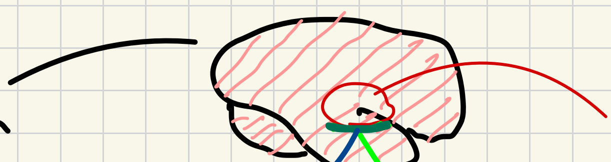
Breasts : lactation → hormones

vegina : where sperm & egg meet

• not only sex organs, we also have chemicals helping in the reproductive system – Hormones – sex hormone

Testostron : Body hair, ...
produced in testes,
responsible for masculinity traits.

Estrogen & Progesteron : egg release
produced in ovaries
development of feminine traits
↳ breast development . e.g.



Job : releases hormones
one's name is gonadotropin releasing hormone or GNRH.

affects another part of the brain called anterior pituitary.

Sits right under the hypothalamus

releases two hormones in response to GNRH :
1. Luteinizing Hormone : LH
2. Follicle simulating Hormone : FSH
↳ affects the sex organs!

Key Terms - The Immune System

Pathogen: A disease-causing organism, including bacteria,
Antigen: Molecule that stimulates an immune response
Innate immune system: Non-specific immune system
Adaptive immune system: Antigen-specific immune system
Antibody: Specialized Y-shaped protein that tags antigens for destruction
B cells: White blood cells that produce antibodies and aid in immunological memory
T cells: White blood cells specialized to assist B cells (helper T cells), or to directly kill infected cells (killer T cells)
Humoral immunity: Adaptive immune defense depending on the action of antibodies
Cell-mediated Immunity: Adaptive immune defense in which foreign cells are destroyed by T cells
Virus: Nonliving particle containing protein and DNA/RNA that can infect a living cell
Vaccine: A killed or weakened form of a pathogen that produces immunity when injected into the body

Infectious disease

Infectious diseases are caused by viruses, bacteria, fungi, protists, and other pathogens.
Pathogens are often spread through coughing, sneezing, and physical contact between people. They can also be spread through contamination of water supply, or through the exchange of body fluids, including sexual intercourse or blood transfusions

Nonspecific defense: the innate immune system

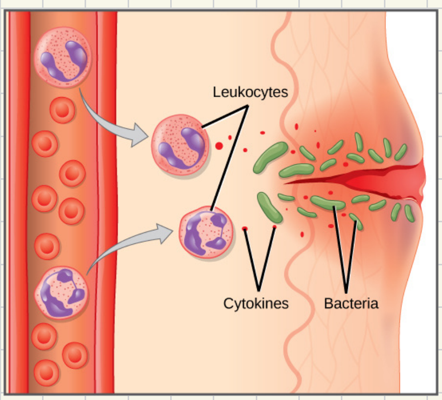
The human body has a series of nonspecific defenses that make up the innate immune system. These defenses are not directed against any one pathogen but instead, provide a guard against all infection.

First line of defense

The body's most important nonspecific defense is the skin, which acts as a physical barrier to keep pathogens out. Even openings in the skin (such as the mouth and eyes) are protected by saliva, mucus, and tears, which contain an enzyme that breaks down bacterial cell walls.

Second line of defense

If a pathogen does make it into the body, there are secondary nonspecific defenses that take place.



An inflammatory response begins when a pathogen stimulates an increase in blood flow to the infected area. Blood vessels in that area expand, and white blood cells leak from the vessels to invade the infected tissue. These white blood cells, called phagocytes engulf and destroy bacteria. The area often becomes red, swollen, and painful during an inflammatory response. When a pathogen has invaded, the immune system may also release chemicals that increase body temperature, producing a fever. Increased body temperature may slow or stop pathogens from growing and helps speed up the immune response.

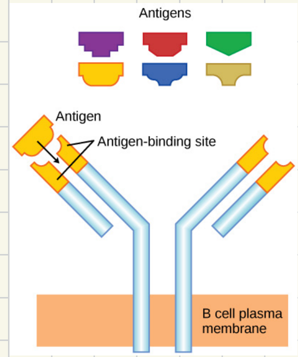
Specific defense: the adaptive immune system

When pathogens are able to bypass innate immune defenses, the adaptive immune system is activated.

