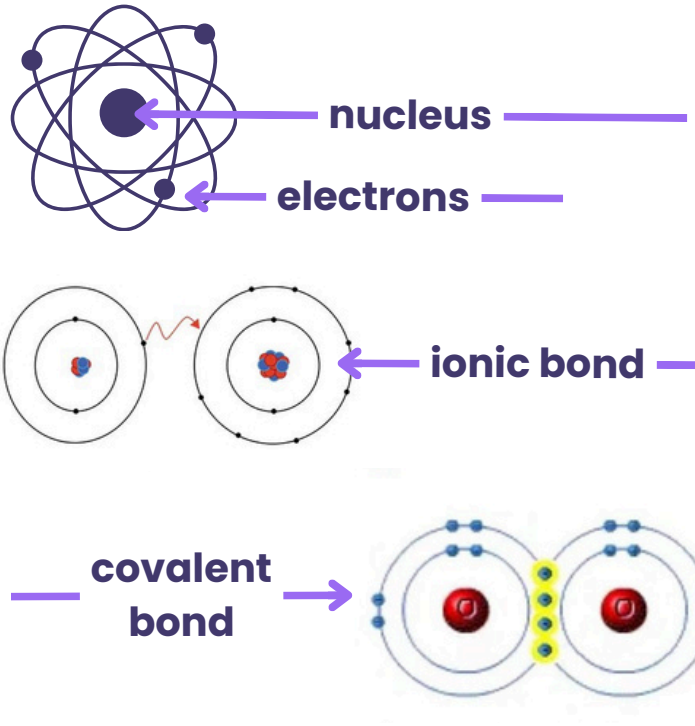
Unit 1

Chemistry of Life

Elements

Elements-Substances that cannot be broken down into simpler substances by any chemical means.

CHNOPS- Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorus, and Sulfur are used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids.
Trace Elements- Required by organisms in small quantities. EX: Iron(Fe), Iodine(I), and Copper (Cu).



Subatomic Particles

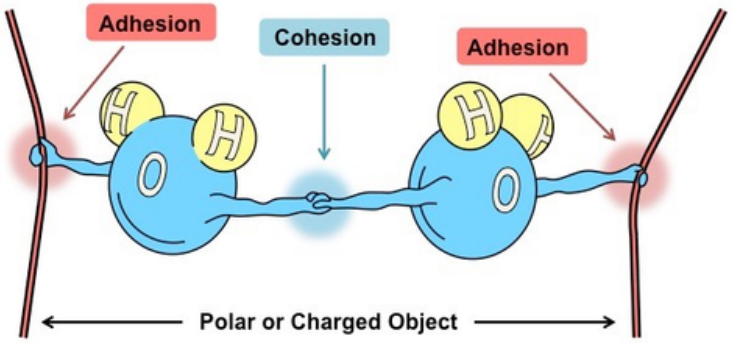
Atoms are the smallest unit of an element that holds its properties. They are considered building blocks of the physical world. Subatomic Particles include **protons**(+ charged), **electrons**(- charged), and **neutrons**(neutral charge). Protons and neutrons are located in the atom's **nucleus** (see diagram). Electrons spin around the nucleus. Atoms with the same number of protons but a different number of neutrons are called **isotopes**.

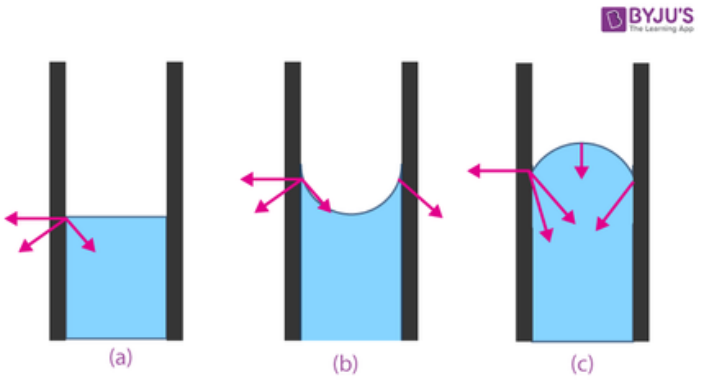
Compounds

A **compound** is when two or more elements combine. Hydrogen and Oxygen are gases in their natural state but when combined in a **chemical reaction** form H2O. Bonds hold compounds together. Types of bonds include...
Ionic bond(Strongest)- When one or more electrons from an atom are transferred to another. **Covalent bond**- When electrons are shared between atoms. If the electrons are shared equally it is a **nonpolar covalent bond**. If the electrons are shared unequally it is a **polar covalent bond**. **Hydrogen Bond(weakest)**-When hydrogen covalently bonds with a more electronegative atom. EX: Oxygen

Water

Water has two hydrogen atoms and are held together by hydrogen bonds to one oxygen atom. The electrons, however, are not shared equally. This gives oxygen a partial negative charge and hydrogen a partial positive charge. When charges are not shared equally it makes the molecule **polar**. This allows water to react well with other polar molecules using hydrogen bonds. Thus, making it versatile. Alone hydrogen bonds are weak but together they contribute to properties of water such as **cohesion, adhesion, surface tension, high heat capacity, and expansion of freezing.**



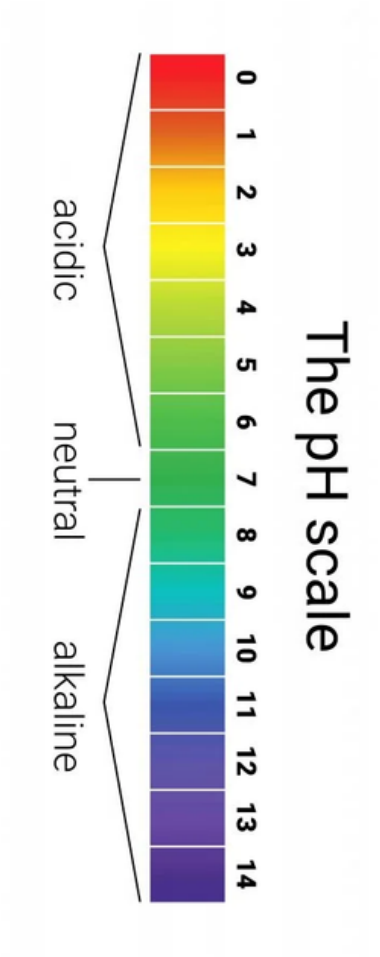


Water Properties

Water is known as a sticky molecule, and this is due to its **cohesive** properties. **Cohesion** describes when hydrogen bonds of water attract the oxygen end of another water molecule. When water forms hydrogen bonds with other polar molecules it is known as **adhesion**. **Capillary action** uses water's properties of cohesion and adhesion to make water rise up from roots, trunks, and branches. Cohesion also allows water to have **surface tension**. When several hydrogen bonds are formed it makes the bonds stronger. This why so many droplets of water fit on a penny or why small bugs can stand on water. Surface tension holds them up.

Acids and Bases

Reactions are not only influenced by water but also by the solution. The solution can either be **acidic, basic, or neutral**. If a solution contains a lot of **H+(hydrogen ions)** it is acidic. This means if you dissolve an acid in water it will release H+. Vice versa acids will have a limited amount o**f OH- ions(hydroxide ions)**. Acids are sour like citric acid. Bases when added to water release OH-. They are considered to be alkaline and slippery like soap.

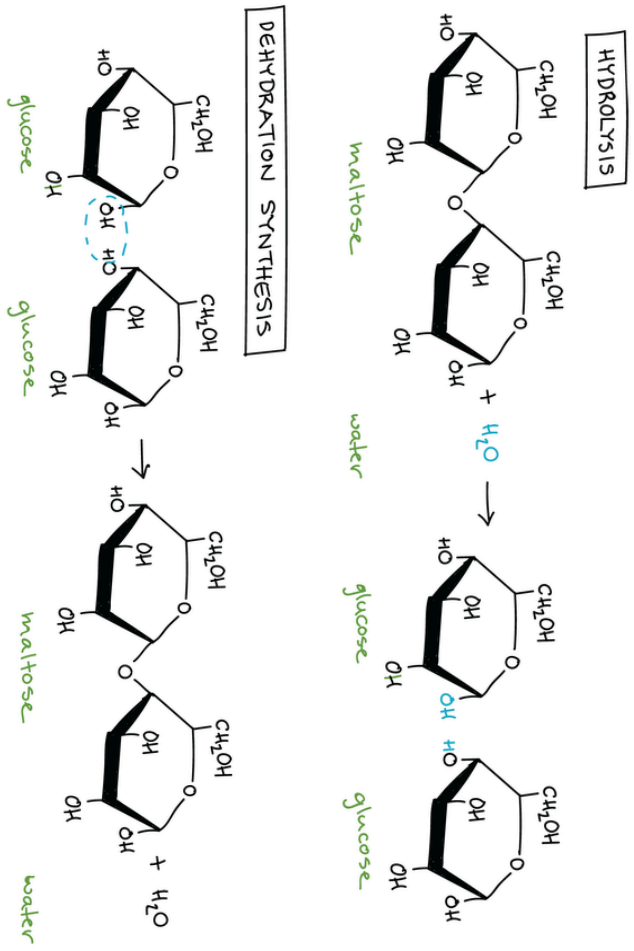


pH Scale

The pH scale measures the **acidity** and **alkalinity** of a solution. The lower the pH the more acidic. This means the more H+ the lower the pH. The higher the pH the more basic and a pH of 7 means the solution is neutral. **The pH scale is logarithmic.** This means the scale increases by tenfold. A pH of 3 is ten times more acidic than a pH of 4 and vice versa. The scale is labeled 1-14 with 7 being the midpoint. Stomach acid has a pH between 1-3. pH becomes significant in enzyme reactions (see later units) as it can cause denaturizing when not at the right level.

Organic molecules

Carbon atoms surrounded by hydrogen atoms are known as **organic compounds**. Therefore compounds that do not have carbon atoms are known as **inorganic molecules**(EX: Salt). Carbon is the backbone of life as it can be bound to another atom from all four sides due to its electron arrangement. Other atoms include hydrogen, nitrogen, oxygen, phosphorous, and sulfur (HNOPS). **Macromolecules** are formed from **polymers** which are formed from **monomers**. All of which contain Carbon and hydrogen.



Dehydration Synthesis and Hydrolysis Reactions

Dehydration Synthesis joins monomers to make polymers while **Hydrolysis** breaks the bond between two monomers. Think of "Dehydration Synthesis" as "synthesis" which means to join. Therefore Hydrolysis will mean to break. In dehydration synthesis water is lost while in hydrolysis it is used. Remember this as Hydro-lysis. Hydro means water so water is used. Dehydration means loss of water so therefore you lose water in Dehydration Synthesis. We will discuss 4 types of organic compounds next: **carbohydrates, proteins, lipids, and nucleic acids**.

Carbohydrates

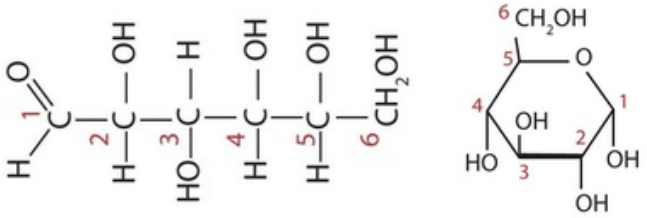
Carbohydrates contain carbon, hydrogen, and oxygen. The ratio of these elements is usually 1:2:1. Carbohydrates can be categorized as either **monosaccharides**, **disaccharides**, or **polysaccharides**. “Saccharides” are a name for sugar. Mono, di, and poly refer to the number of sugars. Carbohydrates are used as an energy source. Just like we get energy from sugar(Ex: Sugar rush).

monosaccharides

Monosaccharides are the simplest sugars. The main examples of monosaccharides are **glucose** and **fructose**. Their chemical formula can be written as C6H12O6. They are depicted as either “straight” or “rings”. **Glucose** is used in photosynthesis to provide energy in plants and fructose is a common sugar in fruits

disaccharides

When two monosaccharides are bound together it is called a **glycosidic linkage**. These form **disaccharides**. To join them use dehydration synthesis and to break them apart add water for hydrolysis.

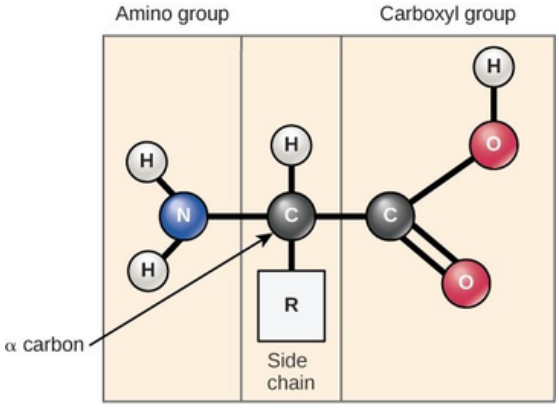


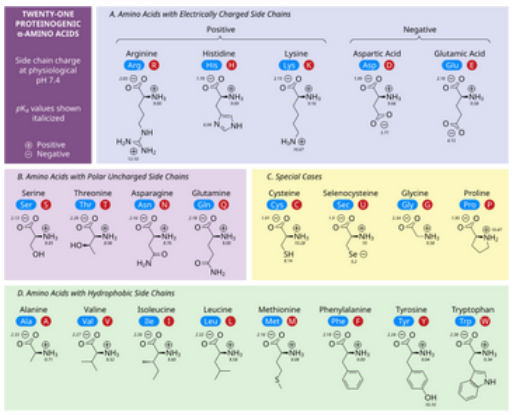
polysaccharides

When multiple monosaccharides are bound together they form a **polysaccharide**. Examples of polysaccharides you should be familiar with are **starch**, **cellulose**, and **glycogen**. Starch and glycogen are used for storage while cellulose is used in plant walls. It is mainly used for structural support.

Proteins

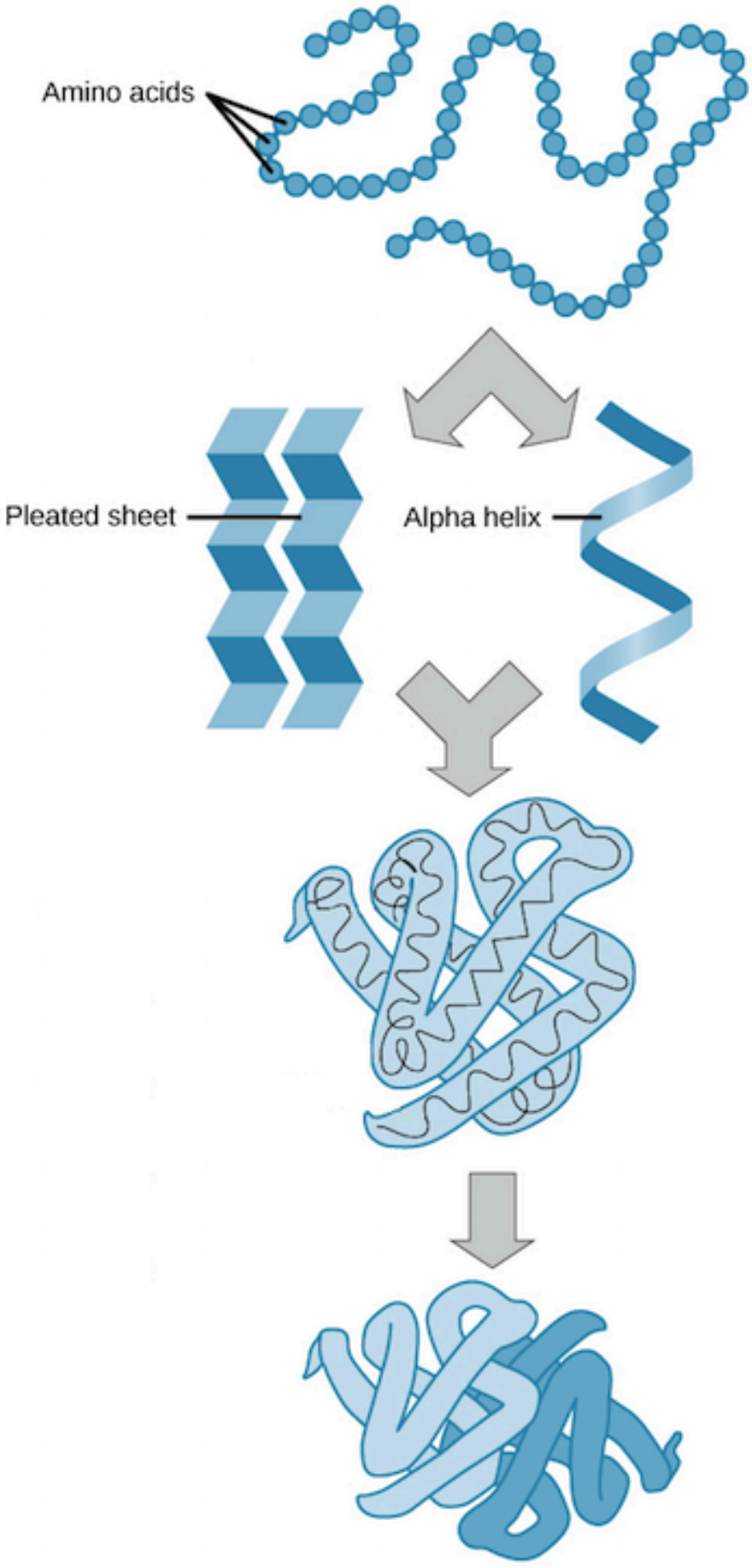
Proteins are used for structure and function. **Amino Acids** are the **monomers** of Proteins. Two amino acids joined together form **dipeptides** and multiple amino acids form **polypeptides**. Once formed a polypeptide will twist and fold to form a three-dimensional structure that is the protein. You will also have to memorize higher **protein structures** (see next page). Sometimes the folding of polypeptides requires other proteins for help. These are known as **chaperone proteins (chaperonins)** The bond between amino acids is known as a **peptide bond**. Proteins contain Carbon, Hydrogen, Oxygen, and Nitrogen.





Amino Acids and R Groups

There are 20 different types of **Amino Acids**. Each Amino acid has 3 parts. An **amino group, a carboxyl group, and an R group.** The R group is obvious but a way to identify the carboxyl group is to look for C, O, and OH. This leaves the last part (NH2) as the amino group(see diagram). Amino acids are differentiated from each other due to their R group. R groups can go from a single atom to multiple. Categories include **polar, nonpolar, positively charged, or negatively charged.**



Primary protein structure
sequence of a chain of animo acids

Secondary protein structure
hydrogen bonding of the peptide backbone causes the amino acids to fold into a repeating pattern

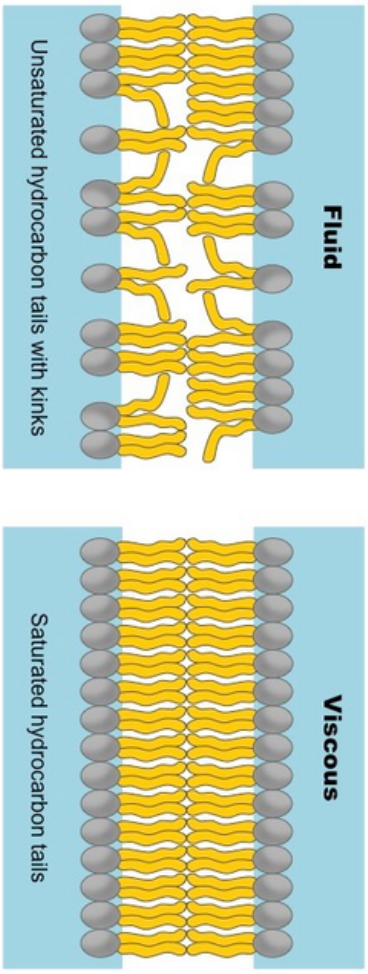
Tertiary protein structure
three-dimensional folding pattern of a protein due to side chain interactions

Quaternary protein structure
protein consisting of more than one amino acid chain

@proteinstructure Khan Academy

Lipids

Lipids are used for energy storage and contain carbon, hydrogen, and oxygen. Types of lipids include **triglycerides, phospholipids, and steroids.** They are non-polar and the main part of the cellular membrane. Triglycerides (Tri=three) have three fatty acid chains attached to them. One end has a carboxyl group. They can either be **saturated** or **unsaturated**. **Unsaturated fatty acids** have a kink in hydrogen bonds(a double bond where there should be a single bond). This allows for more space between the lipids in the **cellular membrane**(see diagram). This also allows for more fluidity. This is why butter is saturated and oil(a liquid) is unsaturated.

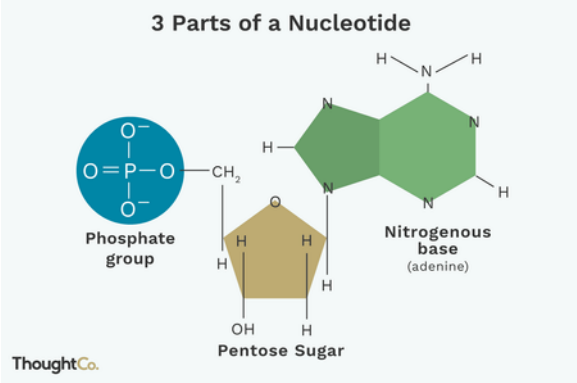


Phospholipids

Phospholipids are the type of lipid that make up the **cellular membrane.** They contain **two fatty acid tails** and **one negatively charged head**. The tails are **hydrophobic(water-hating)** while the head is **hydrophilic(water-loving)**. This makes phospholipids both hydrophilic and phobic. These types of molecules are known as **amphipathic molecules.** This makes the phospholipids orientate themselves in a way where the fatty acid tails are inside of the cell while the heads are facing out touching the aqueous part. **Cholesterol** is also a type of lipid located in the cellular membrane. It is a four-ringed molecule that inserts itself into the cellular membrane to make it more fluid.

Nucleic Acids

The last type of macromolecule is **Nucleic acids**. Their **monomers** are known as **nucleotides**. They contain carbon, hydrogen, oxygen, nitrogen, and phosphorus. There are two types of nucleotides you should know. **Deoxyribonucleic acid(DNA)** and **ribonucleic acid(RNA).** DNA contains all genetic information while RNA is used for protein synthesis.



SUMMARY

Important Biological Macromolecules

Macromolecule	Monomer	Polymer	Linkage Bond	Elements
Carbohydrates	Monosaccharide (e.g., Glucose)	Polysaccharide (e.g., Starch, glycogen, cellulose)	Glycosidic linkage	C, H, O,
Proteins	Amino Acid (e.g., Glycine)	Polypeptide (e.g., Actin)	Peptide bond	C, H, O, N, S
Nucleic Acids	Nucleotides (e.g., Adenine, thymine, guanine, cytosine)	Deoxyribonucleic acid (DNA) Ribonucleic acid (RNA)	Sugar-phosphate phosphodiester bonds	C, H, O, N, P
Lipids	Not a true polymer, but often contains chains of carbons with hydrogens	Triglycerides, phospholipids, cholesterol	Ester bonds	C, H, O, sometimes P

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Unit 1

Chemistry of Life: Review Questions

1. **What is the strongest type of bond?**

A) covalent B) hydrogen

C) ionic D) polar covalent

2. The reason why surface tension is a property of water is because of...

A) adhesion B) high specific heat

C) cohesion D) ionic bonds

3. The facilitation of water moving up plant stems is because of this property

A) universal solvent B) cohesion and adhesion

C) surface tension D) less dense as a solid than a liquid

4. A saturated fat is...

A) liquid at room temp. B) solid at room temp.

C) a carbohydrate D) contains an “R” group

Unit 1

Chemistry of Life: Review Questions

5. Which element is considered the "backbone of life"?

A) Nitrogen B) Oxygen C) Hydrogen D) Carbon

6. Monomers of proteins are known as...

A) Nucleic Acids B) Amino Acids
C) phospholipids D) monosaccharide

7. Changes in the sequence of Amino Acids affects which?

A) Primary Structure B) Secondary Structure
C) Tertiary Structure D) Quaternary Structure

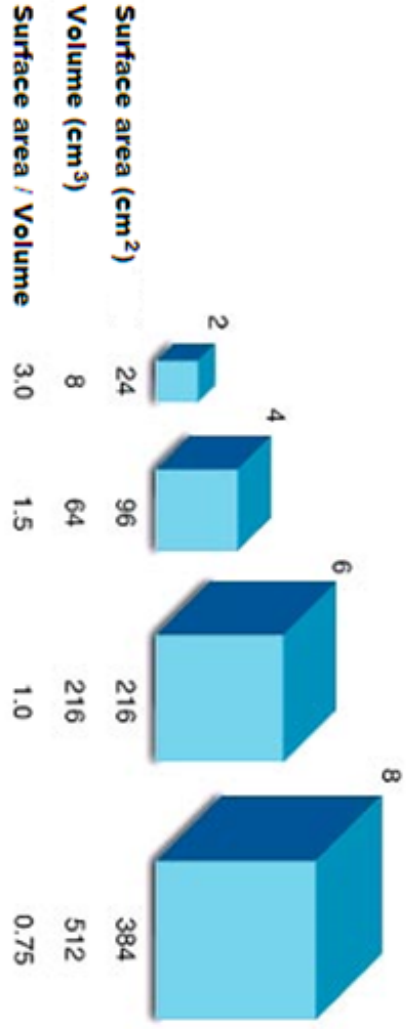
Answer key:
1) C 2) C 3) B 4) A 5) D 6) B 7) A

Unit 2

Cell Structure and Function

Living Things

The **cell theory** is that the cell is the basic unit of structure and function. Something that is living will contain cells. Cells are the smallest unit of living material that carry out duties essential to life. We have small cells so that they can specialize in one task and have a large **surface area-to-volume ratio**. The smaller the cell the larger the ratio and the more efficient the cell is at exchanging materials with its surroundings. This also applies with animals. Smaller animals will lose heat(exchange) much more rapidly than larger animals as they have a higher surface area-to-volume ratio.



How Cells are Studied

Two different types of microscopes are most commonly used to study cell

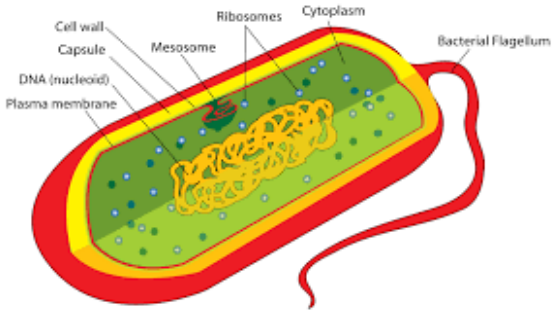
- **Light Microscopes**
  - Most commonly found in labs.
  - Used to study stained or living cells
  - Can magnify organism up to 1,000 times

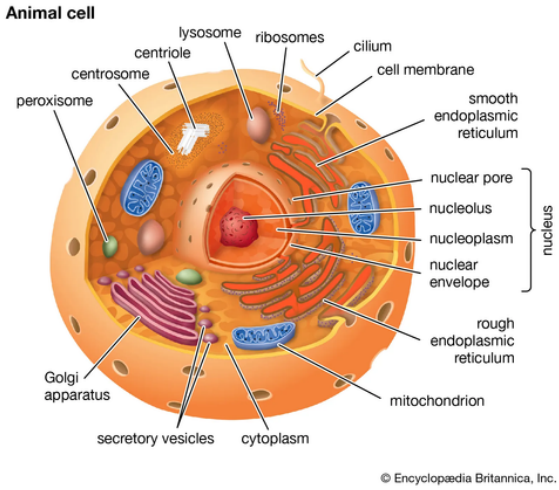
- **Electron Microscopes**
  - Used for detailed structures(that are not easily observed by light microscopy)
  - Can resolve structures the size of nanometers
    - EX: individual virus particles

CELL TYPES

Prokaryotes

There are two cell types (**prokaryotic and eukaryotic**). Prokaryotes are smaller and simpler (EX: Archaea and Bacteria). The inside contains a **cytoplasm**. Prokaryotic DNA is free floating in one continuous circular DNA molecule called the **nucleoid**. Which means it has *NO NUCLEUS*. They also contain a **cell wall** that surrounds a lipid layer, the plasma membrane. Similarly to eukaryotes they contain **ribosomes**, however, prokaryotic ribosomes are smaller. Lastly prokaryotes sometimes contain a tail like structure (the **flagella**) for movement and a thick outer capsule for protection.





Eukaryotes

Eukaryotic cells are much more complicated than **prokaryotic** cells (EX: Fungi, protists, plants, and animals). Eukaryotes have structures within them called **organelles**. Prokaryotes and Eukaryotes share many similarities in organelles. However, one main difference between the two is that prokaryotes do not have **membrane-bound** organelles which eukaryotes do. Each organelles have its own task. Later in these sheets we will describe all of the organelles (including ones previously bolded) and their functions.

Composition of the Membrane

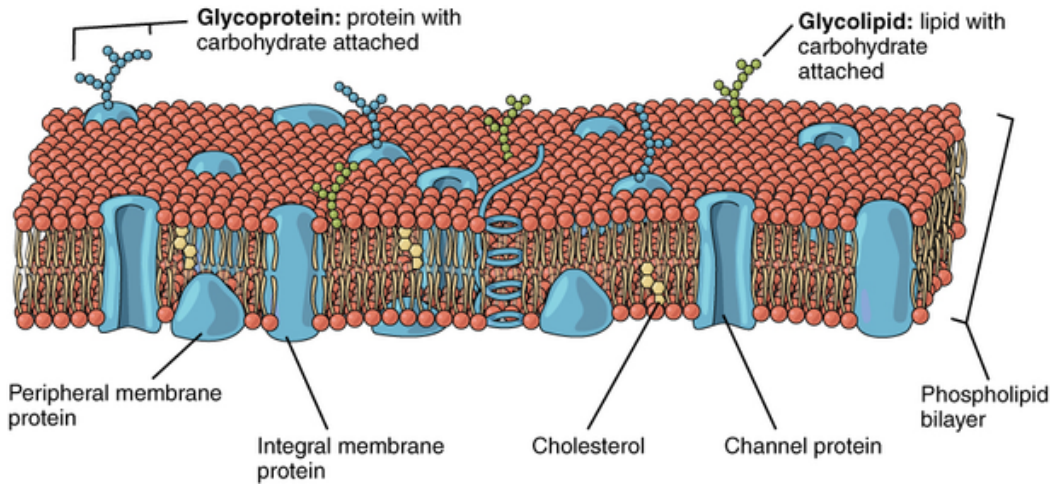
The plasma membrane is the outer envelope of the cell made by a bilayer of **phospholipids** (a group of lipids that contain two fatty acid heads, one glycerol and one one phosphate group attached to it)and proteins. This composition of the plasma membrane also makes it **semi-permeable** which means that it regulates what goes in and out of the cell.

Proteins

- **Integral Proteins**- These proteins are **amphipathic** (contain both hydrophobic and hydrophilic parts) and are firmly bound to the membrane
- **Peripheral proteins**- These are loosely bound to the inner or the outer membrane
- **Receptor Proteins**- Proteins on the membrane that receive signals and other materials. (ex- **hormones**)
- **Transport Proteins**- Proteins that use **ATP** to actively transport substances up the concentration gradient
- **Channel Proteins**- They form **channels** that allow ions and other molecules to pass through

Cell Communication

- The surface of the membrane contains **markers** like **glycoproteins** and **lipids** that aid in cell recognition
- There are also **carbohydrate side chains** present on the outer surface of the membrane which also help in cell communication



The Nucleus

The nucleus is the largest organelle in the cell, controls the functions and aids the cell to reproduce. The nucleus contains hereditary material of the cell which is organized in structures called **chromosomes**. Inside the nucleus is the **nucleolus** where **rRNA** is made and **ribosomes** are assembled.

Ribosomes

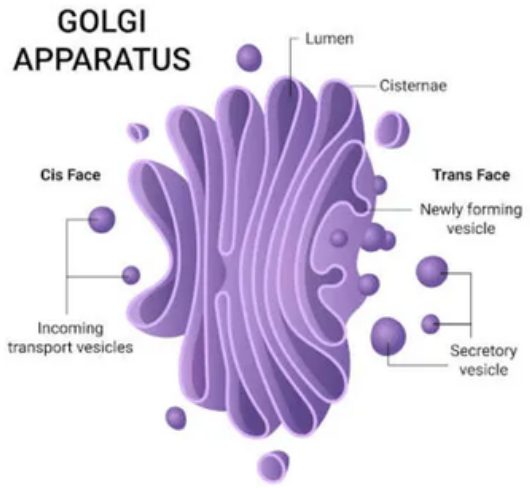
Ribosomes are a structure in the cell made of rRNA and proteins. It is the site of **protein synthesis** of the cell and are made of a small and a large sub-unit. The organelle also helps in synthesizing proteins as it reads the **mRNA** and translates it into **strands of amino acids** which further fold into specific proteins. These ribosomes can be found on either the surface of the ER (endoplasmic reticulum) or freely floating in the cytoplasm

ER

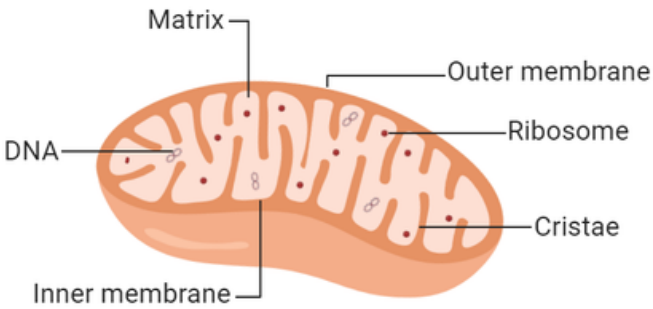
The ER (endoplasmic reticulum) is an organelle that helps in **endocytosis** and **exocytosis** (transporting materials in and out of the cell) The structure is of 2 types- **Smooth and Rough ER**. The rough ER is responsible for folding the protein and post translational modifications. The rough ER also contains ribosomes on its surface. The smooth ER synthesizes lipids, phospholipids, hormones and steroids

Golgi

The **Golgi Complex** has the appearance of flat sacs stacked on each other. Think of the Golgi Complex as a FedX or any shipping company. The Golgi complex takes **synthesized proteins** from the **rough ER** and modifies/sorts them. Instead of boxes, the Golgi places them in sacs called **vesicles**. Vesicles carry the package to the plasma membrane. The Golgi Complex is also used for the production of **lysosomes**.



Mitochondria



Mitochondria

As said many times the **mitochondria** is the “powerhouse” of the cell. This is because they provide cells with **ATP**(Adenosine Triphosphate). ATP=Energy. **Cellular Respiration** occurs in the mitochondria and is used to make energy (will be explained in future units). The mitochondria have a **double membrane**, an oblong shape, and folds. These folds are known as **cristae**. They separate the matrix(the innermost of the mitochondria) from the **inner membrane**. The outer membrane separates the **cytoplasm**(what is outside the cell) from the inner membrane. Cellular respiration mainly occurs on the cristae, so folding the cristae allows for more surface area. As mentioned before more surface area=more efficiency so more folds=more area to make energy.

Lysosomes

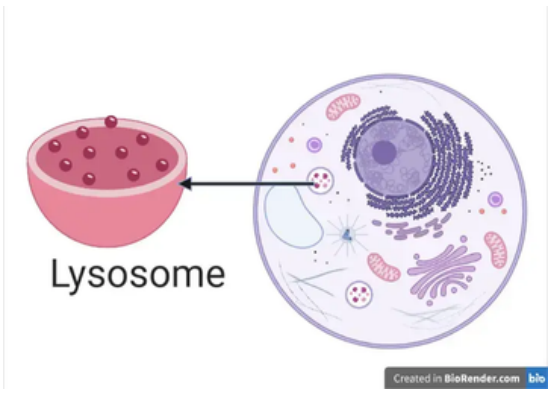
Think of **lysosomes** as the "death" organelles. They are membrane-enclosed structures that carry **digestive enzymes**. These are **hydrolytic enzymes** that only work at an acidic PH. If a lysosome was broken the digestive enzymes would digest integral structures and cause cell death. Lysosomes are also used for cell death (known as **apoptosis**). They help clean up and recycle unnecessary materials in the cytoplasm.

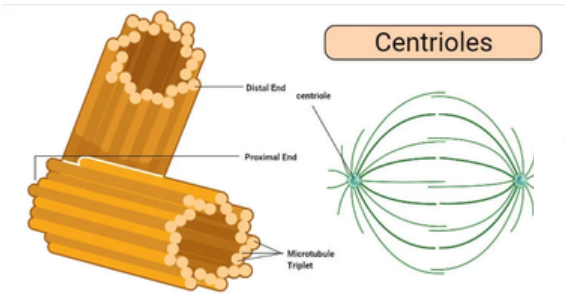
Centrioles

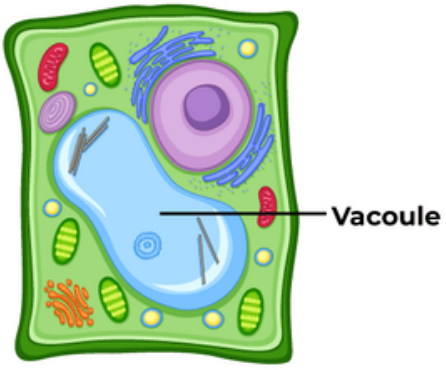
Centrioles are used for cell division. Centrioles produce **microtubules** that pull **chromosomes** apart to opposite sides of the cell. They are tiny structures in a cylindrical shape most common in animal cells.

Vacuoles

Vacuoles can be thought of as storage centers. They are empty sacs filled with fluid often containing food, water, salt, or pigments for the cell. This means they can have a variety of functions.

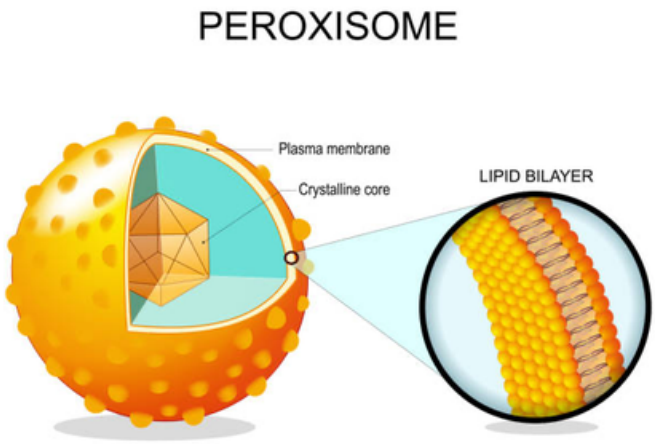


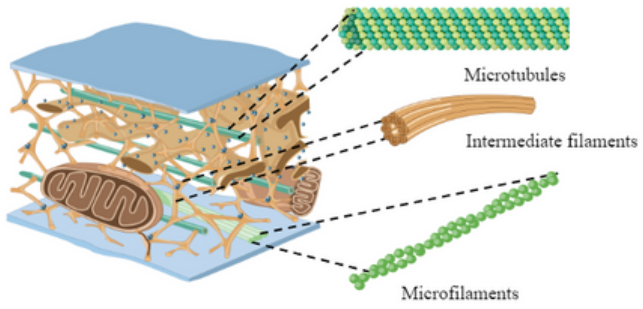




Peroxisomes

Peroxisomes are vesicles that are membrane bound and are found in the cytoplasm of the cell. These organelles contain digestive enzymes that are used to break down toxic materials in the cell, producing hydrogen peroxide. They further convert hydrogen peroxide into safer substances such as water and oxygen by using enzyme catalase





Cytoskeleton

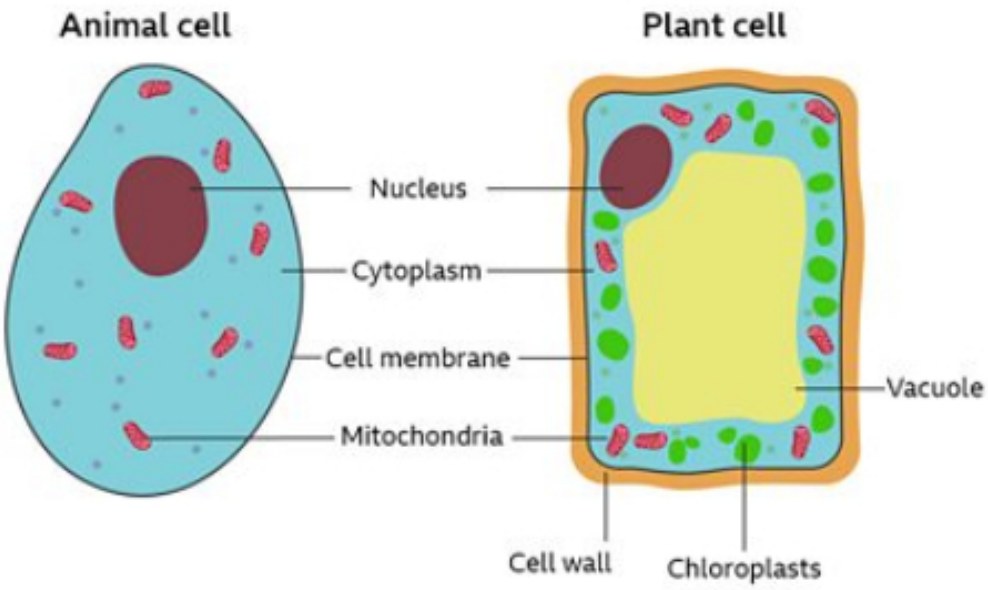
Cytoskeleton is a structure that aid cells in maintaining their shape and internal organization. The cytoskeleton is composed of a network of protein fibers such as microtubules and microfilaments. Microtubules are structures that help in mitosis and attach to the sister chromosomes. MIcrofilaments are made of a protein known as actin which allow cell movement and also contribute to mitosis

Cilia and Flagella

Cilia and Flagella are structures with same function but found in different types of cells. These provide locomotive properties to the cell

Plant Cells vs Animal Cells

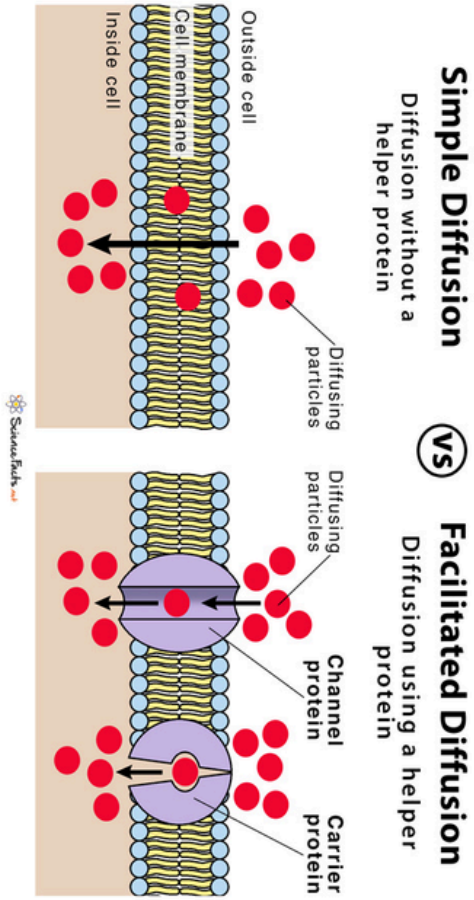
- Plant cells contain a cell wall which is a rigid protective wall outside the membrane. You can think of it as a wall or a fence to a property. The cell wall's main job is to protect the cell
- The plant cell also contains chloroplast which is a double membrane organelle and contains chlorophyll which gives plants its green color.
- While animal cells contain a relatively small vacuole, in plant cells, a huge amount of the cell is taken up by the vacuole
- While animal cells contain centrioles, plant cells do not.



Transport: Traffic Across the Membrane

Simple Diffusion

There are two things to consider for something to move across the membrane. The **semipermeability** of the plasma membrane and the size/charge of the particles that want to go through. **Hydrophic** molecules can easily pass through the membrane because "like likes like". The membrane has a hydrophobic middle so hydrophobic molecules can pass through it. When molecules can pass through the membrane with no assistance it is called **simple diffusion**.



Facilitated Diffusion

When a substance needs assistance to cross the membrane it is called **facilitated diffusion**. **Proteins** act as tunnels/ channels to let these particles through. The most famous of these are **Aquaporins**. Aqua=Water so aquaporins allow water to cross the membrane. I know we've talked about simple and facilitated diffusion but what is diffusion? **Diffusion** can be thought of as the ability of a particle to cross the membrane. Anytime a particle is moving using diffusion it is known as **passive transport**. Think of a ball on a hill. The ball will always roll down the hill (where there is less hill) with no energy needed for it to roll. Similarly, particles will always diffuse to where there are less of them. This will be discussed more when you learn about **osmosis**.

Osmosis

The diffusion of water is known as **osmosis**. Just like passive transport(a ball rolling down a hill) water will want to move from a highly concentrated area to a low concentrated area. Water, however, usually comes mixed with other things(**solutes**) to make solutions. The more solutes there are the less water there is(the space is being taken up by the solute). This means water will want to move wherever there is more solute. Think of it like water moving with the intention of diluting the solution

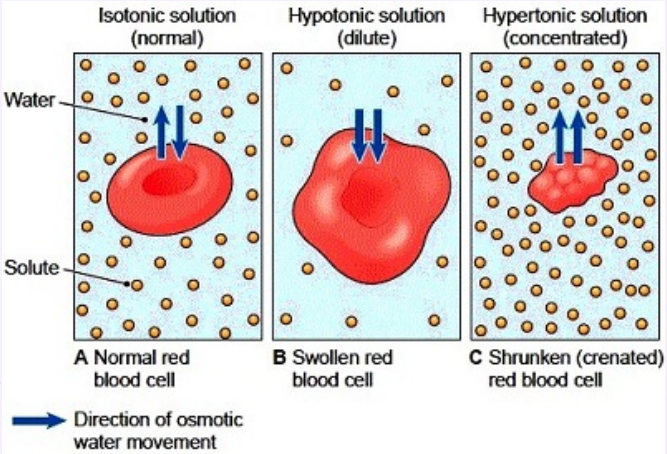
Osmosis Problems

Osmosis problems usually describe a situation where there are two areas that water can move freely through but the **solute** cannot.
EX- A chamber carrying water and a chamber carrying a sucrose solution are connected by a semi-permeable membrane that only lets water through it. Where will the water flow?

Answer: The water will flow into the sucrose solution until the concentration is equal across the membrane. It will dilute the solution

Osmotic Gradients(3)

Tonicity means **osmotic gradient**. When a question asks what is the tonicity of the solution you would answer with either **isotonic**, **hypertonic**, or **hypotonic**.

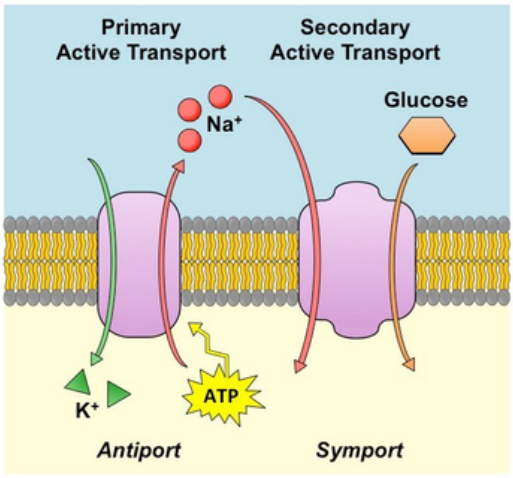


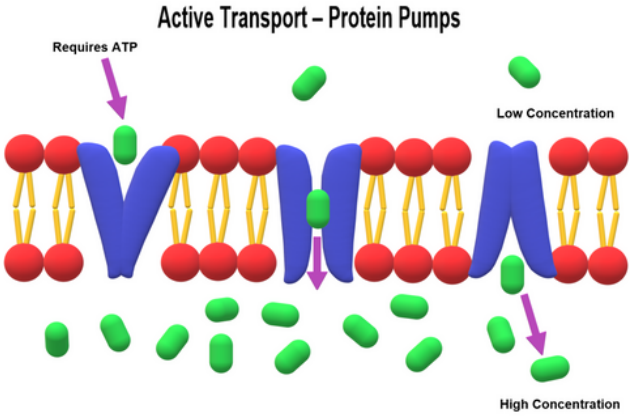
You will have to memorize these three types. **Isotonic** means the solute concentration is the same inside and outside. **Hypotonic** means the solution concentration is greater in the cell so water flows in to dilute it. This makes the cell bloat. **Hypertonic** means the solution concentration is greater outside the cell so water moves out to dilute the solution. This shrinks the cell.

Remember it like this. Hyp-O-tonic makes the cell bloat up like the letter O. Hy-purr-tonic shrinks up like a scared cat.

Active Transport

Active transport is the movement of the movement of substances against the concentration gradient or up the concentration gradient. Which means they go from low concentration to high concentration which is the opposite of what happens in passive transport. This transport is made possible by ATP. There are several pumps embedded in the plasma membrane that utilize ATP to bring ions or other substances across the membrane. There are 2 types of active transport- primary and secondary. Primary transport is when the cell directly uses the ATP to transport substances. However, in secondary active transport, some reaction that takes place and uses ATP ocurs which powers the movement of another substance across the membrane.