Cells that belong in the body carry specific markers that identify them as "self" and tell the immune system not to attack them.

Once the immune system recognizes a pathogen as "non-self," it uses cellular and chemical defenses to attack it. After an encounter with a new pathogen, the adaptive immune system often "remembers" the pathogen, allowing for a faster response if the pathogen ever attacks again.

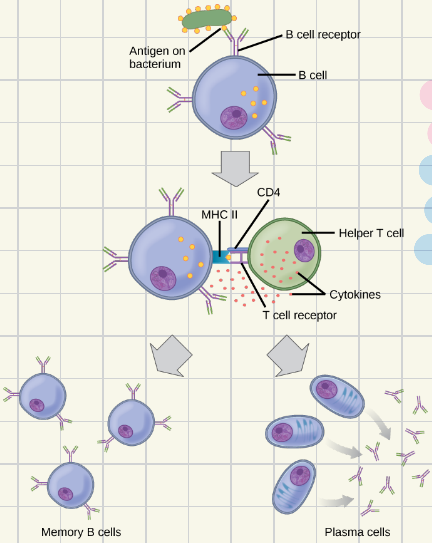
Specific immune responses are triggered by antigens. Antigens are usually found on the surface of pathogens and are unique to that particular pathogen. The immune system responds to antigens by producing cells that directly attack the pathogen, or by producing special proteins called antibodies. Antibodies attach to an antigen and attract cells that will engulf and destroy the pathogen.



The main cells of the immune system are lymphocytes known as B cells and T cells. B cells are produced and mature in bone marrow. T cells are also produced in bone marrow, but they mature in the thymus.

Humoral immunity

Humoral immunity relies on the actions of antibodies circulating through the body.



Humoral immunity begins when an antibody on a B cell binds to an antigen. The B cell then internalizes the antigen and presents it to a specialized helper T cell, which in turn activates the B cell.
Activated B cells grow rapidly, producing plasma cells, which release antibodies into the bloodstream, and memory B cells, which store information about the pathogen in order to provide future immunity.

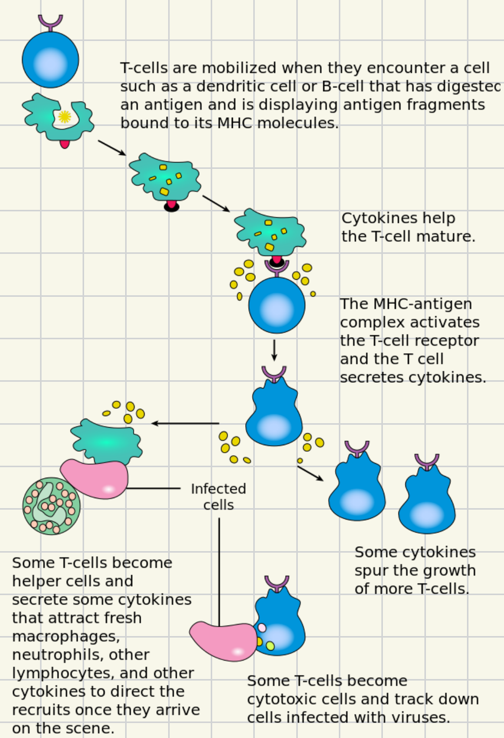
Cell-mediated immunity

Antibodies alone are often not enough to protect the body against pathogens. In these instances, the immune system uses cell-mediated immunity to destroy infected body cells.

T cells are responsible for cell-mediated immunity. Killer T cells (cytotoxic T cells) assist with the elimination of infected body cells by releasing toxins into them and promoting apoptosis. Helper T cells act to activate other immune cells.