Bulk Flow

Bulk flow, in simple words, is the movement of substances across the membrane due to the presence of pressure or temperature gradient

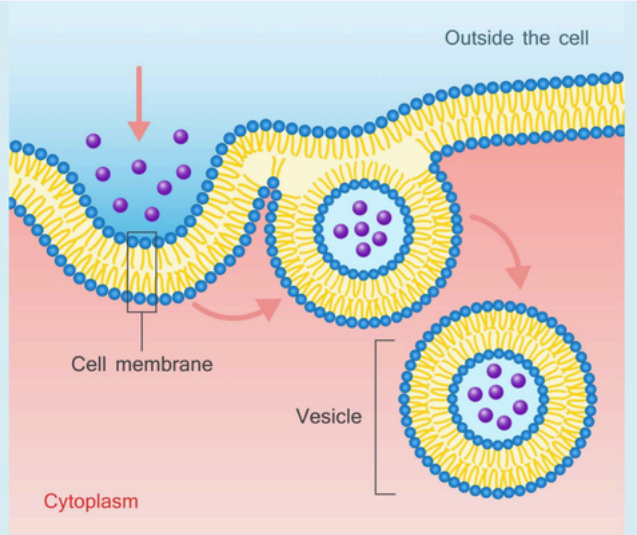
Dialysis

Dialysis is the diffusion or the passive transport of substances across a selectively permeable membrane

Endocytosis

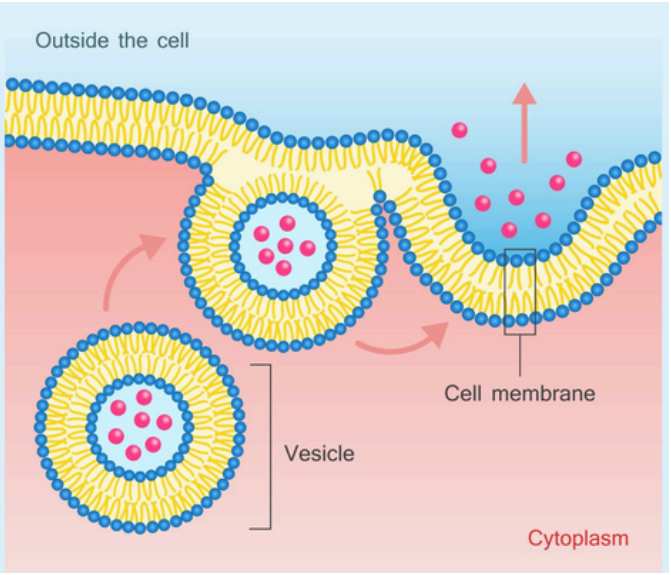
In the word endocytosis, the prefix endo means inside or within and the suffix cytosis means relating to cells. This can help you differetiating between endo and exocytosis. In short, endocytosis occurs when a particle wants to move into the cell and to make it possible, the cell membrane uses a part of the cell membrane. The ,membane further forms into a vesicle which transports the substance further. There are 3 types of endocytosis that you need to know

- Pinocytosis- This is when extracellular fluid is taken into the cells using vesicles
- Phagocytosis- The process through which the cell takes in larger substances including other dead cells
- Receptor mediated endocytosis- In short it's when the cell only allows those ligands to enter which are recognized by the cell and binds to the receptor.



Exocytosis

With the same concept, the prefix exo means outside and the suffix cytosis means relating to cells. Therefore exocytosis is when a cell ejects or forces out substances. This is done through the vesicles binding back to the cell membrane and releasing the substance out of the cell. Think of it as endocytosis working backwards.



Unit 2

Cell Structure & Function: Review Questions

1. If a lysosome broke open what would happen

A) Decreased efficiency B) cell proliferation

C) Increased efficiency D) cell death

2. Integral Proteins..

A) Extend inside the membrane

B) provide passageway

C) attach to the outside of the membrane

D) bind to specific molecules to transfer them

3. Which is incorrect about the nucleus

A) Contains chromosomes B) Cellular Respiration

C) Double membrane D) Contains chromatin

Unit 2

Cell Structure & Function: Review Questions

4. Which part determines the cell's chemical changes with its environment?

A) Cell wall B) Plasa Membrane

C) Cillia D) Cytoskeleton

5. The mitochondria have folds in its cristae in order to...

A) Increase cell proliferation B) increase efficiency

C) Increase filtration D) Dialysis

6. How do large particles cross the membrane

A) Transport Protein B) Exocytosis

C) Endocytosis D) Gated Channels

7. What is the water potential of pure water?

A) -1 B) 0 C) 1 D) 2

Answer key:
1) D 2) A 3) B 4) B 5) B 6) C 7) B

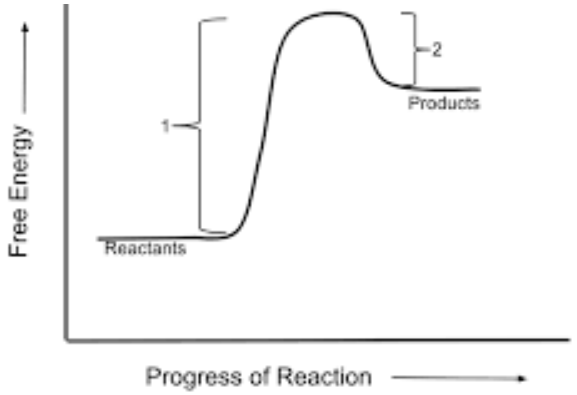
Unit 3

Cellular Energetics

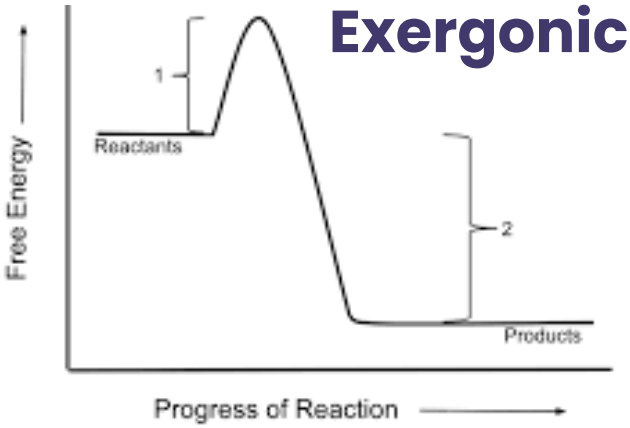
Thermodynamics

Energy cannot be created nor destroyed. **Thermodynamics** deals with heat, work, and pressure in relation to energy. This is especially important in cells. The **First Law of Thermodynamics** is that a cell must harvest energy. This stems from the fact that energy cannot be created. The **Second law of Thermodynamics** is that the transfer of energy leads to less organization. This is known as **entropy**. When you heat up water(add energy) the particles will move faster and faster. Therefore, the more energy the more random the water particles become. For an organism to survive its energy input must exceed its output. Often the product of one step in energy flow is the reactant for another.

Endergonic



Exergonic

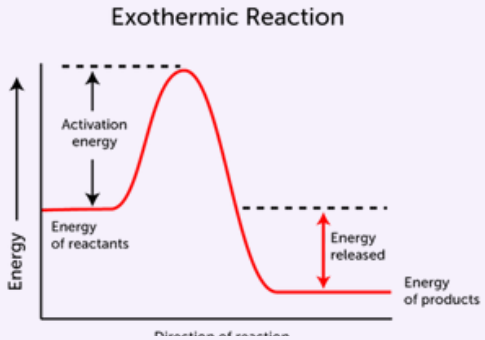


Types of Reactions

There are two types of reactions. **Exergonic** and **Endergonic**. In an **Exergonic** reaction, the reactants have more energy than the products. Think of **Exergonic** as exiting so the energy will exit out. This means there will be less energy at the end. In an **Endergonic** reaction, the reactants have less energy than the products. If **Exergonic** is energy exiting then **endergonic** is energy going in. Since energy goes in during an **endergonic** reaction, there will be more energy at the end. See the diagrams above for a better idea. All of this falls under **bioenergetics** which is study of how cells transform energy.

Activation Energy

The activation energy is the energy needed for the reaction to occur. It usually occurs in the beginning of the reaction and can be lowered by enzymes. In order for a chemical reaction to take place old bonds must be broken to for new ones to be formed. This is why activation energy exists.



Enzymes

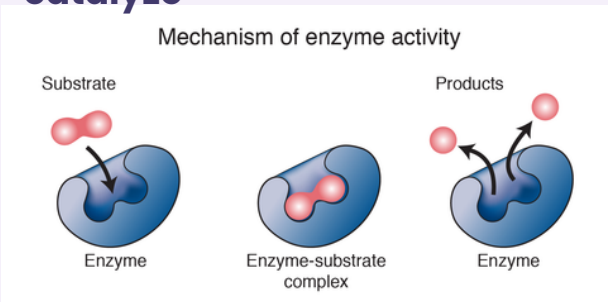
Catalysts speed up reactions. Enzymes are examples of this as they assist in the substrate's reactions(You'll read about substrates after this). The enzymes assist in the reaction by lowering the activation energy. This does not change any other energy in the reaction(only activation).

https://youtu.be/qgVFkRn8f10?si=62_KNGxC2GnB91Ua

Great Resource about Enzymes in general: Amoeba Sisters.

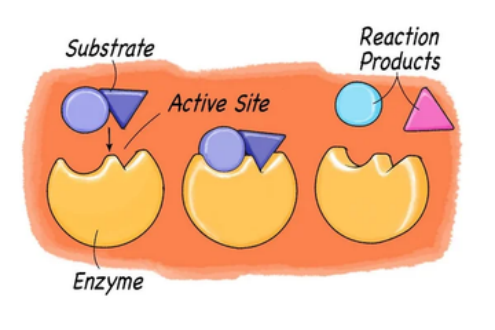
Enzyme Specificity

Enzymes are specific to their **substrates**(the molecules they target). They are **proteins** specifically folded to fit their substrates. They usually only **catalyze** the substrate-specific to them. This is known as **Enzyme Specificity**. This is also why enzymes are usually named according to their substrate. EX: The enzyme **Lactase** is used to catalyze reactions with **Lactose**. A BIG hint that something is an enzyme is that its name ends in -**ase**.



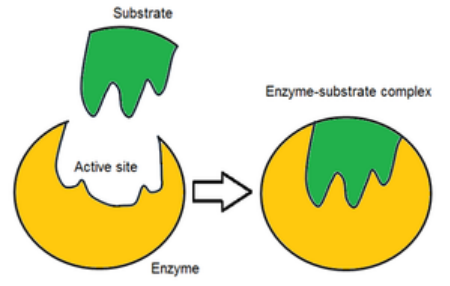
Enzyme Substrate Complex

The part of the **enzyme** mainly used to decrease transition rates is called the **active site**. This is where the **substrate** binds and the reaction takes place. After the reaction takes place the substrate becomes a **product** and the enzyme is free to react with other substrates.



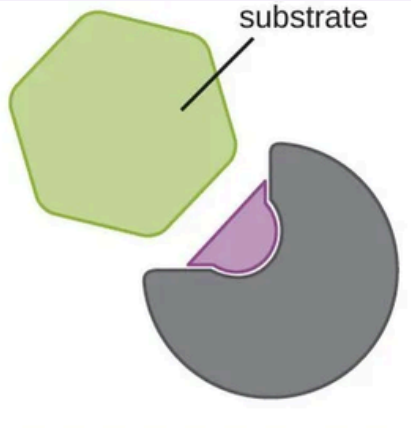
Induced Fit

Although **enzymes** are formed to fit their **substrate** this is often not the case. Many times an enzyme will change its shape to fit its substrate. This is known as **induced fit**. The fitting of the enzyme and substrate have to be like lock and key therefore enzymes only work under certain conditions.



Enzymes Don't Always Work

As stated before **enzymes** work under certain conditions. These include conditions such as **cofactors**. Cofactors can be organic(**Coenzymes**) or inorganic. Cofactors will bind to the enzyme so that the substrate binds perfectly. Examples of cofactors include **vitamins**. They are significant to our body as they are necessary for some enzymes to function.

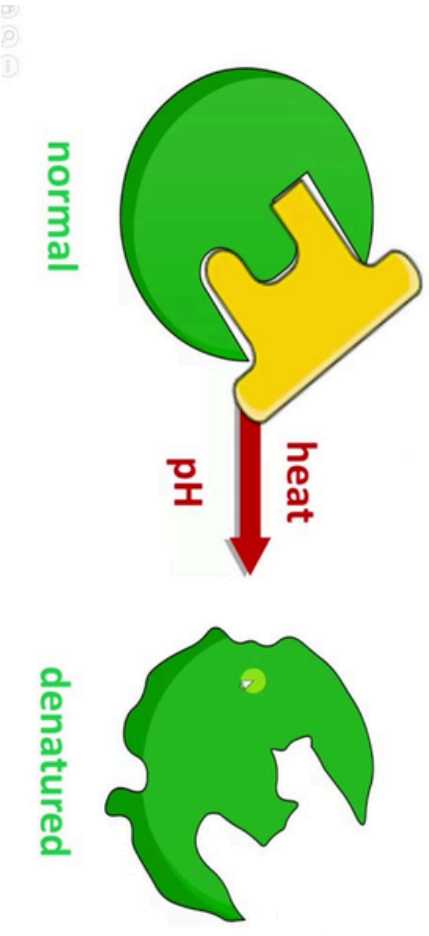


The purple is a cofactor

Factors Affecting Reaction Rates

Temperature

An increase in temperature will lead to an increase in **reaction rates** however when the temperature is too high it leads to **denaturing**. Denaturing is a process in which an enzyme loses its **3-dimensional** shape. In other words, the enzyme melts. As said before the shape of an enzyme is critical to its function. This means the loss of an enzyme's shape means the loss of its function. The optimal temperature for human enzymes is usually 37 degrees Celcius

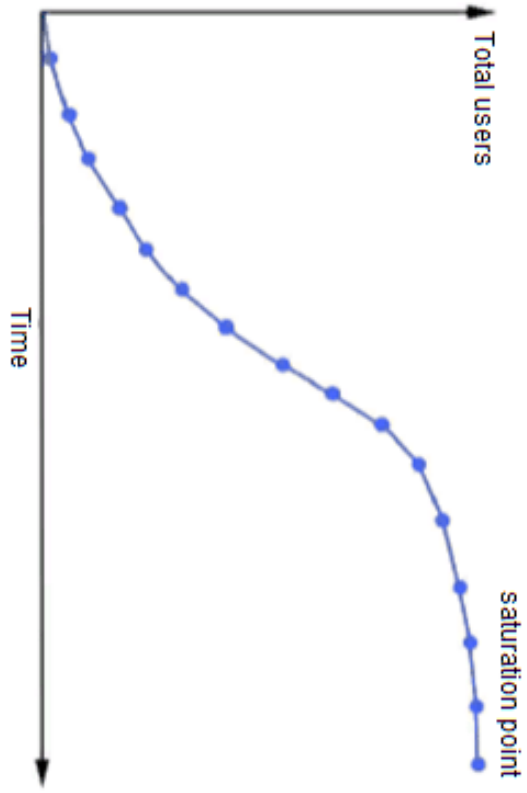


pH

The same goes with **pH** as for temperature. When a pH is too high or too low the **hydrogen bonds** in enzymes are disrupted. This thus changes the structure of the enzymes (**denaturing**) and renders the enzyme useless. Usually, the optimal pH for enzymes is a pH of 7. However, this can vary amongst enzymes.

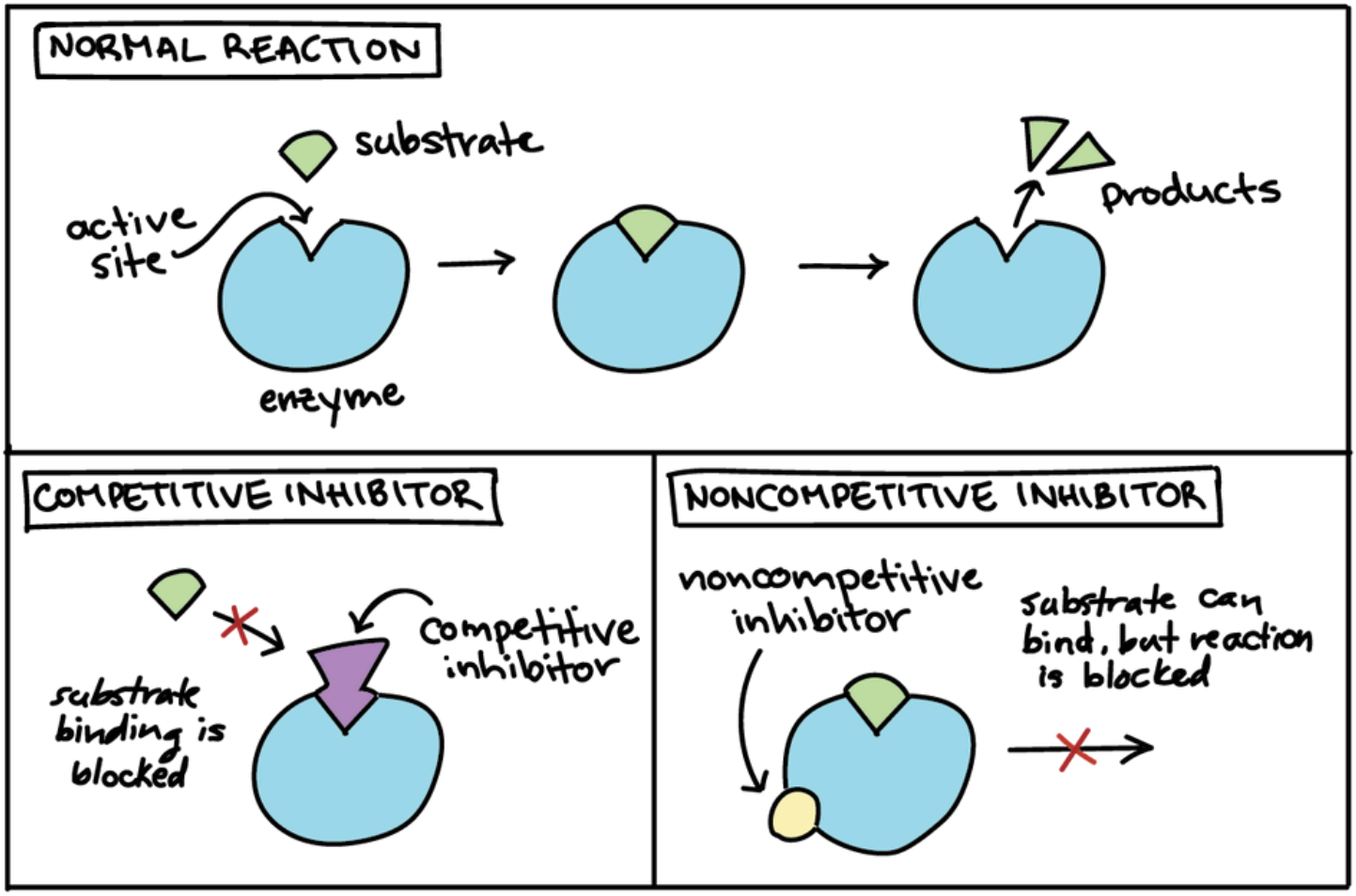
Relative Concentration of Substrateses and Products

The **concentration** of **substrates** available affects the concentration of **products**. If there is a low amount of **substrates** there will be a low amount of **products**. However, if there are too many substrates there will not be enough enzymes available to bind to. This means reaction rates will no longer speed up. This is known as the saturation point and on a graph it'll look a straight line.



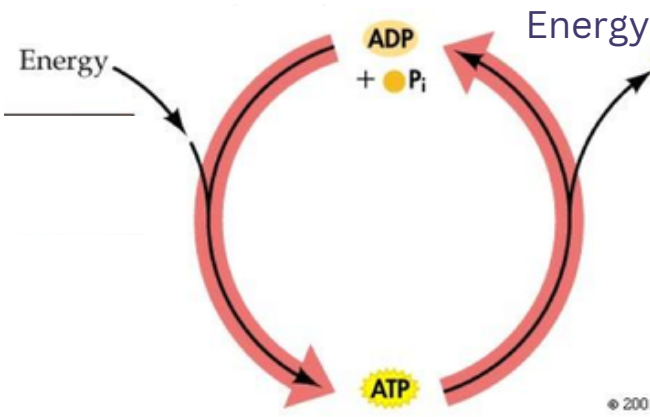
Enzyme Regulation

Enzymes are not always working. By binding things to the enzyme it makes the substrate unable to bind to the enzyme(turns the enzyme off). These things are called **inhibitors** and will sometimes bind directly to the **activation site** or another site known as an **allosteric site**. If an inhibitor binds to the active site it competes with the actual substrate. This is known as **competitive inhibition**. If an inhibitor binds to an **allosteric site** it usually changes the shape of the enzyme so that the substrate can still bind. However, a reaction will not take place. This is known as **non-competitive inhibition**.



Reaction Coupling and ATP

Adenosine triphosphate (ATP) is the primary **energy carrier** in cells, consisting of an adenosine molecule bonded to three phosphate groups. The bonds between these phosphate groups hold a large amount of **potential energy**. When a cell requires energy, ATP undergoes **hydrolysis**, where the bond between the second and third phosphate is broken, forming **adenosine diphosphate** (ADP) and an **inorganic phosphate** (Pi). This reaction releases energy that the cell can then use to power various **endergonic processes**, such as synthesizing organic macromolecules and other essential cellular activities. By coupling the exergonic breakdown of ATP with these energy-requiring reactions, cells efficiently manage and utilize their energy resources.

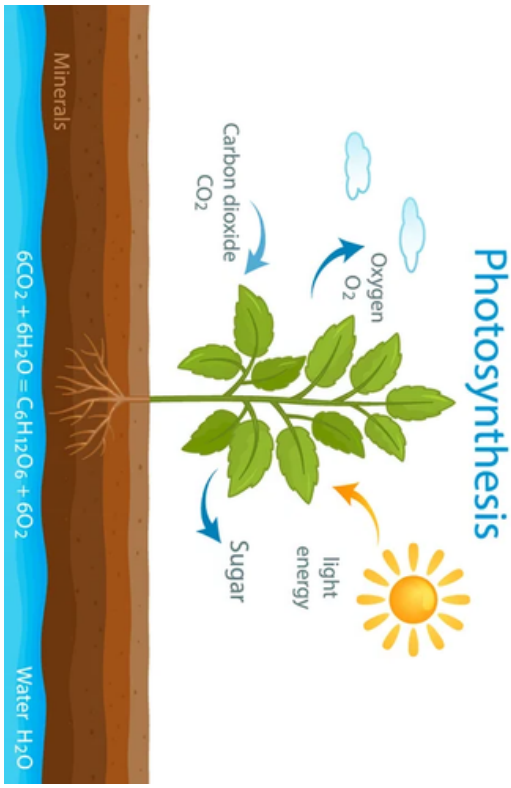


Sources of ATP

ATP is produced in cellular respiration by breaking down sugar. Autotrophs make sugar through photosynthesis, while heterotrophs obtain glucose from food. This glucose is then used to generate ATP.

Photosynthesis

Photosynthesis transforms **light into chemical energy**, using CO_2 and H_2O to form glucose ($C_6H_{12}O_6$) and release O_2. This process was pivotal in the early Earth's evolution, as prokaryotic photosynthesis played a key role in oxygenating the atmosphere. Eventually, it paved the way for eukaryotic organisms to develop their own form of photosynthesis, advancing biological complexity.

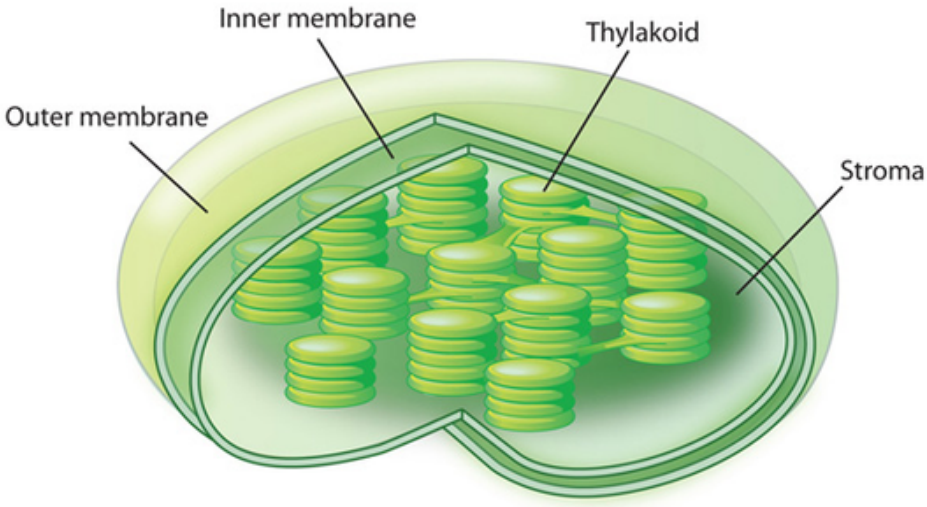


Stages and Byproducts

Photosynthesis consists of two key phases: the **light-dependent reactions and the light-independent (or dark) reactions.** In the first stage, sunlight energizes chlorophyll, triggering electrons to move through a series of carriers, resulting in the production of ATP and NADPH. These energy-rich molecules, along with carbon dioxide, fuel the second stage, where carbohydrates are synthesized. During the light-dependent reactions, **water is also split**, releasing oxygen as a byproduct.