Vaccines

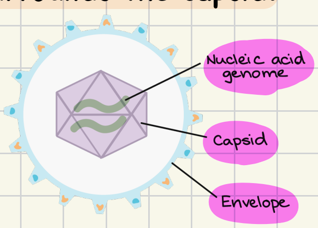
Vaccines work by taking advantage of antigen recognition and the antibody response. A vaccine contains the antigens of a pathogen that causes disease. For example, the smallpox vaccine contains the antigens specific to smallpox. When a person is vaccinated against smallpox, the immune system responds by stimulating antibody-producing cells that are capable of making smallpox antibodies. As a result, if the body comes into contact with smallpox in the future, the body is prepared to fight it.



Viral structure

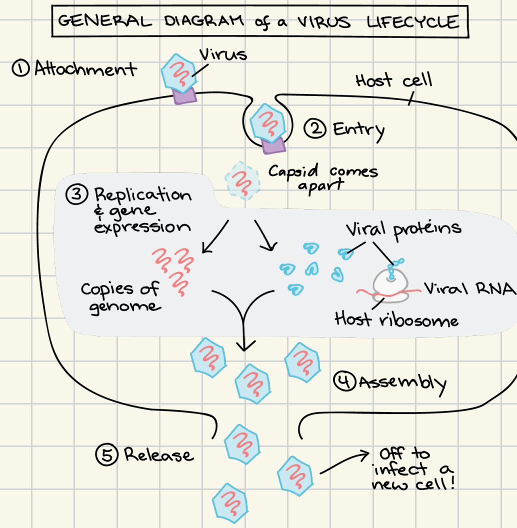
Viruses are infectious particles that reproduce by hijacking a host cell and using its machinery to make more viruses.

There are many kinds of viruses, differing in structure, genome, and host specificity. However, viruses tend to have several features in common. All viruses contain a protective protein shell, or capsid, that houses their nucleic acid genome (either DNA or RNA).
Some viruses also have a membrane layer called an envelope that surrounds the capsid.



Steps of viral infection

Viruses reproduce by infecting their host cells, providing instructions in the form of viral DNA or RNA, and then using the host cell's resources to make more viruses.



1. The virus recognizes and binds to a host cell via a receptor molecule on the cell surface.
2. The virus or its genetic material enters the cell.
3. The viral genome is copied and its genes are expressed to make viral proteins.
4. New viral particles are assembled from the genome copies and viral proteins.
5. Completed viral particles exit the cell and can infect other cells.

Common mistakes and misconceptions

Incorrect: All bacteria are pathogens.
Correct: Most bacteria are actually harmless and, in fact, we would not survive without them! Bacteria help us digest food, produce vitamins, and act as fermenting agents in certain food preparations. Some bacteria also fill niches that would otherwise be open for pathogenic bacteria. For example, the use of antibiotics can wipe out gastrointestinal (GI) flora. This allows competing pathogenic bacteria to fill the empty niche, which can result in diarrhea and GI upset.

Incorrect: We should stop vaccinating people for diseases which are now rare due to vaccines.
Correct: Some diseases have been nearly eliminated through the use of vaccines. However, this does not mean that we should stop vaccinating against these diseases. Most of these diseases still do exist in the human population, and without the continued use of vaccines, people are at risk of getting and spreading the disease.

Incorrect: Vaccines always provide permanent immunity to a disease.
Correct: For some diseases, a single vaccine is sufficient, but for many diseases you must get vaccinated more than once to be protected. For example, the flu vaccine becomes less effective over time because of how rapidly the flu virus mutates. Therefore, the flu shot’s formulation changes each year to protect against specific viruses that are predicted to be prominent each year.

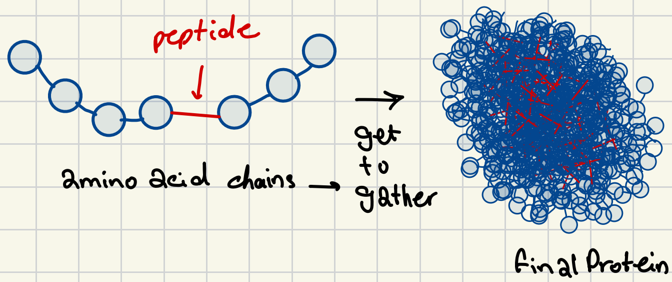
Proteins

Proteins are an essential part of human diet.