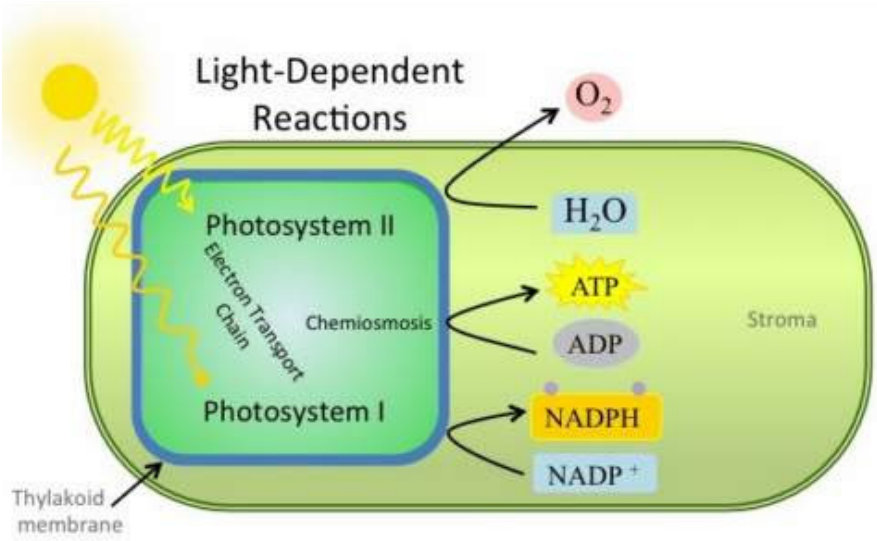
Chloroplast structure

Chloroplasts, found in plant leaves, are the main sites of photosynthesis. Inside a chloroplast, the **fluid-filled region** called the stroma contains stacks of coin-like structures known as **grana**. Each granum is made up of disk-shaped **thylakoids**, which hold chlorophyll and enzymes needed for photosynthesis. The interior of a thylakoid is called the **lumen**. Pigments such as **chlorophyll a, chlorophyll b,** and carotenoids are found in the thylakoid membrane and form antenna complexes that gather light. **Photosystems I (PS I) and II (PS II)** are reaction centers with specific chlorophyll a molecules, which absorb different **wavelengths** of light. Photosynthesis involves converting light energy into ATP through **phosphorylation**. Carotenoids absorb light at the blue-green end of the spectrum, making plants rich in these pigments appear yellow, orange, or red.



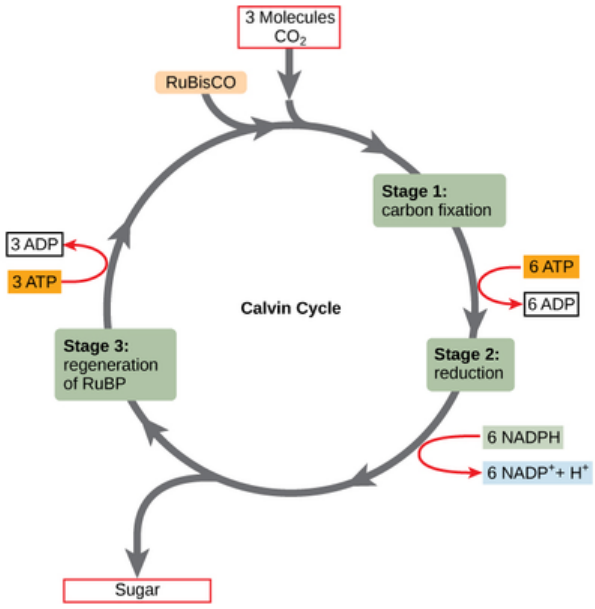
Light Reactions

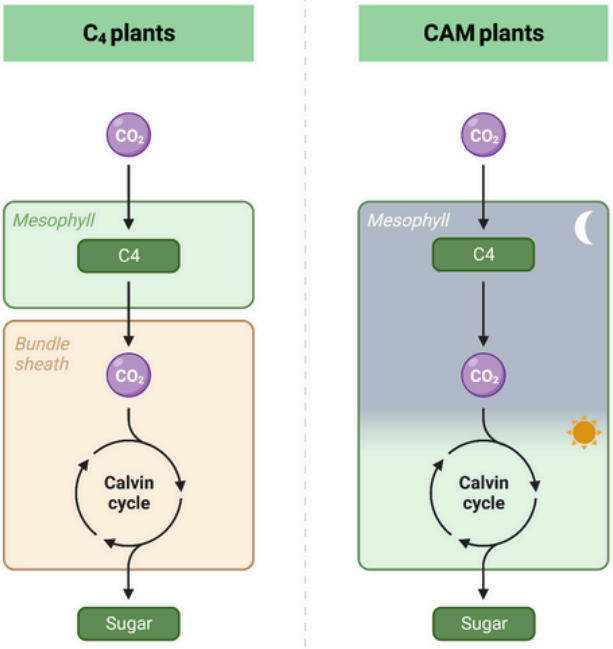
When sunlight hits a leaf, it sends energy to **P680**, which is part of **photosystem II.** Here, energized electrons are captured and passed to a **primary acceptor** before moving through the electron transport chain. As this happens, water molecules are **split into oxygen, hydrogen ions,** and electrons through a process called photolysis. The electrons from **photolysis** replace those lost by photosystem II, and the flow of electrons creates a proton gradient. This gradient powers ATP production as hydrogen ions pass through **ATP synthase**. The electrons continue on to photosystem I, eventually helping to produce **NADPH by reducing NADP+**



Light Independent Reaction (Calvin Cycle)

The light-independent reactions, also known as the Calvin-Benson Cycle, use **ATP and NADPH** produced from the light reactions to synthesize sugar. The carbon source for making glucose is CO2, which is fixed into **carbohydrates** during this process. This phase occurs in the **stroma** of the leaf, where **carbon fixation** converts CO2 from the air into usable carbohydrates for the plant.





Adaptations in CAM and C4 Plants

In hot climates, plants have adapted two strategies to manage carbon fixation. CAM plants separate carbon fixation and the Calvin cycle by time, opening stomata at night to take in CO2 and store it as organic acids. During the day, stomata close, and CO2 is released from these acids to fuel the Calvin cycle. C4 plants, on the other hand, have specialized leaf anatomy that separates CO2 fixation spatially. They create a **four-carbon molecule** during carbon fixation, which helps avoid **photorespiration** by isolating the Calvin cycle from oxygen-rich environments.

Cellular Respiration

In cellular respiration, there are four main stages.

1. glycolysis
2. formation of acetyl-CoA
3. the Krebs, commonly referred to as the (citric acid) cycle
4. oxidative phosphorylation (the e+ chemiosmosis)

Basics

Forumla follows: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

Cellular respiration falls into two main categories. Aerobic and nanaroebic respitration. The presence of oxygen is dubbed, ‘aerobic, and the lack thereof is called, ‘anaroebic.’

Purpose

In order to create an electrochemical gradient across the surface membrane.

Summary

Why Aerobic? The energy production in this form of cellular respiration is much higher than anaerobic. This is the body’s typical route of p yieldingvels. This is the ultimate currency for cells to receive energy. This method is much more efficientconsuming than anarobeic respiration.

Glycolysis

- What is glycolysis? That is, the splitting of glucose
- Glucose: six-carbon molecule that is broken into two three-carbon molecules. This is called pyruvic acid.
- Glucose and its breaking can also result in the net production of two ATP and NADH molecules.

Need to Know

Formula: Glucose + 2 ATP + 2NAD+ → 2 Pyruvic acid + 4 ATP + 2NADH

- NAD+ and NADH are being turned into each other as electrons are carried and unloaded.
- occurs in cytoplasm
- 2 pyruvic acids formed
- net 2 ATPs , and 2 NADH was produced.

Overall:

What is the purpose? Glycolysis breaks down glucose molecules into **pyruvate(pyruvic acid)**. This causes a release of energy that is taken and stored in **ATP** and **NADH**. This is known as the first step to cellular metabolism.

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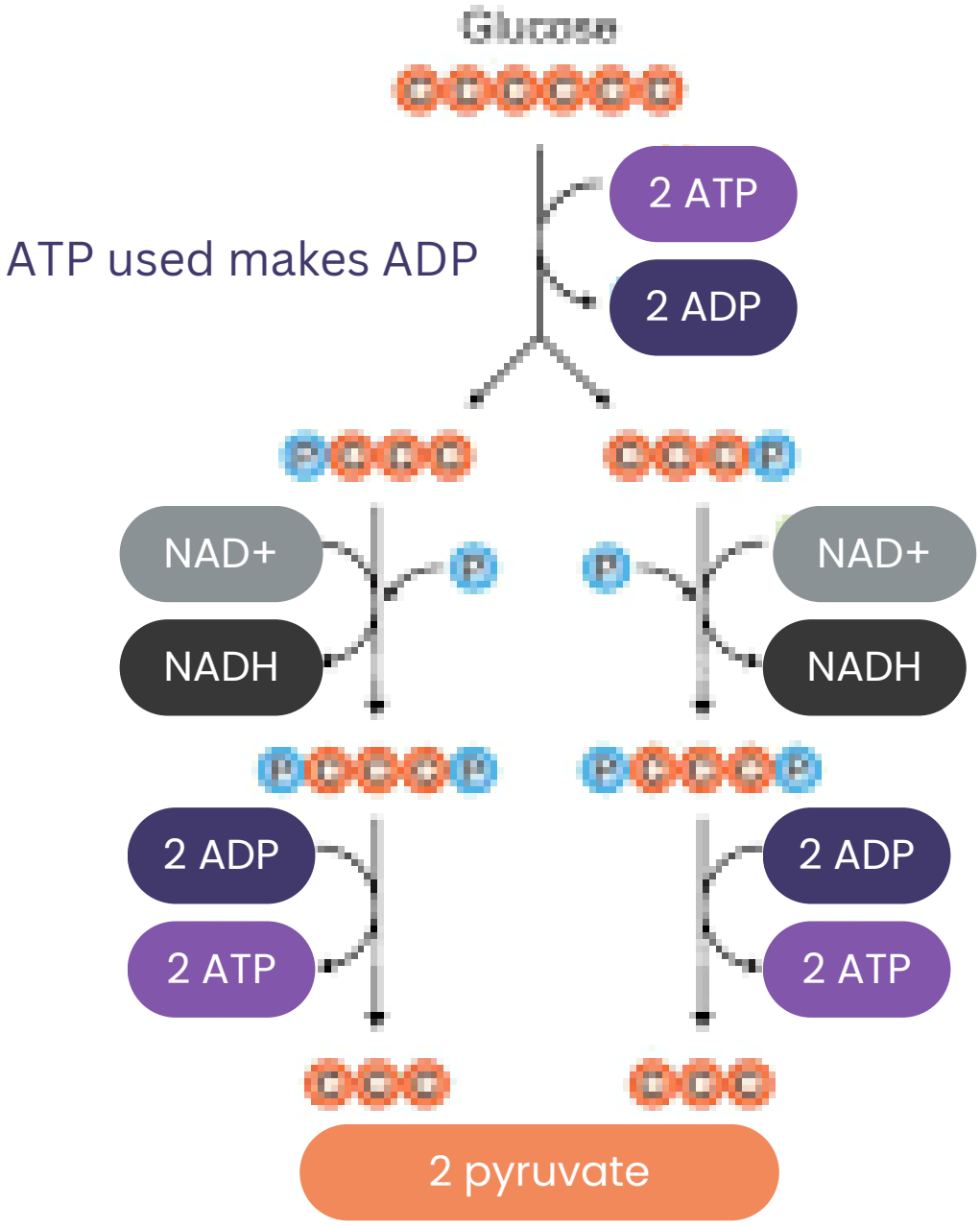
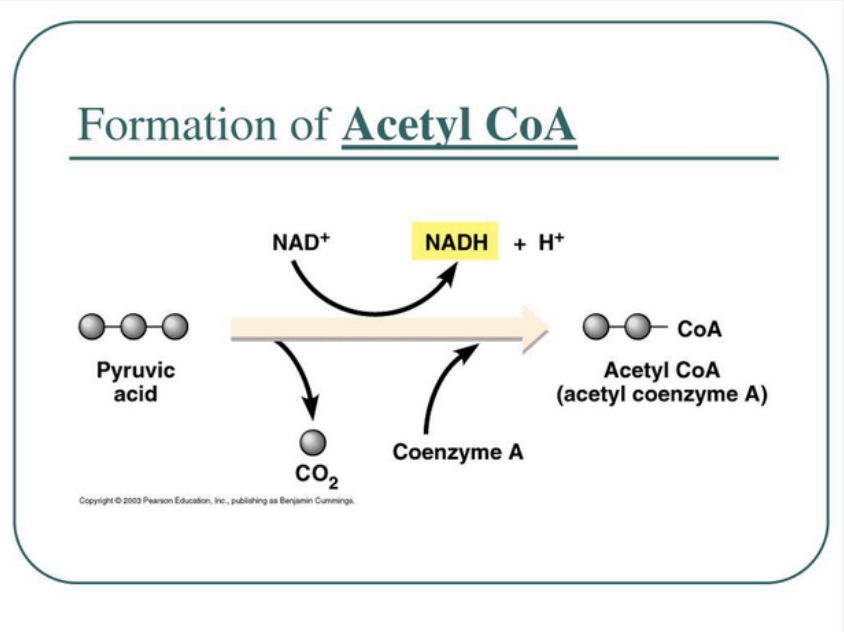
Glycolysis



https://images.app.goo.gl/ZH2VzqGPH4YqBvHCA

- Pyruvic acid gets transported to cell's powerhouse, (the mitochondria.)
- Each 3-carbon molecule, (pyruvic acid,) is converted to acetyl coenyzme.
- A 2-carbon molecule, (acetyl-CoA) and C02 are released.

3-carbon molecules → 2-carbon molecules



2 Pyruvic Acid + 2Coenyzme A + 2NAD+ → 2 Acetyl-CoA + 2CO2 + 2NADH

Using energy from NAD+ the 3-carbon pyruvate is split into a 2-carbon Acetyl CoA and CO2. Excess carbons leave the cell in the form of C02. Since 2 pyruvates are formed in Glycolsis, 2 pyruvates are used during this step. This also means that two molecules of NADH are produced and 2 Acetyl CoA

This process turns pyruvic acid into acetyl-CoA. Acetyl-CoA is used in the Krebs Cycle.

Krebs Cycle (Citric Acid)

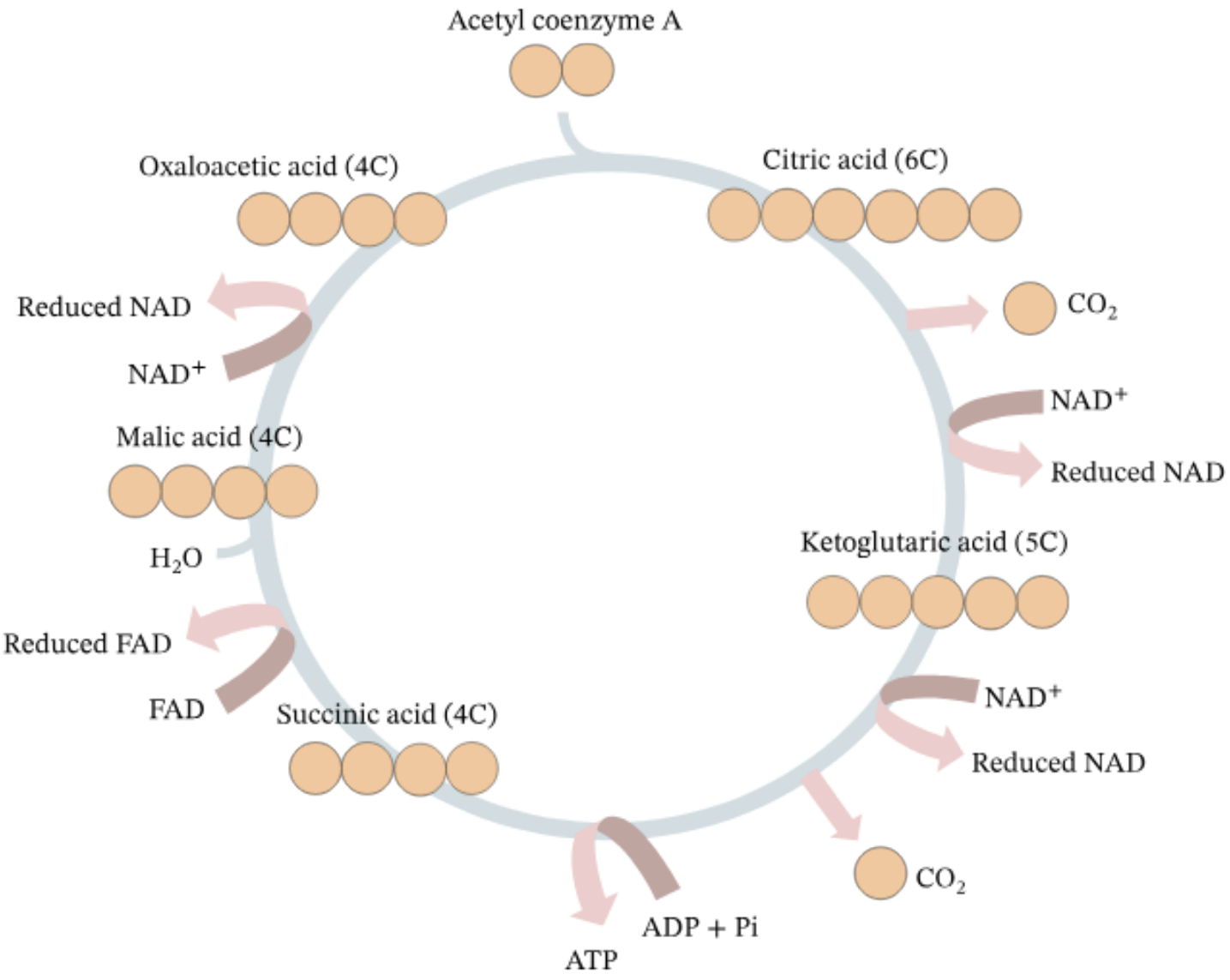
Beginning with each **acetyl-CoA** molecule, (made in **aerobic respiration's** second stage,) combining with **oxaloacetate(4 carbon)**. This 4-carbon molecule together with the **acetyl-CoA(2 carbon)** creates **citric acid/citrate(6 carbons)**. (2+4=6 carbons). 6 carbon becomes 5 carbon as CO2 leaves. NAD+ and FADH are electron carriers. So they use the Krebs cycle to get electrons. NAD+ is turned into NADH. Then this happens again with another NAD+. Then another carbon is lost and turns into CO2. This makes the 5 carbon a 4 carbon. Then FADH turns into FADH2 and this happens with NAD+ one last time. Then the cycle starts over with a 4-carbon molecule. THIS IS CONFUSING!!! Look at diagrams like the one below for help.

Recommend watching Khan Academy Videos on this(linked below).

https://www.khanacademy.org/science/biology/cellular-respiration-and-fermentation/pyruvate-oxidation-and-the-citric-acid-cycle/v/krebs-citric-acid-cycle

location: mitochondrial matrix,
acetyl-CoA + oxaloacetate = citric acid, ending with oxaloacetate, 1 ATP, 3 NADH, and 1 FADH2. (Again, double this if you are counting per glucose.)
Citrate→ into several other things. Though the cycle begins with a four-carbon molecule, oxaloacetate, it gets turned back into **oxaloacetate.** This maintains the cycle, continuing the set with acetyl-CoA, which is already on its way down the pipeline!

- note: 3 energy types are produced every cycle: 1 ATP, 3 NADH, and 1 FADH2
- product total per glucose molecule = product # doubled.


Acetyl coenzyme A
Citric acid (6C)
CO_2
NAD^+
Reduced NAD
Ketoglutaric acid (5C)
NAD^+
Reduced NAD
CO_2
ADP + Pi
ATP
Succinic acid (4C)
Reduced FAD
FAD
H_2O
Malic acid (4C)
Reduced NAD
NAD^+
Oxaloacetic acid (4C)

KREBS CYCLE

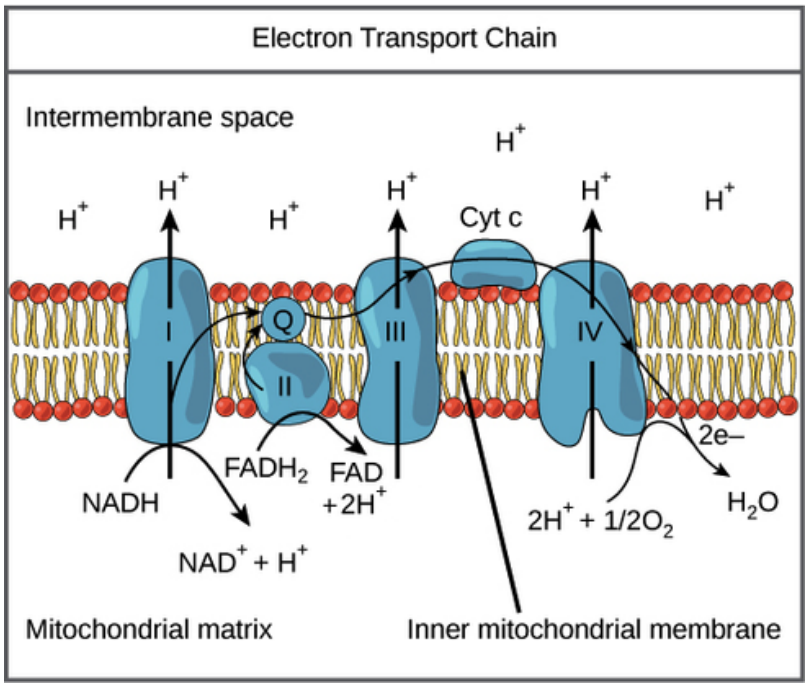
Oxidative Phosphorylation: ETC

Oxidative phosphorylation is the last step of aerobic respiration. The **NADH** and **FADH2** carrier molecules bring electrons from the other steps of respiration to the **Electron Transport Chain (ETC)**. After dropping the electrons off, NADH and FADH2 reduce back to NAD+ and FAD+ to be reused. The electrons are travel down a series of membrane protein complexes embedded in the **inner mitochondrial membrane**. The electrons are passed from one complex to another, and each complex is more electronegative than the previous one. **Oxygen** acts as the **final electron acceptor** because it is the most electronegative. Without O2 available, the ETC cannot function because the electrons would have nowhere to go.

Carriers

- 2 NADH -glycolysis
- 2 NADH -acetyl CoA production
- 6 NADH -Krebs Cycle
- 2 FADH2 -Krebs Cycle

- Total: 10 NADH + 2 FADH2 (12 carriers)

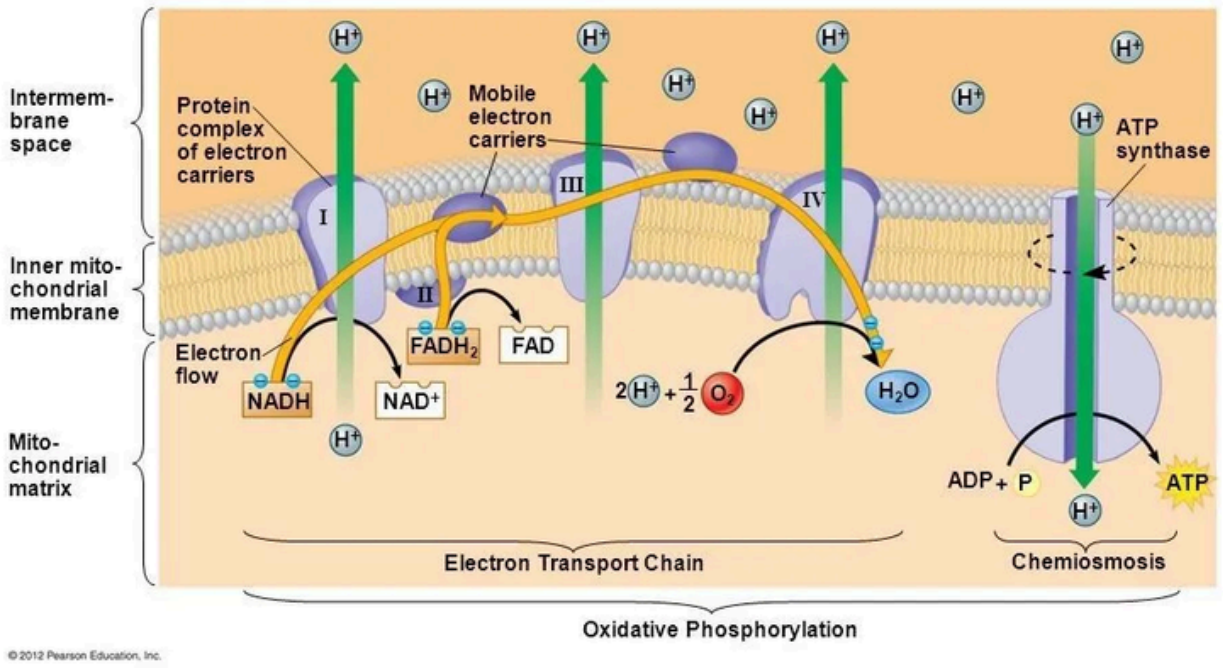


Oxidative Phosphorylation: Chemiosmosis

Chemiosmosis uses energy from a **proton (H+) gradient** to drive cellular work. In aerobic respiration, chemiosmosis occurs across the **inner mitochondrial membrane** after the ETC. The energy released by ETC electrons is used to pump protons from the **matrix** across the inner mitochondrial membrane into the **intermembrane space**, forming a concentration gradient. Due to this gradient, the protons diffuse back into the matrix through the protein complex **ATP synthase**. Using the movement of the protons passing through, ATP synthase makes ATP by phosphorylating ADP with organic phosphate.

ATP Yields

- every NADH from glycolysis yields 1.5 ATP
- all other NADH yields 2.5 ATP
- every FADH2 yields 2.5 ATP
- NET total ATP from chemiosmosis: 26-28 ATP



Both Cellular Processes

- have **electron transport chain** (ETC) that pumps protons to create a proton gradient
- have **ATP synthases** driven by proton gradients

Photosynthesis

- Chloroplast (and cytoplasm)
- Endergonic: negative net ATP
- NADPH carriers

- ETC and ATP Synthase in the **thylakoid membrane**
- Protons are pumped from **stroma -> thylakoid lumen**
- Higher acidity (more H+) in lumen

- **Calvin Cycle** reduces CO2 into carbohydrates

Cellular Respiration

- Mitochondria (and cytoplasm)
- Exergonic: positive net ATP
- NADH and FADH2 carriers

- ETC and ATP Synthase in the **inner mitochondrial membrane**
- Protons are pumped from **mitochondrial matrix -> intermembrane space**
- Higher acidity in intermembrane space

- **Krebs Cycle** oxidizes carbohydrates into CO2

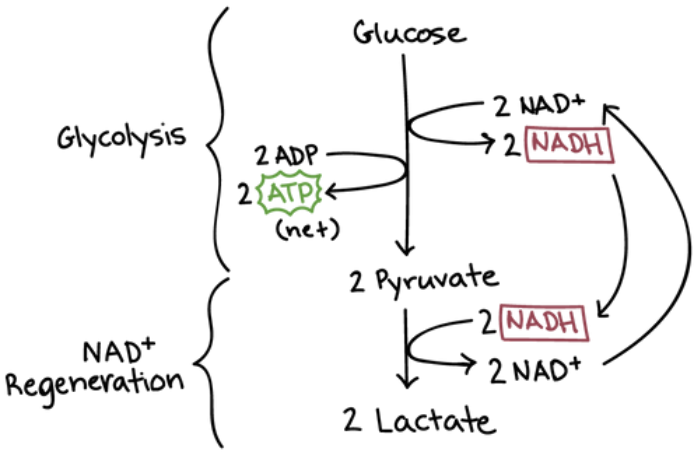
Fermentation

Fermentation (a type of anaerobic respiration) occurs when oxygen is not available. In these cases, only glycolysis continues to run. Glycolysis yields **2 ATP**, 2 pyruvate, and 2 NADH. Since the ETC no longer works, NAD+ must be regenerated by other means. So, the NADHs oxidize the pyruvates into either lactate (**muscles**) or ethanol (**yeast**). These are called **lactic acid fermentation** and **alcohol fermentation**, respectively. Since the net ATP yield is so little (2 ATP per glucose), anaerobic respiration is a very inefficient process and is only used in emergencies!

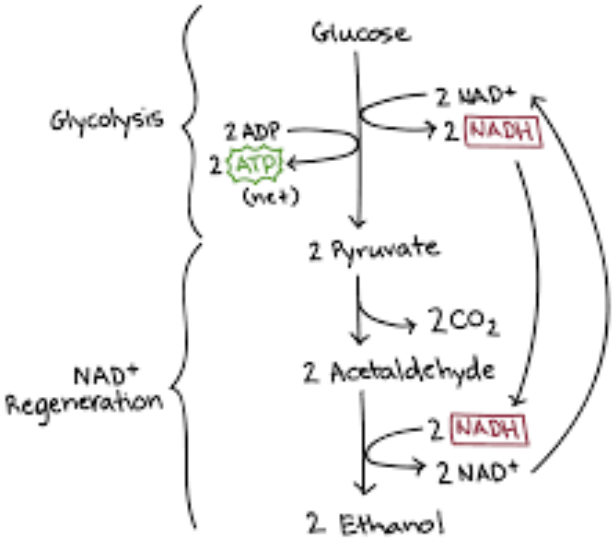
Anaerobic Respiration

In some other cases, acetyl-CoA production, Krebs Cycle, and chemiosmosis continue to run without oxygen. Instead of oxygen, the final electron acceptor is another highly electronegative molecule (e.g. sulfur).

Lactic Acid Fermentation



Alcohol Fermentation



Unit 3

Cellular Energetics: Review Questions

1. **Which color of light is absorbed during photosynthesis?**

   A) orange B) blue C) green D) red

2. **NADH and FADH2 are examples of ...**

   A)carbohydrates B) proteins
   C) pyruvates D) electron transports

3. **Which stage of Cellular Respiration produces the MOST ATP?**

   A) Glycolysis B) Oxidative Phosphorylation
   C) Citric Acid Cycle D) ETC

4. **Giving birth is an example of what type of feedback?**

   A) Positive B) Negative
   C) Allosteric D) Accelerated

Unit 3

Cellular Energetics: Review Questions

5. Allosteric Sites use...

A) competitive inhibitors B) substrates

C) non-competitive inhibitors D) products

6. Which part of photosynthesis takes place in the stroma?

A) Light reactions B) Calvin Cycle

C) Glycolysis D) Citric Acid Cycle

7. Enzymes are used to_____reactions.

A) Denature B) Slow down

C) Synthesize D) Catalyze

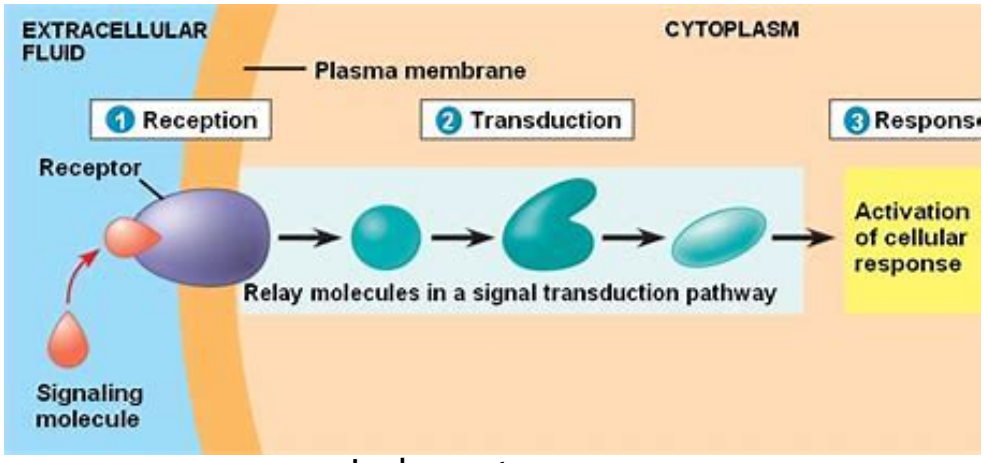
Answer key:
1) C 2) D 3) B 4) A 5) C 6) B 7) D

Unit 4

Cell Communication and Cell Cycle

Cell Communication

The ability to communicate with other cells is greatly significant for **stimulation** and **inhibition**. In cases including **Unicellular** organisms cell communication can be used to find a mate, adapt metabolism rates, or change their rates in gene expression according to cell populations (quorum sensing). The movement of an organism in response to stimuli is known as **Taxis**. This can be **positive**(moving towards stimulus) or **negative**(moving away from stimulus). Sometimes you'll hear the word **Chemotaxis**, an organism's response to chemicals. An example of this is the flagella of bacteria rotating to avoid poisons



Labroots.com

Signal Transduction Pathways

Cell signaling can be **intercellular**(between another cell), **intracellular**(within the cell), **short-range**, **long-range**, use **gap junctions**, or use signaling molecules known as **ligands** that bind to receptors. Just like a substrate to its enzyme ligands change the shape of receptors so they can bind to it. This is especially utilized in **Signal Transduction pathways** where a signal outside the cell is transmitted into the cell.

1. A ligand binds to a receptor (Reception)
2. a pathway is activated(Transduction) (See Image)
3. a response is produced(Response)

Signal Transduction Part 2

As known from Unit 2 **hydrophobic** molecules can slip through the membrane. This means hydrophobic signaling molecules have similar properties. Sometimes these molecules have receptors in the membrane. **Hydrophilic** molecules cannot slip through the membrane, therefore, they need receptors on the plasma membrane to transmit signals. There 3 main types of **plasma membrane receptors.**

Ligand-Gated Ion Channels

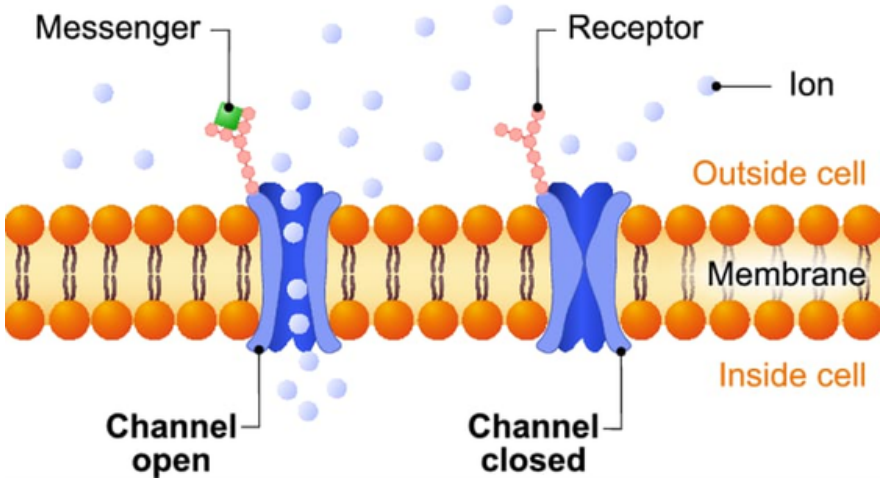
A **ligand** will bind to a channel protein which depending on the receptor will open or close the channel. When open, **ions** can pass through. One examples is a **sodium channel** where the channel will open in response to **acetylcholine**.

Catalytic(enzyme-linked) Receptors

An **active site** will be located outside of the cell where a **ligand** will bind. After binding a pathway is **activated**. An example of this is an **insulin receptor**. After insulin is bonded a pathways activated to synthesize glucose(THIS IS AN IMPORTANT EXAMPLE WORTH MEMORIZING)

G-protein-linked receptor

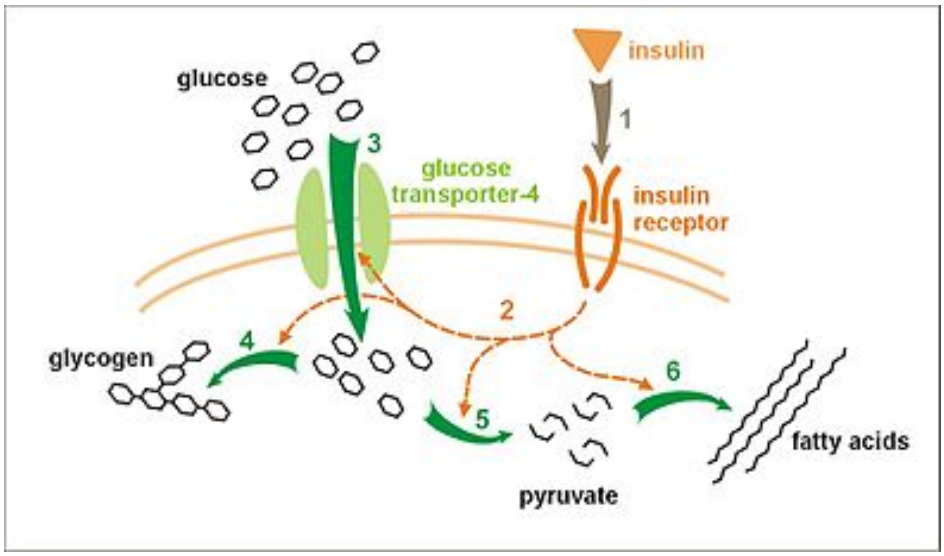
A key hint that a receptor is a **G-protein receptor** is if it uses a second messenger and one very common is **cAMP**. In this receptor, a ligand will bind outside of the cell signaling a version of G protein(GDP or GTP) which activates a second messenger that work to amplify the signal.



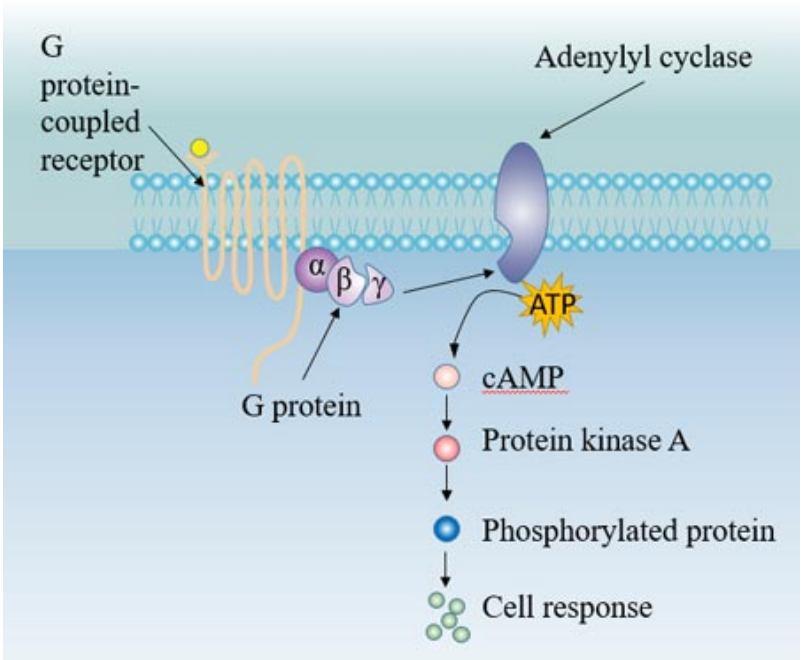
Ligand Gated

ChemDiv.com

Enzyme Linked



InsulinReceptor-Wikipedia.com

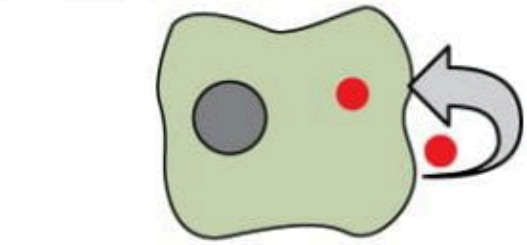


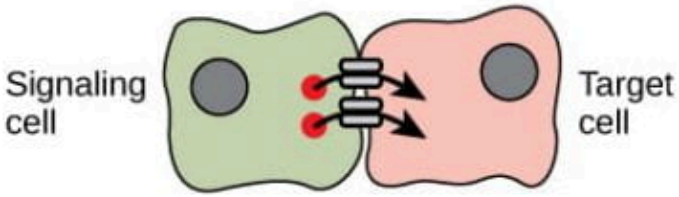
G-Protein

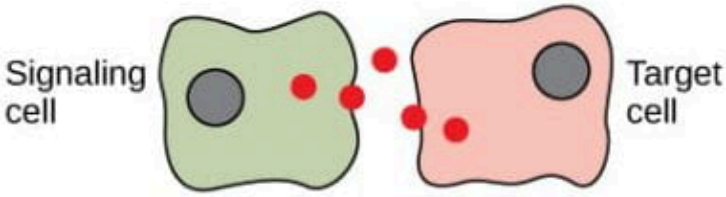
Cusabio.com

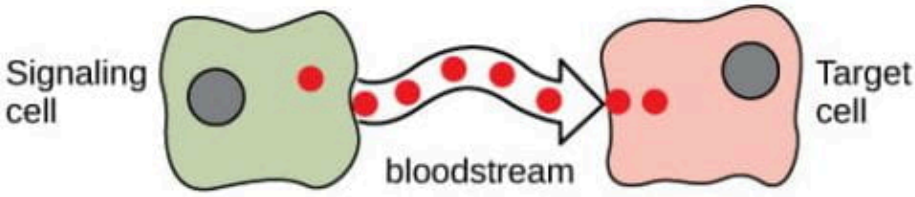
More Types of Cell Signalling

Forms of Chemical Signaling	
Autocrine	A cell targets itself.
Signaling across gap junctions	A cell targets a cell connected by gap junctions.
Paracrine	A cell targets a nearby cell.
Endocrine	A cell targets a distant cell through the bloodstream.









Courses.lumenlearning.com

Homoeostasis:

Homeostasis is the ability to resist a particular change in order to maintain a balanced and relatively stable internal environment. **Negative feedback** loops counteract changes of different properties from their target values, (set points). Keeping the system stagnant. Contrastingly, **positive feedback** loops emphasize their initiating **stimuli**, moving the system away from its starting state.

What is the Cell Cycle?

The **eukaryotic cell cycle** has several phases. The **mitotic** phase (M) includes both **cytokineses** and **mitosis**. This is where division of the **nucleus** and **cytoplasm** take place. The other three phases (**G1**, **S**, and **G2**) are generally dubbed holistically as **interphase**. This stage is where the cell grows, performs routine life processes, and performs division preparation.

Example:

AdobeStock.com

****body producing sweat as a cool-down response****

Why?

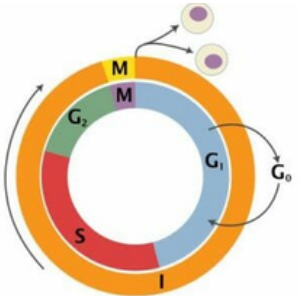
The cell cycle is necessary for all living organisms to develop, grow, repair damaged tissues, and replace dead/old cells by the creation of new ones. All this is possible through the controlled process of cell division.

Interphase

Interphase is the longest stage in a **eukaryotic** cell cycle
"What happens?"
The cell acquires nutrients, makes and utilizes proteins/other molecules, and begins its **cell division** process with DNA replication. **Interphase** has three distinct stages; **G1**, **Synthesis**, **G2**. All in all, **interphase** is preparation for cell division, (happening at different stages of the cell cycle).

G1

G1 occurs after **mitosis**(which you'll learn about later) where two new cells enter into the first stage of interphase: Gap 1(G1). In G1, cells perform their normal functions and grow in size. The cell is also **replicating organelles** as necessary. Sometimes cells can leave G1 and enter $\mathbf{G_0}$ (resting phase). If a cell is an actively dividing cell, it continues interphase by entering its next phase: synthesis.



Biology dictionary.net
-All the orange is interphase

G2

G2 occurs after Synthesis. During G2 volume is being added to the **cytoplasm**, replicating many important **organelles**. G2 extends until the cell enters cell division. (Mitosis)

Synthesis

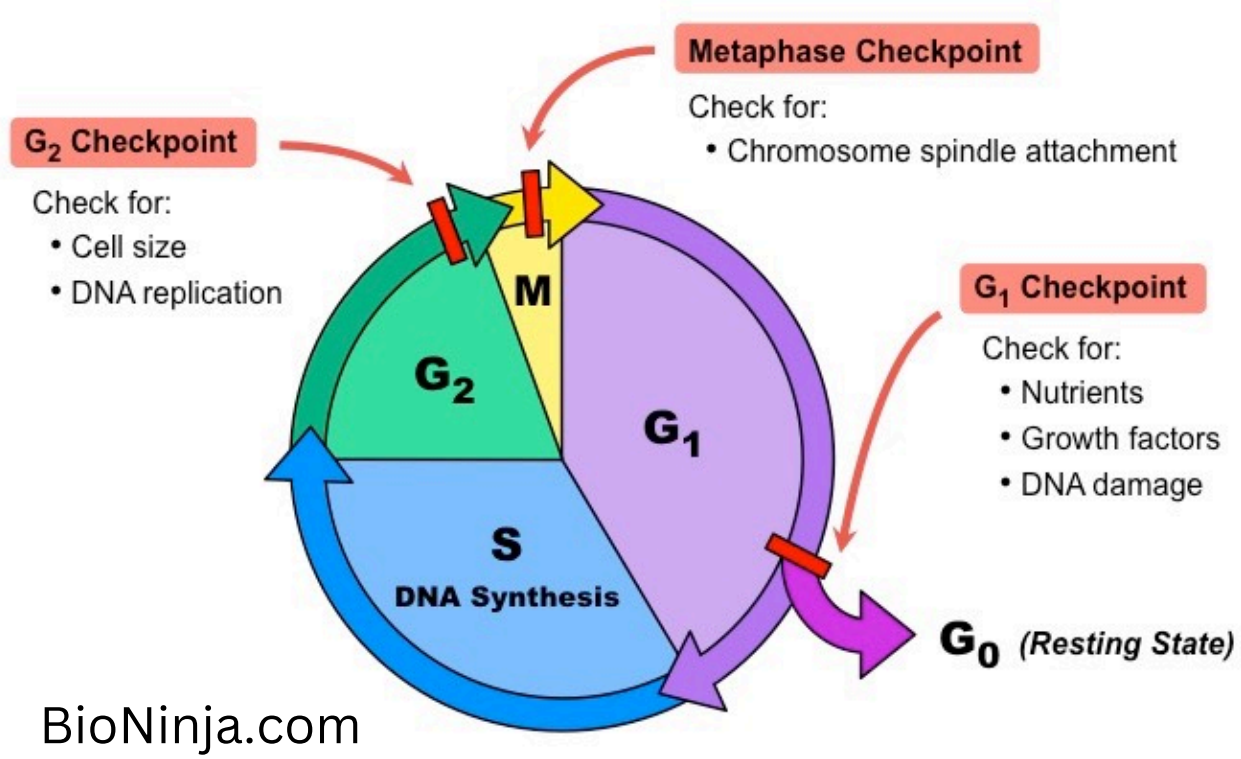
In this stage, a cell pauses its normal functions. All its resources are dedicated to **DNA replication**. To Synthesize is to make so synthesis is to make more DNA. DNA must replicate as you'll see later it split in half during mitosis.

Cell Cycle Regulation

- during interphase **G1** and **G2**, cells grow and duplicate organelles
- G1 and G2 also have cell cycle checkpoints, regulated by proteins called **cyclins** and **cyclin-dependent kinases (CDK)**

Interphase Checkpoints

- **G1-S checkpoint:** towards the end of G1, the cell is checked to ensure that it is ready for cell division.
  - if YES: continues to S phase (DNA replication)
  - if NO: halts cell cycle to attempt to fix problem, OR sends cell to **G0** (apoptosis/non-dividing state)
- **G2-M checkpoint:** at the end of G2, the cell is checked for proper chromosome duplication.
  - if YES: continues to mitosis
  - if NO: halts cell cycle to attempt to fix DNA problem



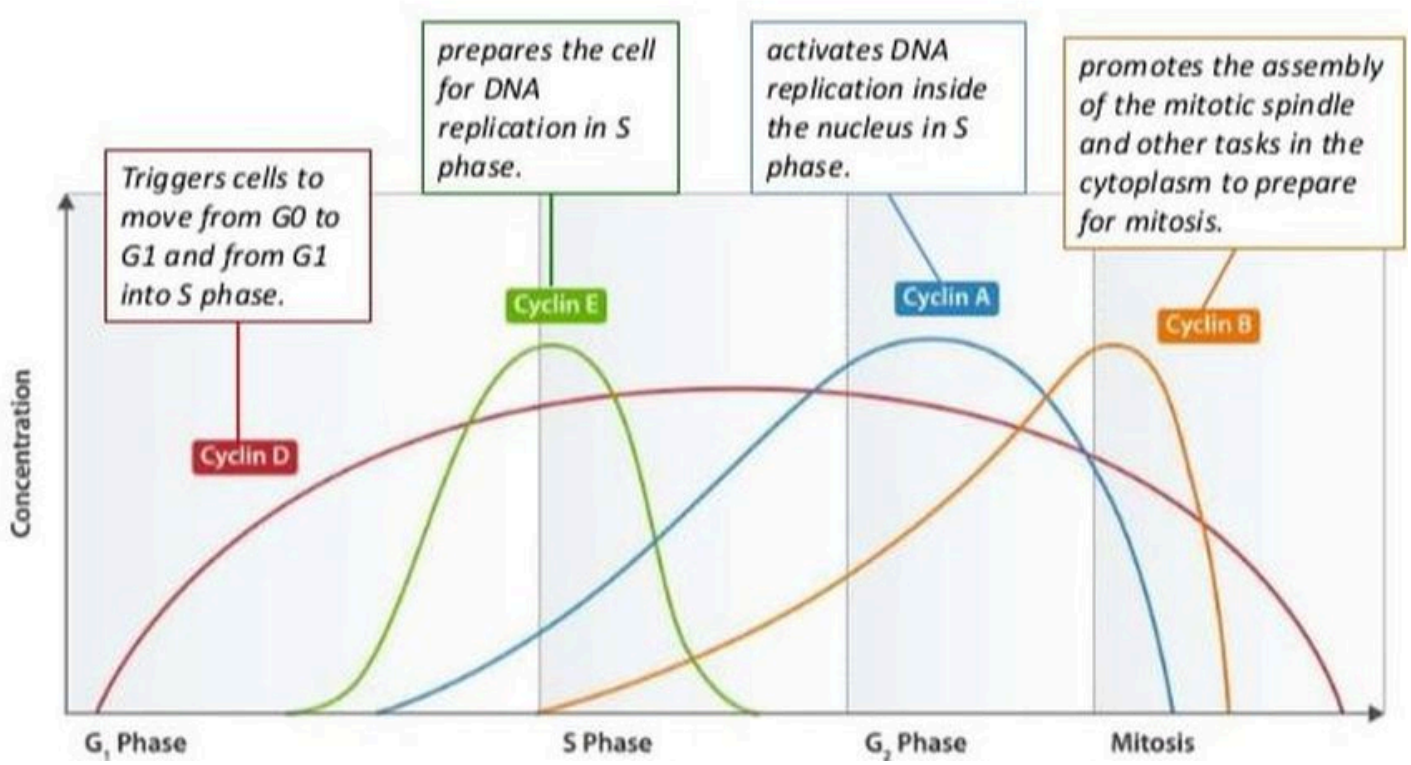
BioNinja.com

Cyclins & CDKs

- **cyclin-dependent kinases**: protein kinases that are activated by attachment of a regulatory cyclin protein
- when many CDK complexes are activated, the cell can progress in cell cycle
- when most CDK complexes are kept apart, the cell cannot proceed to next step

Concentrations

Notice that each cyclin (besides D) has one distinct peak. Each type of cyclin regulates a checkpoint located towards the end of their respective phases.