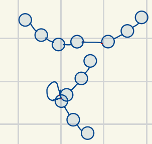
↳ found in plenty of food: meat, nuts, vegetables

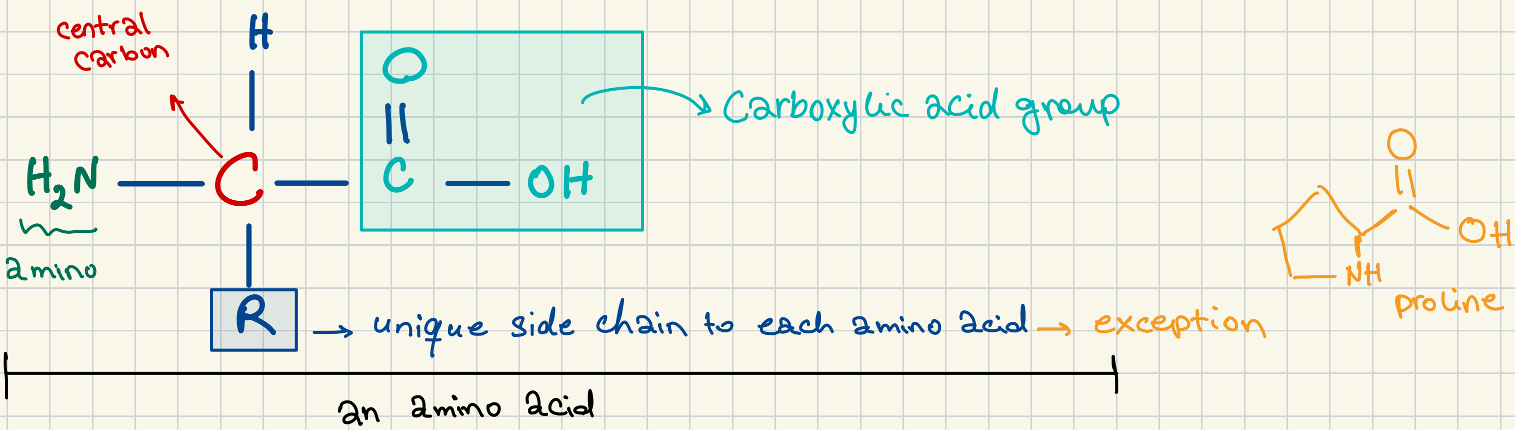
proteins' jobs: ① fighting infections
② helping cells divide

At simplest form: a protein is a chain of amino acids bound to one another by peptide



→ after eating protein, it breaks down to each individual amino acid





There are 100s of amino aids in nature, human body only uses 20 of them.

Organisms maintain stable internal environments

Homeostasis describes the tendency of organisms to maintain relatively stable internal environments.

Homeostasis keeps conditions inside an organism's body within an optimal range, despite changes in the external environment, diet, or activity level. This inner stability allows cells to function properly, keeping the organism alive in a constantly changing world.

Homeostasis in humans regulates many physiological variables, including body temperature, blood sugar (glucose) levels, water balance, and concentrations of ions in the blood.

Homeostasis in humans is primarily controlled by the endocrine and nervous systems. However, when a physiological variable goes outside of its normal range, many body systems work together to restore homeostasis.

Negative feedback loops counteract change

Physiological variables have a set point (an ideal value) and a normal range (a range of acceptable values above and below the set point). If a variable starts to move away from its set point, a negative feedback loop will counteract the change and restore homeostasis.

For example, if a person's body temperature rises far enough above the typical set point of 98.6 °F (37.0 °C), responses (such as sweating) will counteract this change and cool the body down. Similarly, if body temperature drops too low, responses (such as shivering) will counteract the change and warm the body up. The overall result is that the body is kept at a relatively stable temperature, which is ideal for cellular functions.

Positive feedback loops drive processes to completion

In contrast to negative feedback loops which counteract a physiological change, positive feedback loops amplify signals to help complete physiological processes.

For example, during childbirth, the baby's head presses on the cervix (the bottom of the uterus) and activates neurons in the mother's brain. These neurons trigger a release of the hormone oxytocin from the pituitary gland. Oxytocin increases the frequency and intensity of uterine contractions, which help push the baby's head downward, increasing pressure on the cervix. This causes a release of even more oxytocin and produces even stronger contractions. This positive feedback loop continues until the baby is born.

Feedback loop vocabulary

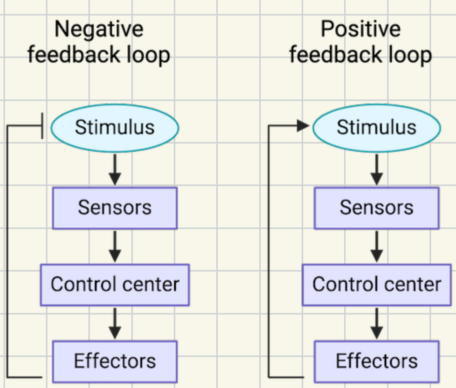
All feedback loops involve stimuli, sensors, a control center, and effectors:

Stimuli (singular: stimulus) are signals that trigger a response. A variable moving away from its set point is an example of a stimulus.

Sensors monitor an organism's internal and external conditions and detect stimuli. Sensors are often specific types of neurons.

A control center is the area of the body that receives and processes signals from the sensors, and then coordinates a response. Many control centers are in the brain.

Effectors are body components that carry out the response to a stimulus. Muscles, organs, glands, and cells can all be effectors.



Negative feedback loops maintain homeostasis in organisms

Homeostasis describes the tendency of organisms to maintain relatively stable internal environments despite changes in external conditions, diet, or activity level. Homeostasis is a fundamental property of life: all organisms regulate their internal environments.

The primary way that organisms maintain homeostasis is through negative feedback loops. These feedback loops counteract, or oppose, a change in the organism. In this article, we'll cover examples of negative feedback loops. Then, we'll touch on what happens when a negative feedback loop goes wrong.

- our bodies can't function in too much of a temperature ⇒

the body responses to over heating

↳ ① physiological responses: internal changes our bodies carry out unconsciously

sweating - blood vessels dilating - getting thirsty

↳ ② behavioral responses: actions we carry out consciously in response to needs

find shade - get out of sun - drinking water

- The tendency of an organism to maintain internal conditions within an acceptable range despite changes in its external enviroment is called **Homeostasis**.

- Negative Feedback Loop

stimulus → **detection** → **response**

stimulus: a detectable change in internal conditions
e.g. increase in body temperature

detection: detecting that change
internal temp moved outside the acceptable range
36.5 - 37.5 °c
97.5 - 99.5 °F

response: counteracting the change through negative feed-back
sweating - (too low → shivering)

Homeostatic responses

Thermoregulation: keeping the body cool when it gets hot
making the body warm when it gets cold

example of negative feedback loop

Osmoregulation → specifically in Salmon

- Salmon: spends their lives in
  - **freshwater**: where the concentration of salt in water is less than the salt concentration in fish's body
  - **Saltwater**: concentration of external salt in water > concentration of internal salt in fish's body

- in Freshwater fish tends to absorb water & lose salt through their skin.