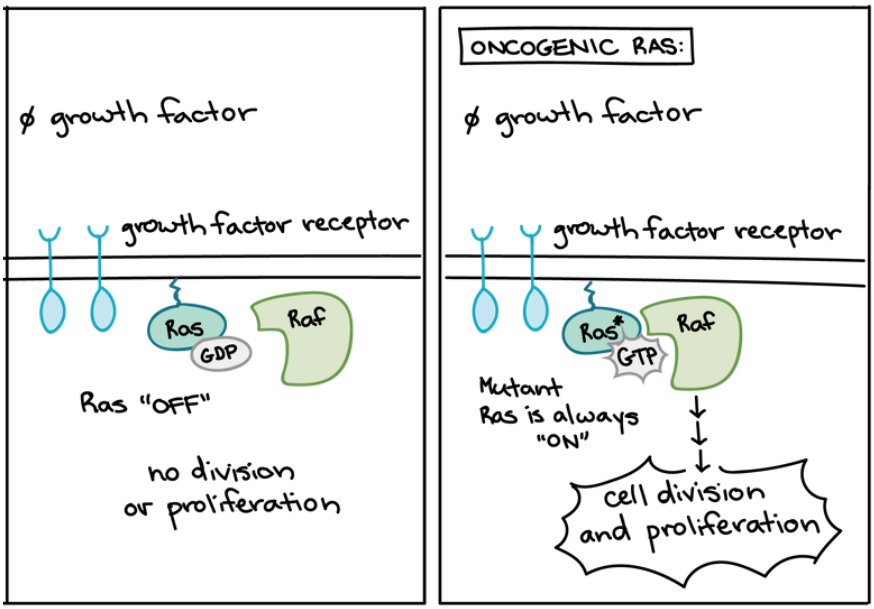
KhanAcademy.com

Cancer

Cancer occurs when cells grow and divide abnormally. Gene **mutations** may cause too many growth factors and/or lack of inhibition factors, causing cells to divide uncontrollably. Cancer cells do not follow cell cycle checkpoints.

Oncogenes

- **proto-oncogene:** codes for proteins that help with initiation and advancement of cell cycle
- **oncogene:** a mutated proto-oncogene; causes over-initiation of cell cycle



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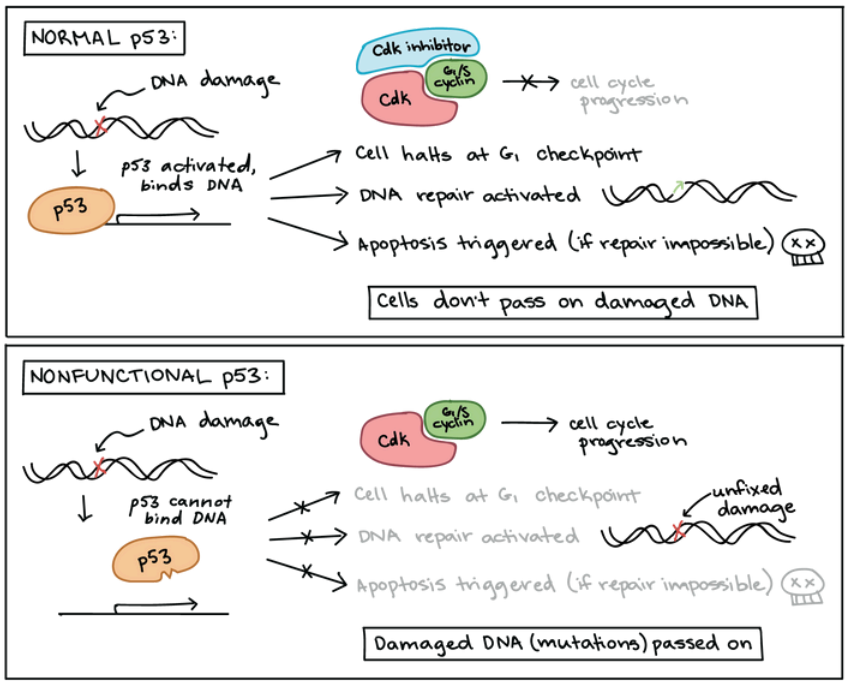


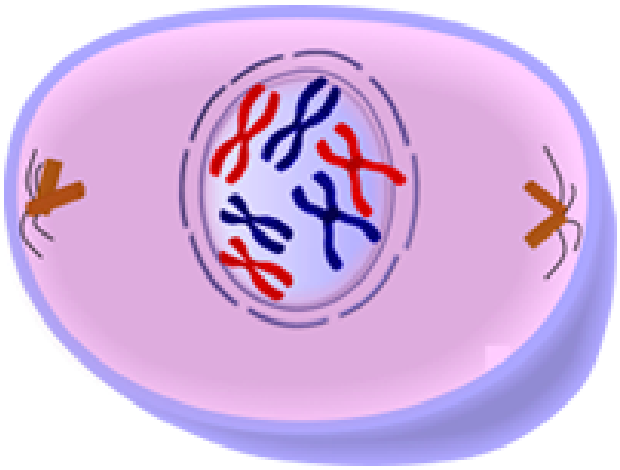
KhanAcademy.com

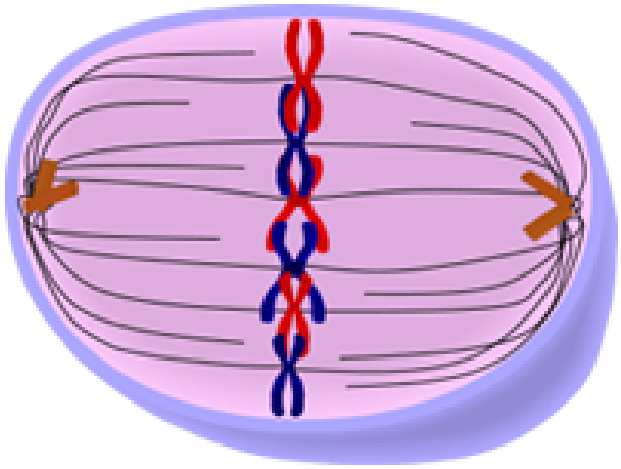
Tumor Suppressor Genes

- **tumor suppressor gene:** codes for proteins that prevent cells from dividing too often
  - most common: p53
- **mutated:** lack of tumor suppressor proteins will lead to unrestricted cell division

Mitosis

The process by which an **eukaryotic** cell divides its nucleus and cytoplasm to produce two **genetically identical** daughter cells. It's a critical part of the cell cycle that enables tissue repair, growth, and asexual reproduction in some organisms. The process occurs in several phases: **Prophase**, **Metaphase**, **Anaphase**, and **Telophase**. The phases can be remembered as the acronym, PMAT.





edupic.net

Prophase

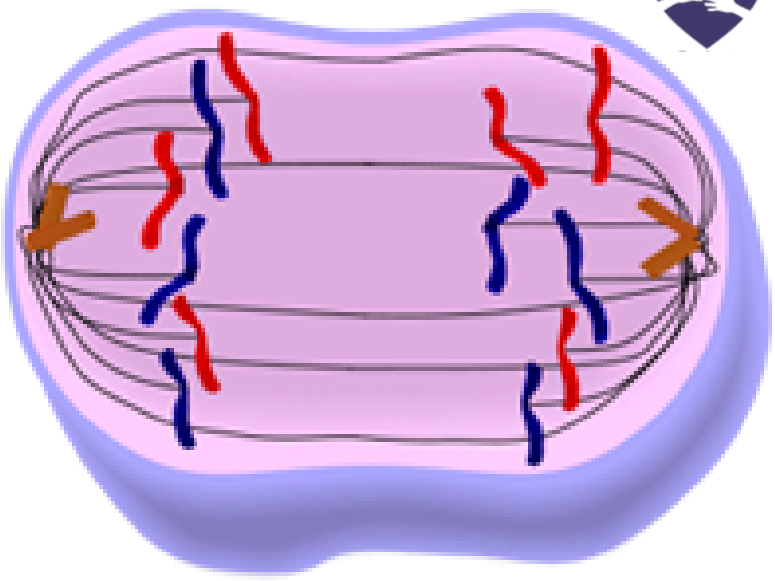
Prophase is the first stage of mitosis where chromosomes condense and the nucleolus disappears. The centrosomes move to opposite poles and form spindle fibers.

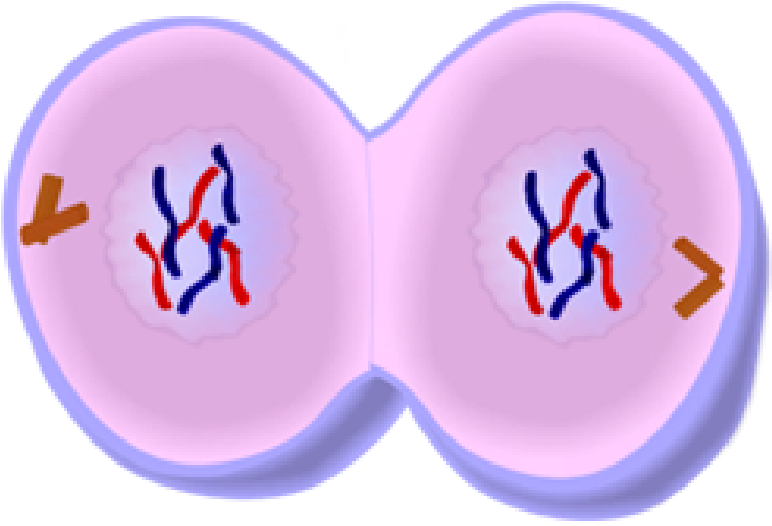
Metaphase

The second stage of mitosis is Metaphase. Chromosomes align at the cell's equator, forming a straight line. The spindle fibers attach to the centromeres or each chromosome, ensuring that they are properly positioned for separation.

Anaphase

In Anaphase, the centromere splits into sister chromatids. The sister chromatids are pulled apart toward opposite poles of the cell and the spindle fibers shorten, separating the chromatids. The process ensures that each pole gets an identical set of chromosomes.



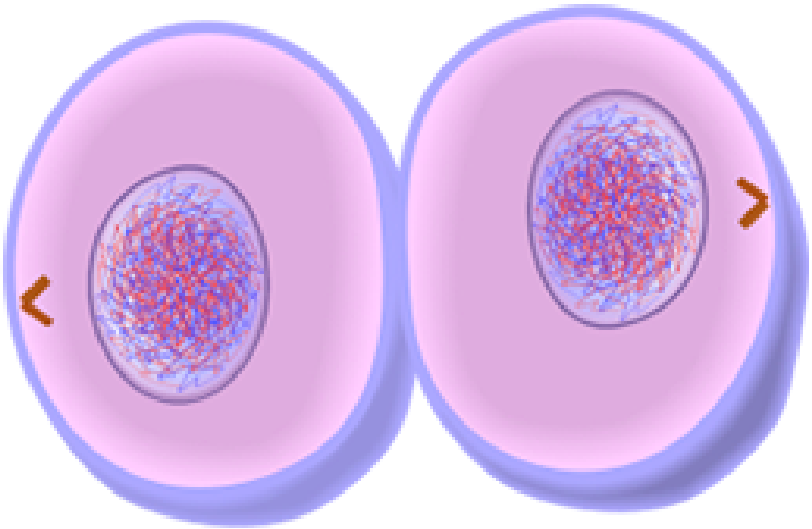


Telophase

The chromosomes reach the poles of the cell and nuclear envelopes form around each set of chromosomes, creating new distinct nuclei. The nucleolus reappears and the cell prepares for cytokinesis.

Cytokinesis

The final stage of mitosis, where the cytoplasm of a cell divides, creating two distinct daughter cells.



Unit 4

Cell Communication and Cell Cycle: Review Questions

1. **How many mutations does a proto-oncogene need to become an oncogene?**

   A) 1 B) 2 C) 3 D) 4

2. **How many mutations does a tumor suppressor gene need to become cancerous?**

   A) 1 B) 2 C) 3 D) 4

3. **Giving birth is an example of...**

   A) stimuli B) negative feedback loop
   C) positive feedback loop D) Autocrine

4. **Which form of cell signaling is used for long distances?**

   A) Paracrine B) Endocrine
   C) Autocrine D) Gap Junctions

Unit 4

Cell Communication and Cell Cycle: Review Questions

5. The insulin receptor is an example of which type of receptor?

A) Ligand Gated B) Channeling
C) G-Coupled D) Enzyme-linked

6. A 2nd messenger or cAMP is a giant hint that a receptor is...

A) Ligand Gated B) Channeling
C) G-Coupled D) Enzyme-Linked

7. The G0 phase is also known as...

A) Replication phase B) Translation phase
C) Resting phase D) Transition phase

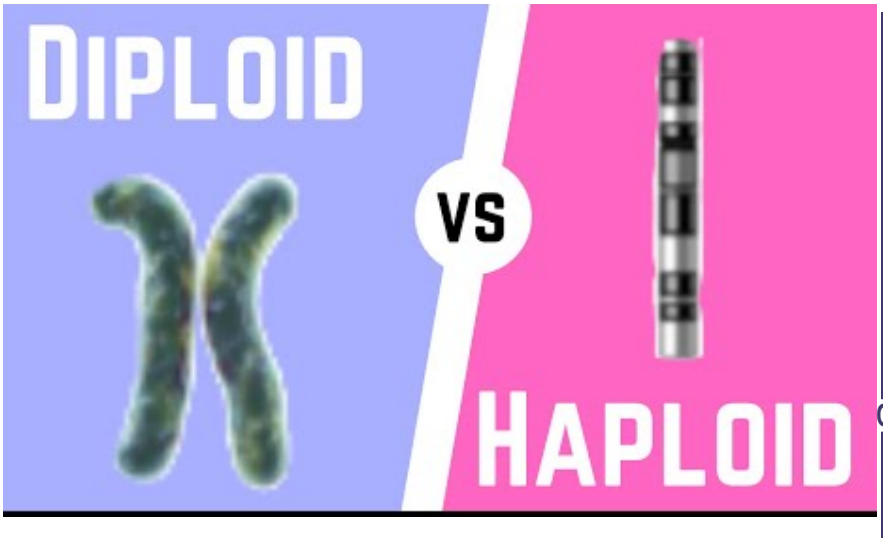
Answer key:
1) A 2) B 3) C 4) B 5) D 6) C 7) C

Unit 5

Heredity

Haploid vs. Diploid

Homologous chromosomes: duplicate versions of each chromosome
How Can You Tell?
In each pair: similar in size and shape; contain same genes in the same locations.



diploid: a cell that has two sets of chromosomes
chromosome #: "2n" (2 copies of each chromosome
Haploid: cell only contains 1 chromosome.
Symbol: "n"

Law of Dominance

Gregor Mendel: discovered genetics

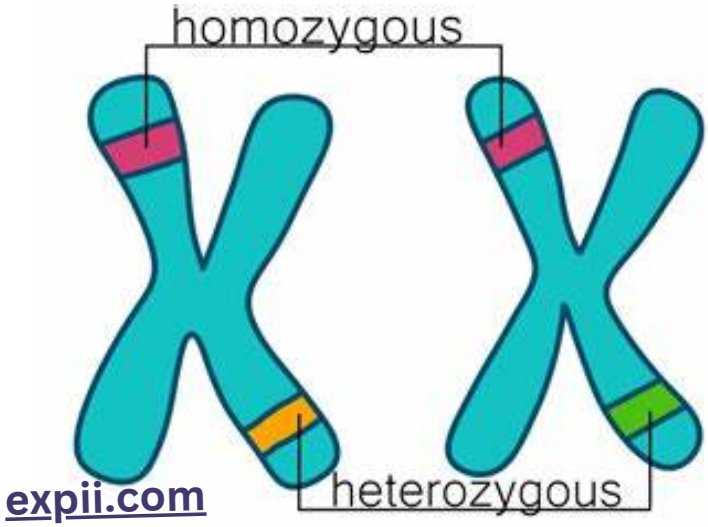
genes: what traits are influenced by (one or many)

locus: position of a gene on chromosome

diploid: two copies of each one, one on each homologous chromosome.

homologous: 2 copies of the chromosome in a diploid cell/organism

Humans: have **23 pairs** of homologous chromosomes.



homozygous: two identical alleles for a given trait

heterozygous: two different alleles for given trait

phenotype: physical appearance of a cell

genotype: alleles organism contains.

Dominant allele: capital letter, **recessive allele**: lowercase of the same letter.

1st generation in an experiment: parent/P generation.

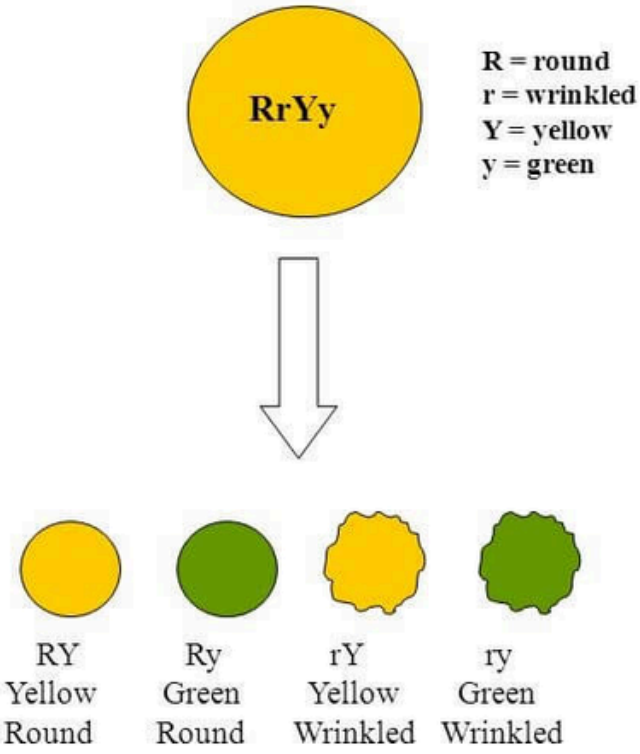
Offspring of P generation: first filal/**F1** gen. Following generation, (grandchildren,) **F2.**

3 Genetic Principles: **Law of Dominance, law of Segregation, and Law of Independent Assortment**

Law of Dominance

One of Gregor Mendel's foundational principles of genetics. It states that in a pair of genes **(alleles)** for a particular trait, one allele can mask the expression of another. In other words, when an organism inherits two different alleles for a trait, one will be dominant and the other recessive.

Dominant Allele: This allele expresses its trait whenever it is present. It "dominates" over the other allele.
Recessive Allele: This allele only expresses its trait if both alleles in the pair are recessive.



Law of Segregation

The Law of Segregation states that during the formation of gametes, each parent's two alleles for a trait separate, so only one allele is passed to each gamete. Offspring then receive one allele from each parent, restoring the pair.
Ex. A parent with alleles Aa will pass either A or a to its offspring, not both.

The Law of Independent Assortment

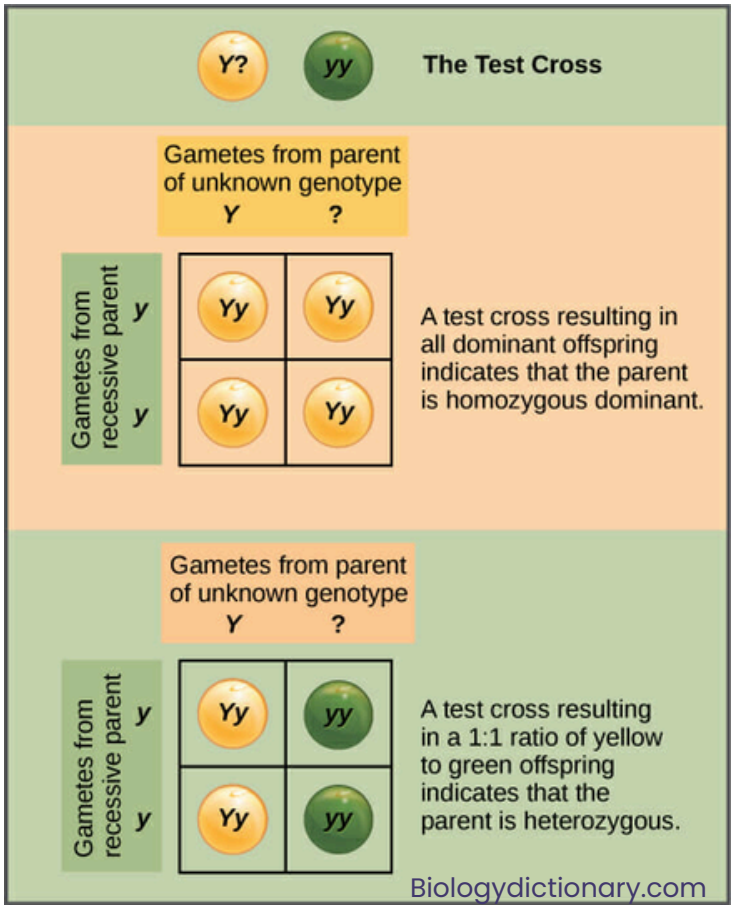
Genes for different traits are inherited independently of each other, as long as the genes are on different chromosomes. This means the inheritance of one trait doesn't affect the inheritance of another.
Ex. the gene for seed shape in peas (round or wrinkled) is inherited independently of the gene for seed color (yellow or green). A pea plant can inherit any combination of these traits, like round and yellow or wrinkled and green, due to independent assortment.

Rules of Probability

- Product Rule: The probability of two independent events both occurring is the product of their individual probabilities.
- Sum Rule: The probability of either of two mutually exclusive events occurring is the sum of their individual probabilities.

Monohybrid Cross
A genetic cross examining the inheritance of a single trait (ex. flower color). Involves one pair of contrasting alleles.

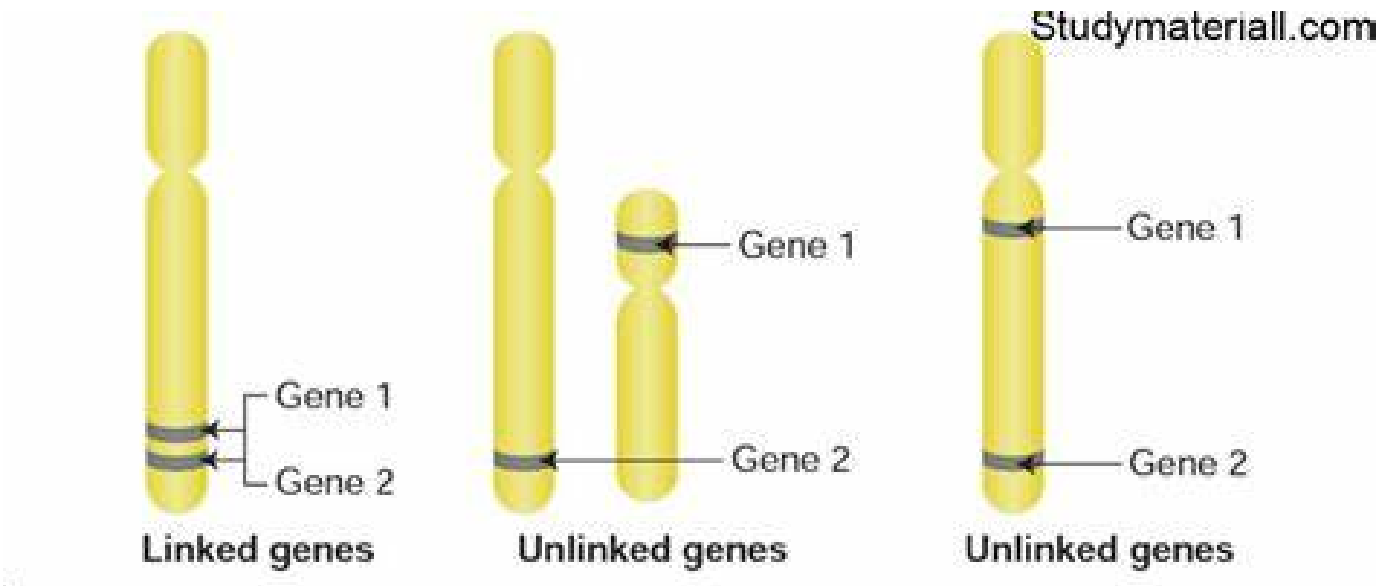
Dihybrid Cross
A genetic cross examining the inheritance of two traits (ex. flower color and seed shape). Involves two pairs of contrasting alleles.