- in saltwater fish tends to lose water & salt

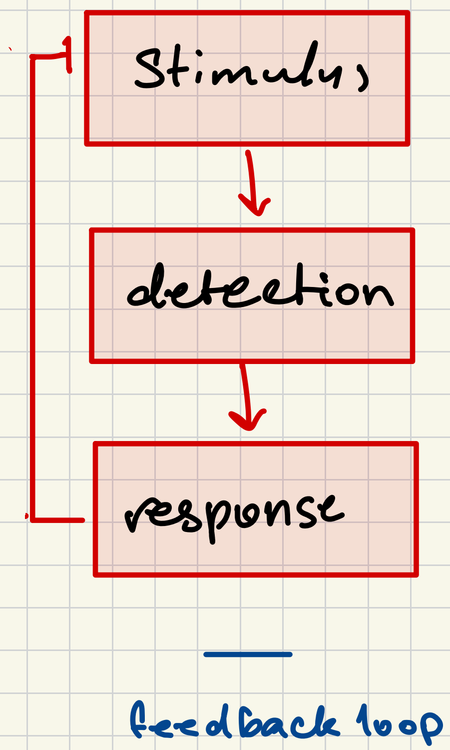
- any change in the internal salt & water condition can be fatal for salmon.

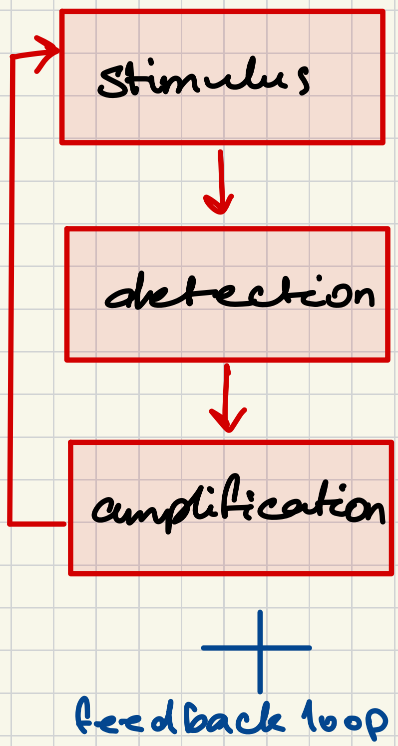
- negative feedback loop that detects the change in salt & water concentration and responds to that:

① taking up/exereting salt through the gills ② having more or less dilute urine ⇒ to establish ideal salt-water concentration

• negative feedback loop opposes the stimuli.

• positive feedback loop amplifies the stimuli.

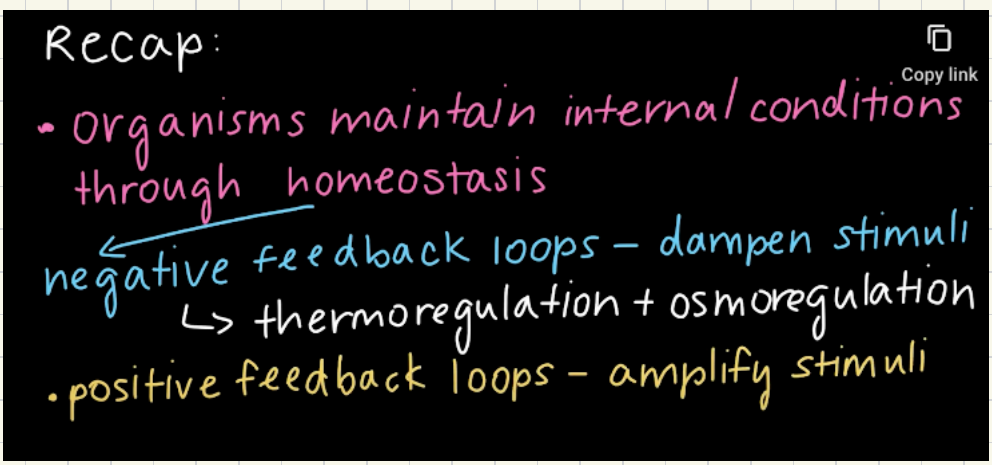




: like child birth

baby's head presses against the cervix.

neurons send a message to the brain to release a hormone called oxytocin. which makes the uterus to contract, which causes more pressure on cervix, which sends more neural signals, which releases more oxytocin.



sensor: a body component that monitors internal and external conditions, detecting stimuli
control center: an area that receives and processes signals about the body, then coordinates a response
effector: a body component that carries out the response to a stimulus