Test Cross
A cross between an organism with an unknown genotype and a homozygous recessive organism to determine the unknown genotype.

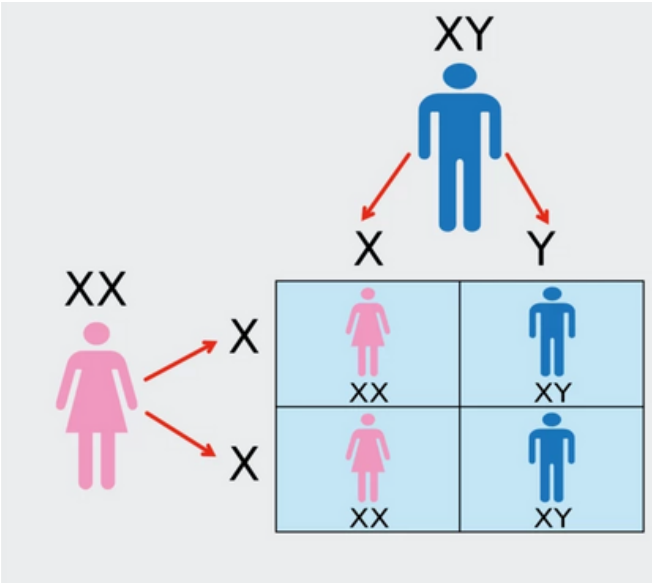
Linked Genes

Genes located close together on the same chromosome tend to be inherited together because they are less likely to be separated during crossing over in meiosis. This reduces the independent assortment of these genes. It is impossible for linked genes to be on different chromosomes



Chromosomes and sex determination

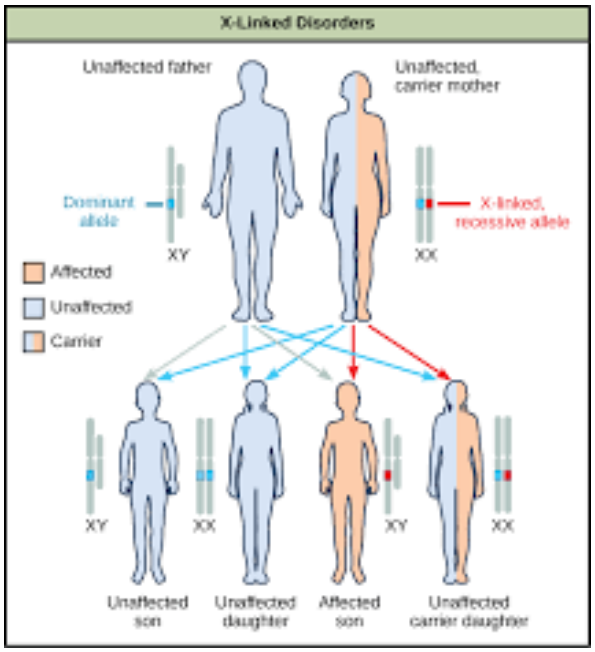
There are **23 pairs** chromosomes in the human body. 22 of them are **autosomes or body cells.** The other pair contains sex chromosome or **gametes**. These help determine the sex of an organism.
The probability of producing a female offspring is 50% and a male is 50% too. There are 2 combinations that determine the sex- **XX and XY**. These produce female and male respectively.



storymd.com

Expression of sex-linked traits

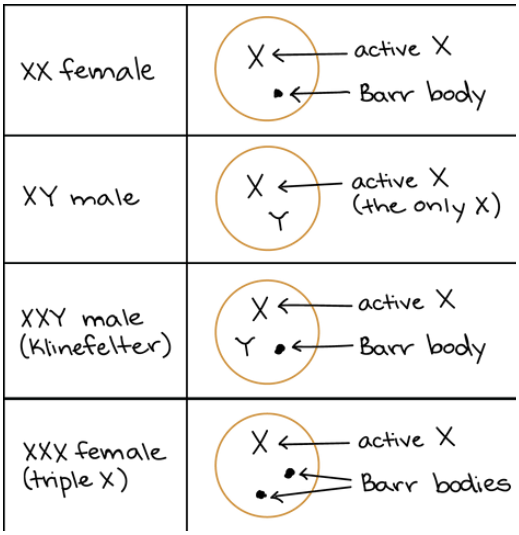
There are many traits and diseases that are more likely to occur to one sex than the other. These are called **sex-linked traits.** Mostly sex-linked traits are found on the **X chromosome**. So if a male has an affected X chromosomes, he's highly likely to inherit that trait/disease since males have only **one X chromosome**.
Females on the other hand, won't inherit that disease unless both of her X chromosomes are affected making her a **carrier** of the trait. A carrier is an individual who has an affected chromosome, doesn't express it **but can pass it on to her offsprings**. **(Only females can be carriers)**



bio.libretexts.org

Barr Bodies

A Barr body is an i**nactivated X chromosome** found in **female** mammals. Since females have two X chromosomes, one becomes inactive to **balance gene expression** between males and females. This inactive chromosome forms a dense structure in the nucleus. Barr bodies help determine X chromosome abnormalities in conditions like Turner syndrome (XO) or Klinefelter syndrome (XXY).



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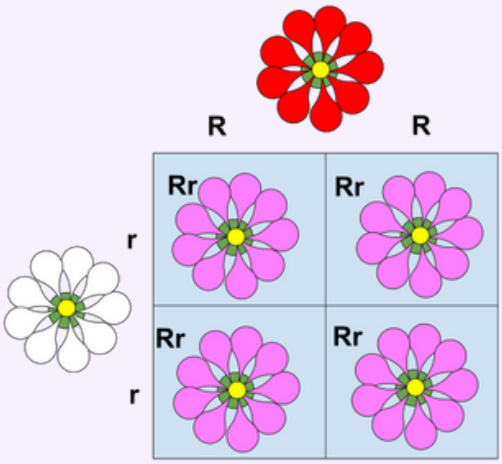
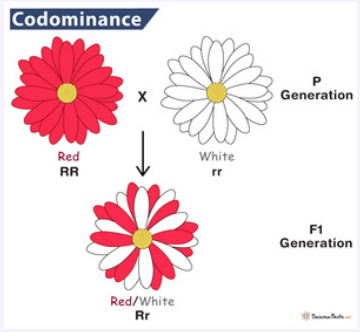
Inheritance patterns

Incomplete dominance- In some cases, when one traits doesn't completely dominate the other, an offspring is produced which has a mix of both of the traits. Which means that no trait is dominant over the other. **For example, in this case if you cross red and a white flower and get a pink offspring**, the offspring shows incomplete dominance



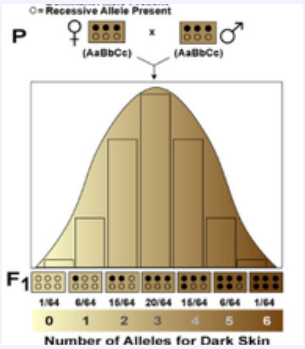
biology dictionary.net



sciencefacts.net

Co dominance- This occurs when both the traits are **equally expressed**, with none being dominant over the other. In this case, if you cross **red and a white flower and they produce a flower with both the colors in it, then it would be an example of co-dominance**

Polygenic inheritance-The inheritance of a trait based on **more than one genes.** This is usually more complicated than flowers and helps determines a person skin, eye color etc.

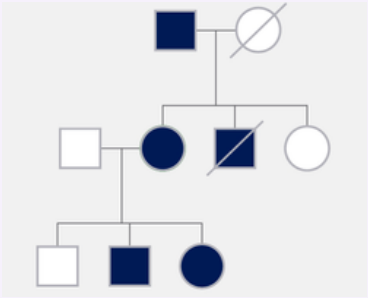


socratic.org

Non nuclear inheritance- if you thought that the nucleus you'd be only partially right because so does mitochondria and cytoplasm. When the inheritance of genetic material from **cytoplasm or mitochondria** (can be only inherited from the mother) occurs, its called non-nuclear inheritance

Pedigrees

A **pedigree** is a chart that represents family relationships and tracks the **inheritance of traits or genetic conditions** across generations. It uses symbols to show how traits are passed down and helps identify patterns, such as whether a condition is inherited from one or both parents. Pedigrees are used in genetics to study family histories, **predict the likelihood of a trait** appearing in future generations, and determine if someone is a **carrier** of a genetic condition. This makes them especially useful in genetic counseling and medical diagnoses.



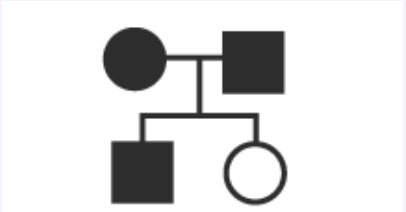
genome.gov

Strategies for Pedigrees/ Sex-Linked

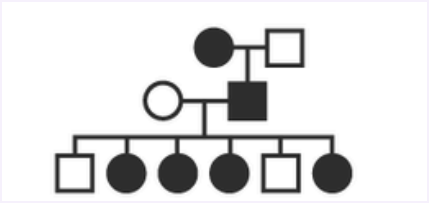
Pedigrees can be hard to decipher but once you get some practice with it they seem really easy. There are some strategies you can use to understand the pedigrees better. In pedigrees, **squares represent males,** and **circles represent females,** with **shaded symbols indicating individuals affected** by a trait. A key rule for X-linked dominant inheritance is that **affected fathers always pass the trait to their daughters** because they contribute their X chromosome, which carries the trait. However, they never pass it to their sons, who inherit their father's Y chromosome. **Affected sons must inherit the trait from an affected mother** since males only get their X chromosome from their mothers.

Autosomal and Sex-linked Traits

Inheritance is of 2 types- **autosomal and sex-linked**. Autosomal traits are located on **non-sex chromosomes** (chromosomes 1-22), meaning males and females inherit them equally. If a trait is autosomal, the affected individual's chromosomes carry the gene for the trait regardless of gender. However, X-linked traits **are carried on the X chromosome**, so inheritance patterns differ between males and females as explained above.



Autosomal inheritance



Sex-Linked inheritance

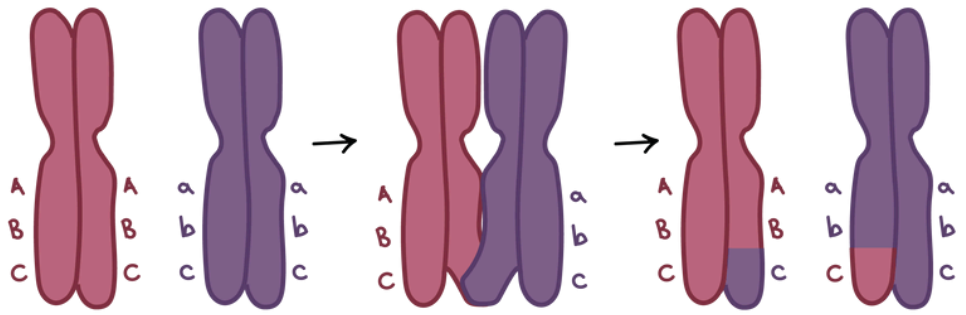
geeksforgeeks.org

Meiosis Intro

Meiosis is a another type of cell division specifically for **gametes**. Organisms that reproduce sexually only need **haploid** cells. This differs for male and female. Cells from meiosis for males are used in the **gonads(testes)** while cells from meiosis for females are used in the **ovaries**. These cells, known as **germ cells**, which contain a haploid amount of chromosomes are later combined with each other during fertilization to produce a **diploid** number. Meiosis has two rounds of cell division and through **"crossing over"** (will be explained further down) causes genetic variation.

Prophase 1

Similar to Mitosis there are 4 stages to **Meiosis**(Prophase, Metaphase, Anaphase, and Telophase[better remembered as PMAT]. Meiosis Prophase, however, differs from Mitosis as it includes **synapsis**. **Synapsis** is when the chromosomes line up side by side as homologous chromosomes. After lining up to form tetrads(4 chromatids) regions of the chromosomes will **cross over** and switch parts. This causes **genetic variation** as not all chromosomes will have their original alleles.



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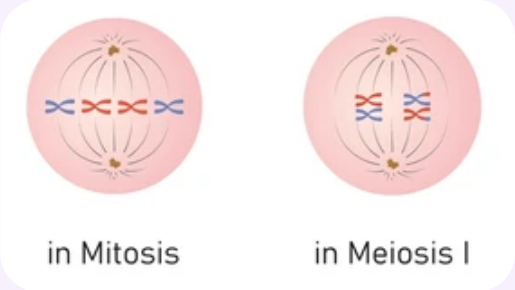
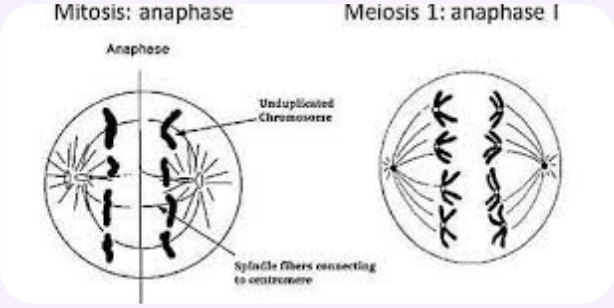
Metaphase 1

Metaphase 1 in Meiosis is equivalent to that of Mitosis as the chromosomes line up at the metaphase plate. However in Meiosis the chromosomes will line up in pairs instead of individually



Anaphase 1

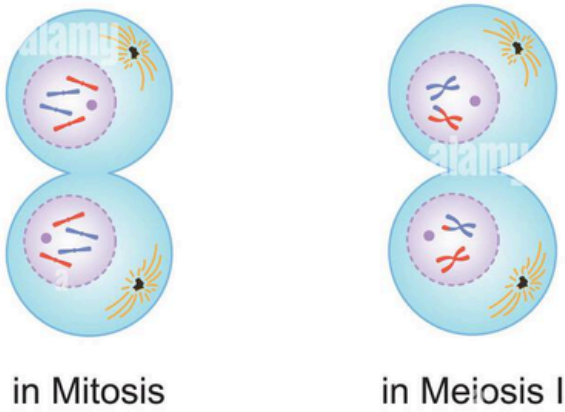


In **Anaphase 1** a pair of chromatids are pulled to the poles rather than a singular chromatid in Mitosis.

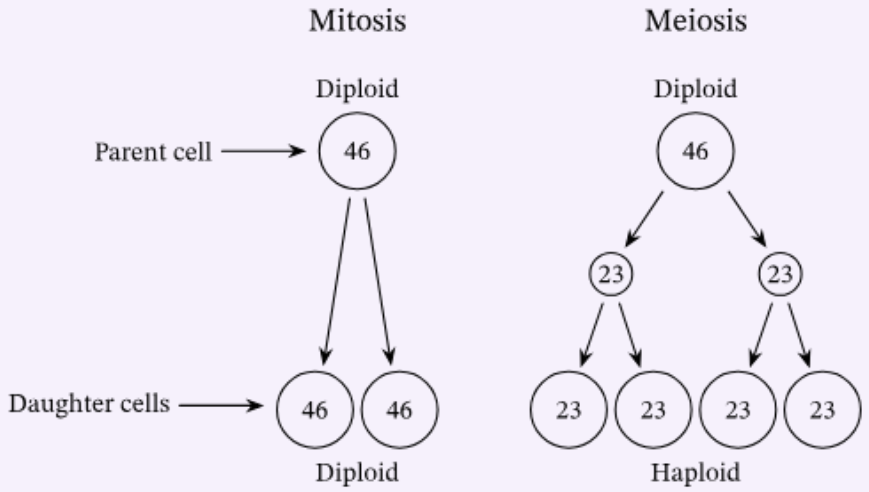
BiologyOnline.com

Telophase 1

In **Telophase 1** the nuclear membrane begins to form and two daughter cells are formed.



Chromosome # Mitosis vs Meiosis



Nagwa.com

After meiosis 1 cell division occurs just like it would in mitosis for a second round with 23 chromosomes. The second round includes **Prophase 2, Metaphase 2, Anaphase 2, and Telophase 2.**

Meiotic Errors

Meiosis doesn't always occur smoothly. At times sets of chromosomes can have extra or missing chromosomes. **Nondisjunction** cause this and occurs when chromosomes fail to separate correctly. Effects can range from miscarriages to genetic defects. Examples include **down syndrome**, also known as **Trisomy 21** where there is an extra 21st chromosomes. Other errors include **Translocation**, where segments of chromosomes will detach and reattach to other chromosomes. Effects vary.

Unit 5

Hereditary: Review Questions

1. **Which of Gregor's Laws involves one allele masking the other?**

   A) Segregation B) Dominance

   C) Independent Assortment D) Probability

2. What is it called when genes are located close to one another on the same chromosome?

   A) Barr Bodies B) Combined Genes

   C) Linked Genes D) Dihybrid Genes

3. If a male has an affected X chromosomes, he's____ to inherit that trait/disease

   A) Highly likely B) Highly unlikely

4. When Pink flowers are the offspring of Red and White flowers this is an example of?

   A) Incomplete Dominance B) Polygenic

   C) Non-nuclear D) Co-Dominance

Unit 5

Hereditary: Review Questions

5. Black fur in mice (B) is dominant to brown fur (b). Short tails (T) are dominant to long tails (t). What fraction of the progeny of the cross BbTt × BBtt will have black fur and long tails?

A) 1/16 B) 1/2

C) 9/16 D) 1/4

6. A nondisjunction of chromosome 21 is known as...

A) Angelman Syndrome B) Turners Syndrome

C) Williams Syndrome D) Down Syndrome

7. Sexual reproduction causes variation in populations through which mechanism?

A) Random Fertilization B) Crossing Over

C) Independent Assortment D) All of the above

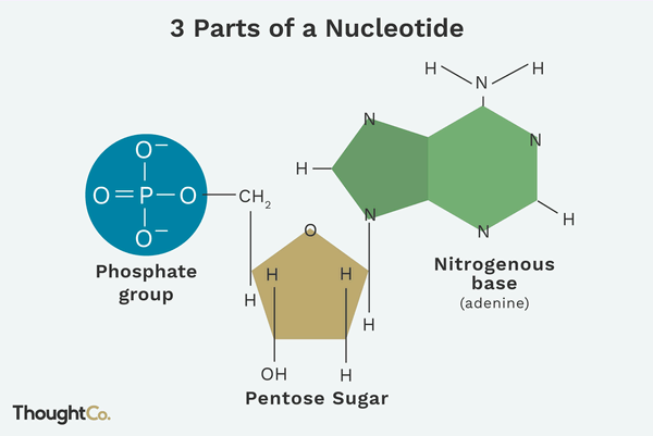
Answer key:
1) B 2) C 3) A 4) D 5) B 6) D 7) D

Unit 6

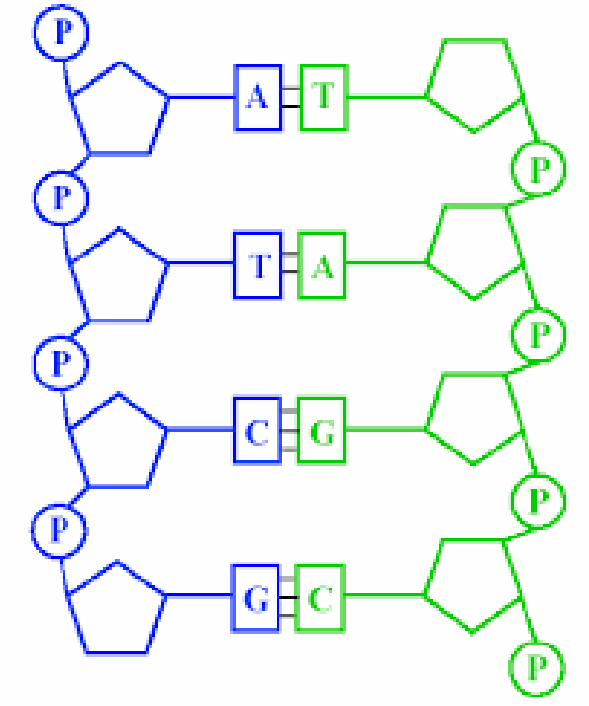
Gene Expression and Regulation

DNA Shape

DNA is composed of repeating units of **nucleotides**. A nucleotide contains a **five-carbon sugar**, a **phosphate**, and a **nitrogenous base**.



thoughtco.com



ResearchGate.com

Bases

"Penta" means 5 so therefore a pentose sugar will have 5 sides. The name of this sugar in DNA is known as deoxyribose. There are 4 types of nitrogenous bases related to DNA

- **adenine**(purine)(double ringed)
- **guanine**(purine)(double ringed)
- **cytosine**(pyrimidine)(single ringed)
- **thymine**(pyrimidine)(single ringed)

DNA links up in strands creating what is known as the "sugar-phosphate backbone".

Two DNA Strands:

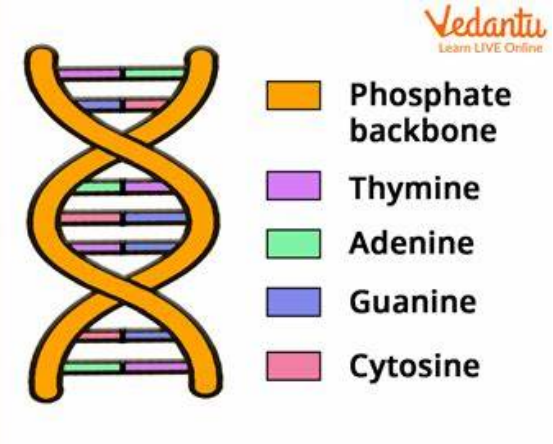
Each DNA molecules has two strands that wrap around one another to form a long, ladder like structure(DNA Helix).

This was founded by 3 scientists: Watson, Crick, and Franklin in 1953.

DNA strands are **complementary** meaning the certain bases are complementary to each other.

One way to remember which bases are paired with which are...Apples fall from trees, (Adenine and Thymine). {A - T} 2 hydrogen bonds and Cars park in garages. (Cytosine and guanine.) {C - G} 3 hydrogen bonds.

DNA strands are linked by **HYDROGEN** bonds.



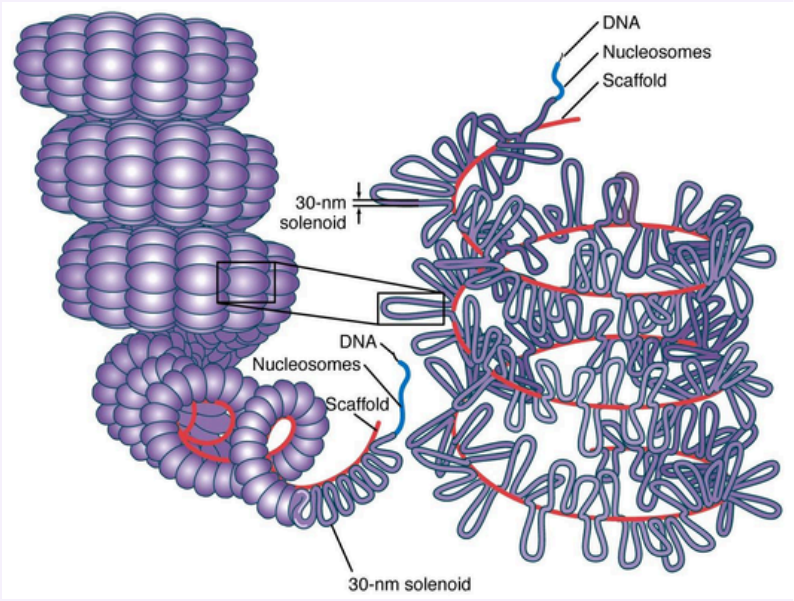
www.vendantu.com

Structure:

A phosphate group is present at the 5' end, while an OH, or "hydroxyl," group is present at the 3' end. The 5' end of one strand is always opposite of the 3' end of the other strand. The strands are therefore antiparallel.

Genome Structure:

To keep DNA organized it is wrapped around **histones**(proteins). A group of histones is known as a **nucleosome**.



mun.ca

When genetic material is in a loose form in the nucleus it is known as **euchromatin**
(Genes are active/available for transcription.)
When genetic material is tightly wrapped around the histones it is known as **heterochromatin.**
Some more Vocab...
Genome: All of the DNA for a species.
Chromosome: Each separate part of DNA in a genome.

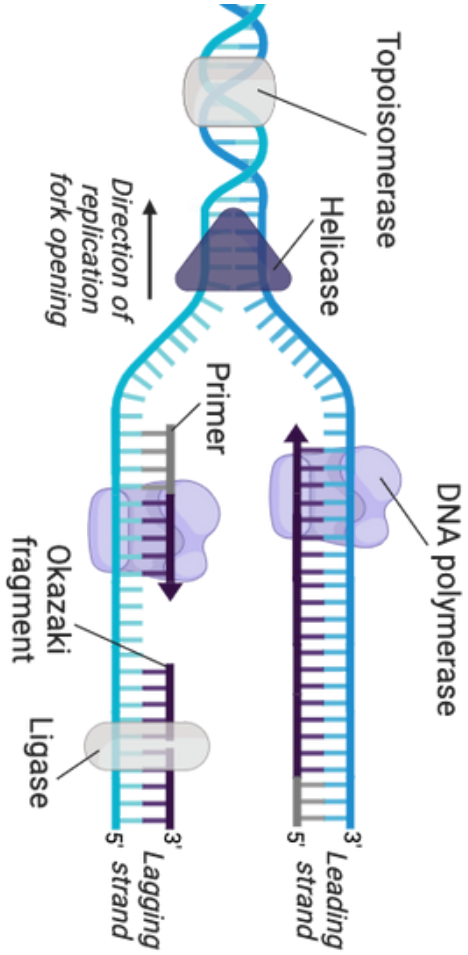
KhanAcademy.com

DNA Replication

Due to Mitosis and Miosis we know that DNA must be replicated before it can be passed down. The copying occurs through DNA replication.

Steps of DNA Replication

1. Helicase enzyme unwinds DNA at the replication fork.
2. DNA twists so the enzyme topoisomerase keeps the DNA from tangling.
3. RNA primase adds a short strand of RNA nucleotides to prime the strand for replication. (primer is later degraded and replaced with DNA.
4. DNA Polymerase the adds nucleotides to DNA strand. (This can only be added to the 3' end).
5. DNA will have a leading a lagging strand. The leading running 3' to 5' and the lagging running 5' to 3'
6. Polymerase can only run 3' to 5' so the lagging strand's addition of nucleotides is not continuous



Okazaki Fragments

The **lagging strand** is built in the opposite direction. Due to this DNA polymerase has to hop back to the replication fork to continue copying. This creates fragments of DNA(see photo). In order to make the replication continuous an enzyme known as **ligase** links the fragments together. With replication the new molecule dose not contain all of its original DNA but rather half of it. It is "**semiconservative**".

In summary...

- The **Helicase** unwinds
- **DNA polymerase** adds nucleotides
- **Ligase** joins **Okazaki** fragments
- **Topoisomerase** keeps the DNA together
- **RNA primase** starts replication

Central Dogma

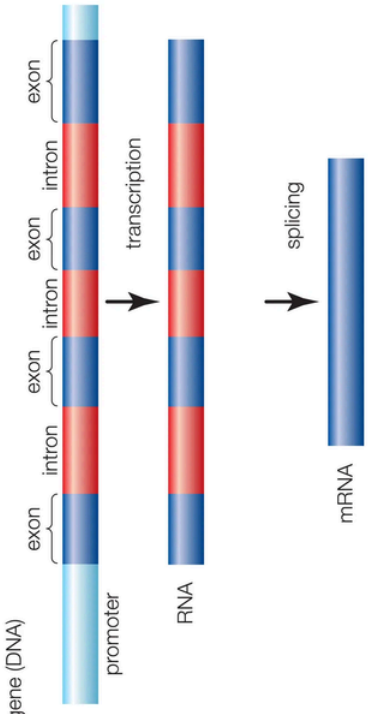
Central dogma refers to the flow of genetic information from **DNA -> RNA -> protein** through the processes of transcription followed by translation.

RNA is a single-stranded nucleic acid, with **ribose** as the sugar instead of deoxyribose.

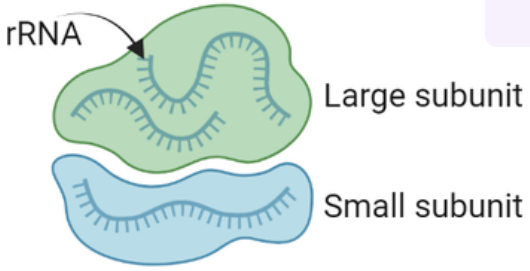
There are 3 main types of RNA:

mRNA

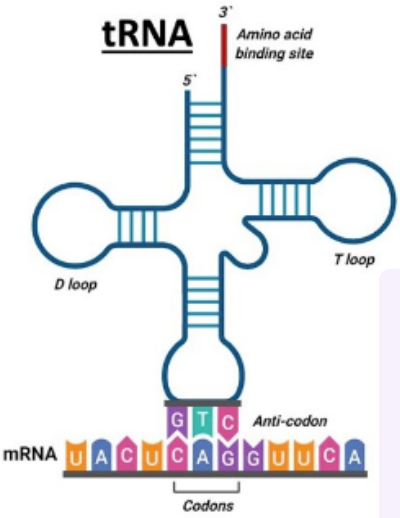
- messenger RNA
- the final "message" transcripted from DNA
- made in nucleus, transported to ribosomes



https://www.youtube.com/watch?app=desktop&v=IgJ4U2TiV4Y



https://www.ahmadcoaching.com/2021/12/types-of-rna-and-its-function-mrna-trna.html



https://www.britannica.com/science/messenger-RNA

rRNA

- ribosomal RNA
- works with proteins to become ribosome
- translates the mRNA
- located in cytoplasm or on rough ER

tRNA

- transfer RNA
- pairs the correct anticodon to mRNA codon
- brings the amino acid to ribosomes

Transcription

Transcription is the synthesis of RNA from a DNA gene.

- **initiation -> elongation -> termination**

The two strands of DNA are separated:

- template/noncoding/antisense/minus strand
- nontemplate/coding/sense/plus strand

The protein **RNA polymerase** synthesizes RNA on the **coding** strand, while the "template" strand reflects the RNA's code.

Initiation

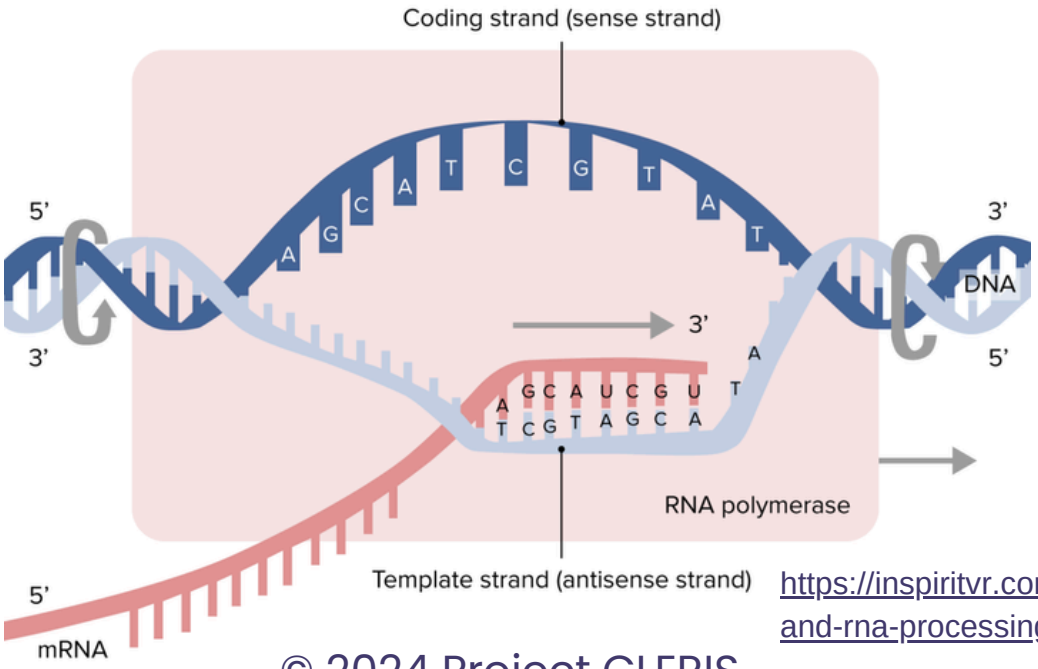
- **promoter**: where RNA polymerase attaches
- **start point:** where RNA synthesis begins
- **transcription factors**: proteins that bind to DNA to regulate gene expression

Elongation

- RNA polymerase moves across template/ antisense strand
- adds nucleotides to **3'** end (5'->3')
- **transcription unit**: stretch of DNA that codes for RNA, downstream of promoter

Termination

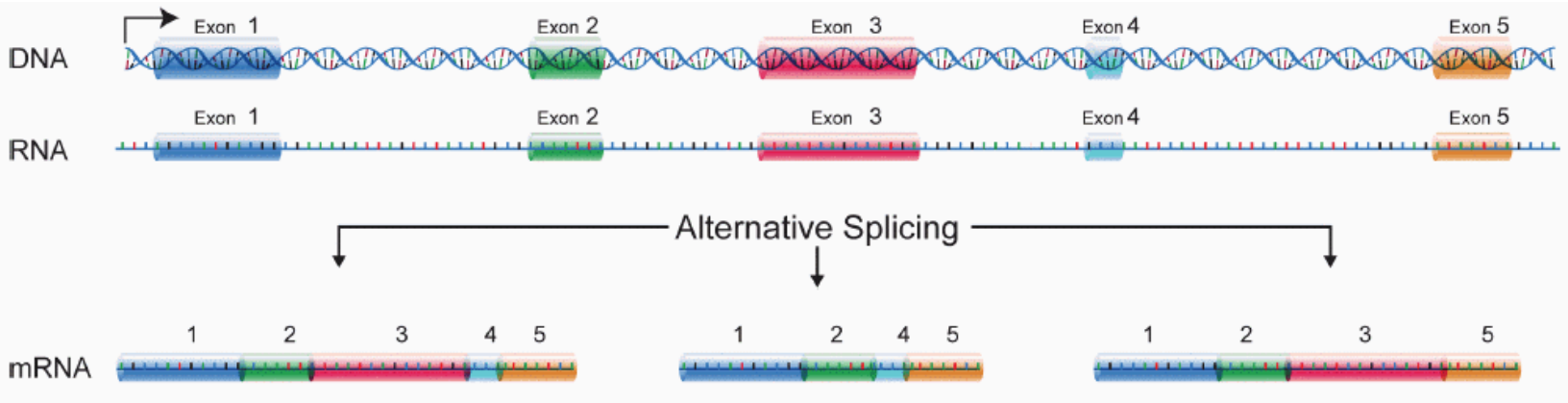
- **terminator**: DNA sequence marking the end of coding section
- once RNA poly. reachers terminator, the RNA transcript is released
- RNA polymerase detaches



https://inspiritvr.com/transcription-and-rna-processing-study-guide/

RNA Processing

- after transcription, RNA requires edits before becoming a mRNA and leaving the nucleus
- **spliceosome**: RNA-protein complex that cuts RNA to remove introns
- **exons** are *expressed*
- **introns** are removed

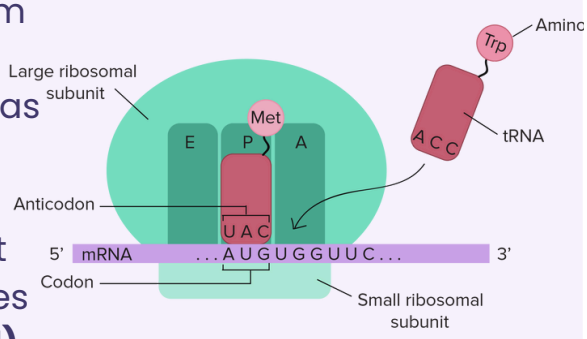


https://en.wikipedia.org/wiki/Alternative_splicing

- **alternative splicing**: one RNA template can be spliced & reconnected differently to produce different mRNAs

Translation

Translation is the process of **synthesizing proteins** from mRNA, occurring on ribosomes in the cytoplasm and on the **rough endoplasmic reticulum**. Each sequence of three nucleotides on the mRNA, known as a **codon**, specifies a unique amino acid. The tRNA, which carries an amino acid on one end, has a complementary sequence called an **anticodon** that binds to the mRNA codon. At the ribosome, three sites facilitate translation: the **A (aminoacyl), P (peptidyl), and E (exit) sites,** where tRNA molecules enter, bind their amino acid to the growing chain, and exit, respectively. Additionally, the third nucleotide position may undergo **wobble pairing,** allowing atypical matches, such as guanine pairing with uracil. Translation occurs in three stages: **initiation, elongation, and termination**.



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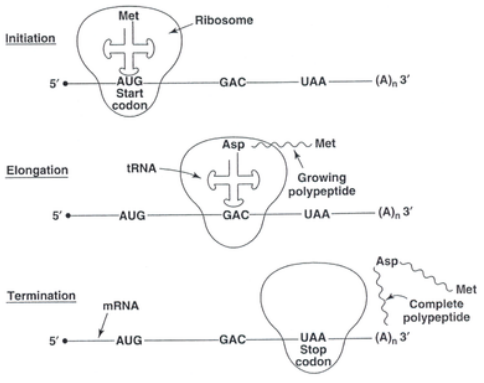
Initiation, Elongation, Termination

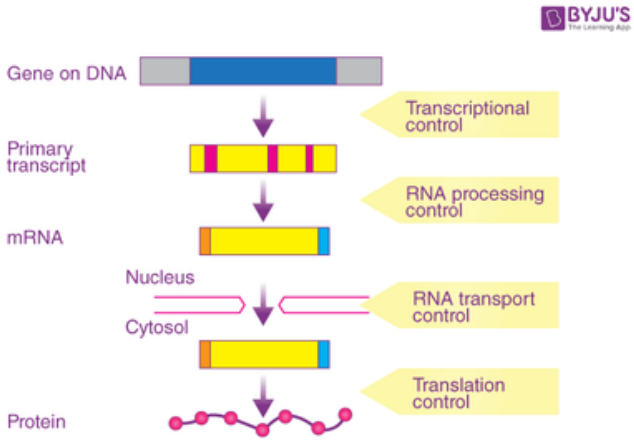
Initiation starts as a ribosome binds to mRNA, locating the **start codon AUG**, and signaling tRNA to bring in methionine. The ribosome then moves along the mRNA in **elongation**, reading each codon and adding amino acids to build the polypeptide chain. **Termination** occurs when the ribosome encounters a stop codon, where release factors help detach the ribosome, freeing the completed protein and ending translation



researchgate.net

Regulation of Gene Expression

Gene expression can be regulated at multiple stages, with the most significant control occurring before transcription, known as **pre-transcriptional regulation**. This involves transcription factors that either **promote or inhibit gene transcription.** Additionally, epigenetic changes in the packaging of DNA can affect how accessible a gene is to the transcription machinery, thereby influencing its expression.



Byjus.com

Post-Transcriptional & Post-Translational Regulation

After RNA synthesis, post-transcriptional regulation can occur, determining whether the RNA is translated into protein. This is mediated by **RNA interference (RNAi)**, where RNAi molecules bind to RNA, forming **double-stranded RNA** that **prevents translation**. Furthermore, post-translational regulation can also occur, allowing a cell to produce a protein but delay its activation, thus providing additional control over protein function as needed.

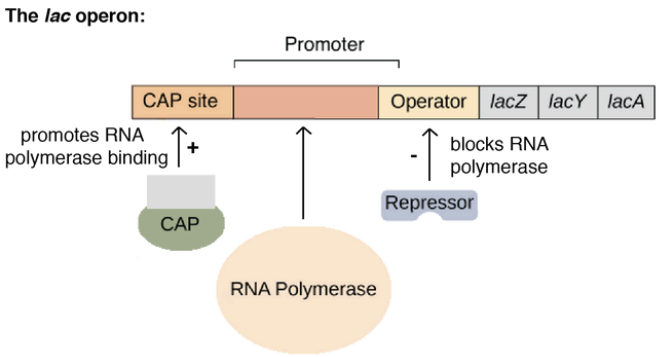
Operons in Bacteria

In bacteria, a group of genes can be organized into **operons**, controlled by a single promoter. An operon consists of:

- **Structural Genes**: These code for enzymes needed in specific biochemical reactions and are transcribed together.
- **Promoter Gene:** The region where RNA polymerase binds to start transcription.
- **Operator**: A regulatory region where a repressor can bind, controlling whether transcription will occur.
- **Regulatory Gene**: This gene codes for the repressor protein that can block transcription by binding to the operator.

Lac Operon

The lac operon is a genetic system found in **E-coli** that regulates the metabolism of lactose. It allows the bacterium to utilize **lactose** as an energy source when glucose is scarce. Understanding the lac operon provides insights into gene regulation and metabolic control in **prokaryotes**.



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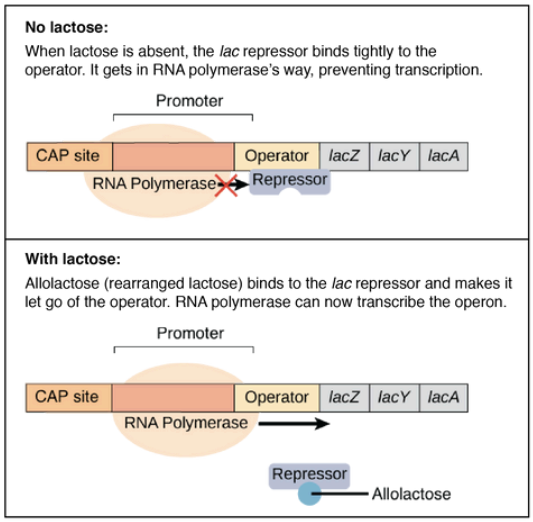

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Mechanism

- **Absence of Lactose**: The lac repressor (from lacI) binds to the operator (O), blocking transcription of the structural genes (lacZ, lacY, lacA).
- **Presence of Lactose**: Lactose binds to the repressor, causing it to release from the operator, allowing transcription to occur.
- **Role of Glucose:** High glucose levels inhibit the lac operon by lowering cAMP, preventing the activation of transcription.

Key Points

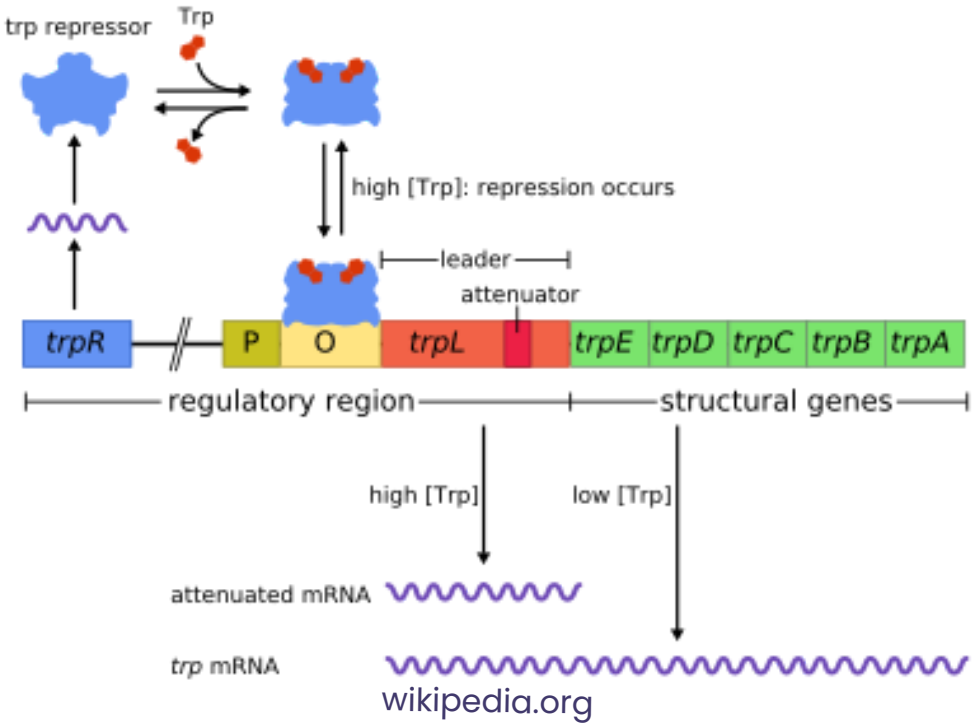
Components: lacZ, lacY, lacA (structural genes), lacI (regulatory gene), promoter (P) and operator (O).
Regulation: Controlled by lactose and glucose availability.

Tryptophan (trp) Operon

The trp operon in E. coli controls the synthesis of the amino acid tryptophan. It is a repressible operon, meaning it is usually active but can be turned off when tryptophan is abundant.

Key Points

- When tryptophan is scarce: The repressor is inactive, and the operon is transcribed to produce enzymes for tryptophan synthesis.
- When tryptophan is abundant: Tryptophan binds to the repressor, stopping transcription, as more tryptophan isn't needed.



Regulation Mechanism

- Repressor Protein: Encoded by the trpR gene, the repressor is produced in an inactive form.
- Tryptophan as a Corepressor: When tryptophan levels are high, it binds to the repressor, activating it.
- Repressor-Operator Binding: The active repressor binds to the operator, blocking RNA polymerase and stopping transcription of the trp operon.

Mutations

Changes in the DNA sequence that can affect gene expression or function. They may arise spontaneously or be caused by environmental factors (mutagens).

Base Substitution (Point Mutations)

A single nucleotide is replaced by another, which can affect a single amino acid in a protein.

- **Silent Mutation**: Alters a nucleotide but does not change the amino acid due to redundancy in the genetic code.
- **Missense Mutation**: Changes one amino acid in the resulting protein, potentially affecting protein function.
- **Nonsense Mutation**: Converts a codon to a stop codon, resulting in premature termination of the protein.

Gene Rearrangements

Large-scale mutations that alter the structure or location of genes within the genome.

- **Insertion**: Addition of extra nucleotides into the DNA sequence, which can cause a frameshift.
- **Deletion**: Loss of nucleotides, which may also cause a frameshift and disrupt the reading frame of a gene.
- **Duplication:** A segment of DNA is copied and inserted into the genome.
- **Inversion**: A section of DNA is reversed within the chromosome, which may disrupt gene function.
- **Translocation**: A segment of DNA is moved from one location to another, possibly affecting gene regulation.

Bacteria

Single-celled organisms that can reproduce on their own through binary fission. They can be beneficial (ex., gut bacteria) or pathogenic.

Viruses

Non-living particles composed of genetic material (DNA or RNA) surrounded by a protein coat. They require a host cell to reproduce.

Viruses use two main cycles to replicate within a host: the Lytic Cycle and the Lysogenic Cycle.

Lytic Cycle (Active Cycle)

- Attachment: The virus attaches to the host cell's surface.
- Entry: The viral genetic material is injected into the host cell.
- Replication and Assembly: The host cell's machinery is hijacked to replicate viral DNA/RNA and produce viral proteins.
- Lysis and Release: The new viruses assemble and burst out of the host cell, destroying it in the process, and spread to infect other cells.
- Key Point: The lytic cycle is fast and destructive, leading to the immediate death of the host cell.

Lysogenic Cycle (Dormant Cycle)

- Attachment and Entry: Similar to the lytic cycle, the virus attaches and injects its genetic material.
- Integration: Viral DNA integrates into the host cell's genome, becoming a prophage.
- Replication with Host: Each time the host cell divides, it copies the viral DNA along with its own, passing it to new cells.
- Trigger to Lytic Cycle: Environmental factors (ex., stress, UV light) may activate the virus, causing it to enter the lytic cycle.
- Key Point: The lysogenic cycle allows the virus to remain dormant and propagate without killing the host cell immediately.

Recombinant DNA

Recombinant DNA occurs when DNA is combined to make unique molecule not naturally found. Sometimes using genetic engineering the DNA of bacteria can be removed and replaced with other DNA. This can therefore produce new organisms

PCR

Polymerase Chain Reaction(PCR) is used to make billions of copies of genes. PCR mimics DNA replication in order to amplify DNA fragments for a practical use.

Gel Electrophoresis

Gel Electrophoresis seperates DNA by molecular weight and charge. DNA is placed at the start of a gel and at the end there positive current. Since DNA is (-) charged depending on it's speed it will flow to the other end at different lengths.

Transformation

Giving bacteria foreign DNA is known as transformation.

DNA Sequencing

Ordering nucleotides according to a DNA pattern is known as sequencing.

Unit 6

Gene Expression & Regulation: Review Questions

1. What is the name of the DNA strand that elongates away from the replication fork in a series of segments?

A) RNA primer
B) Leading strand
C) Lagging strand
D) Okazaki fragment

2. Which of the following RNA mutations would least significantly alter the final amino acid sequence?

A) frameshift mutation
B) deletion of 3 nucleotides
C) insertion of 1 nucleotide
D) nonsense mutation

3. What are the repetitive sequences of DNA on the ends of chromosomes that protects coding DNA from degradation?

A) telomeres
B) Okazaki fragments
C) 5' and 3' caps
D) centrosomes

4. Which of the following is found in prokaryotic genes but not eukaryotic genes?

A) promoters
B) transcription factors
C) operons
D) stop codons

Unit 6

Gene Expression & Regulation: Review Questions

5. Which of the following correctly describes the role of a regulatory gene in gene expression?

A. It encodes for enzymes directly involved in metabolic pathways.
B. It encodes for proteins, such as repressors, that regulate the transcription of other genes.
C. It synthesizes tRNA molecules needed for translation.
D. It activates ribosomes to speed up translation.

6. Which process is regulated during gene expression

A. DNA replication B. RNA Splicing
B. Translation Initiation D. Protein Folding

7. What role does the operator play in prokaryotic gene expression?

A. It enhances transcription.
B. It binds repressors to block transcription.
C. It promotes translation.
D. It recruits RNA polymerase.

Answer key:
1) C 2) D 3) A 4) B 5) B 6) C 7) B

Unit 7

Natural Selection