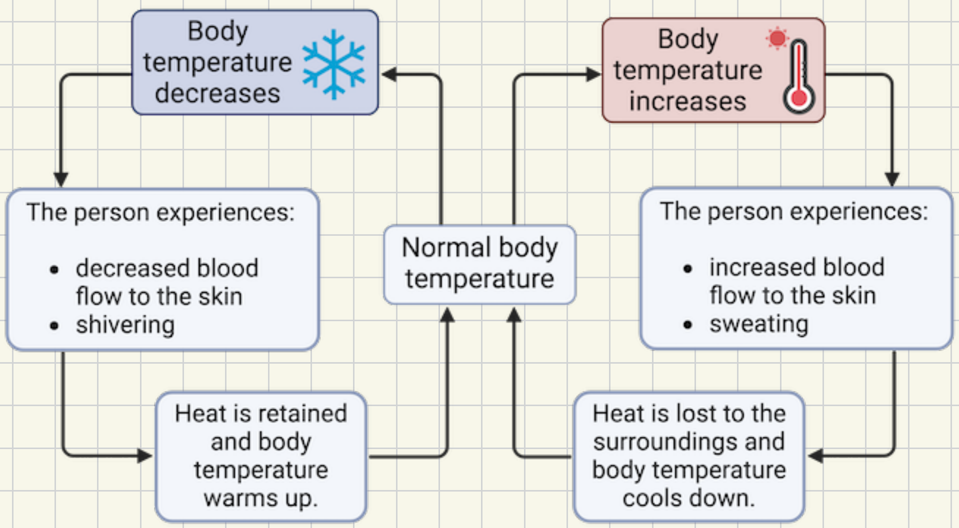
Example #1: Regulation of body temperature

Temperature affects many processes in the human body, including enzymes function and the transmission of nerve signals. So, it is critical that body temperature stay near a set point of about 98.6 °F (37.0°C). To maintain this temperature, the human body uses negative feedback loops.

First, nerves in the body and brain detect if a person is getting too hot or too cold. These signals are sent to the hypothalamus, which is the region of the brain that controls body temperature. The hypothalamus then coordinates a physiological response:

- If body temperature is too high, the person begins to sweat and blood vessels dilate (widen), increasing blood flow to the skin. This increases the amount of heat lost to the surroundings.
- If body temperature is too low, the person begins to shiver so that their muscles will generate more heat through cellular respiration. In addition, blood vessels constrict (narrow), decreasing blood flow to the skin which limits heat loss.

Body temp↓



Body temp ↑
sweat- dilated vessels → blood flow

Homeostatic regulation can also involve behaviors to stay near or return to a set point. For example:

If a person gets too hot, they may feel like lying down without moving, which will minimize heat production.

If a person gets too cold, they might feel like moving around, or they may seek out a source of warmth.

Notably, the set point for body temperature is not always exactly 98.6t °F (37.0 °C). It changes throughout the day as a result of a person's circadian rhythm. The body temperature set point tends to be highest in the late afternoon and lowest in the early morning. In addition, a fever involves a temporary increase in a person's body temperature set point. This increase in temperature helps the body fight infections.

Example #2: Balancing water loss and photosynthesis in plants

Photosynthesis is the process by which plants use energy from sunlight to convert water and carbon dioxide into glucose and oxygen. The glucose is used by the plants for energy, and the oxygen is released into the environment as a by-product.

When photosynthesis occurs, CO2 enters the leaf, and O2 exits. This gas exchange occurs through small pores (openings) on the undersides of leaves called stomata. Stomata are formed by two neighboring guard cells that swell or shrink to open or close the pore.

Open stomata allow for gas exchange and photosynthesis to occur. However, they also allow water to evaporate out of leaves through a process called transpiration. If plants lose too much water, they become dehydrated. So, plant leaves must balance their need for gas exchange with their need to retain water. To do this, plants use negative feedback loops that involve stomata: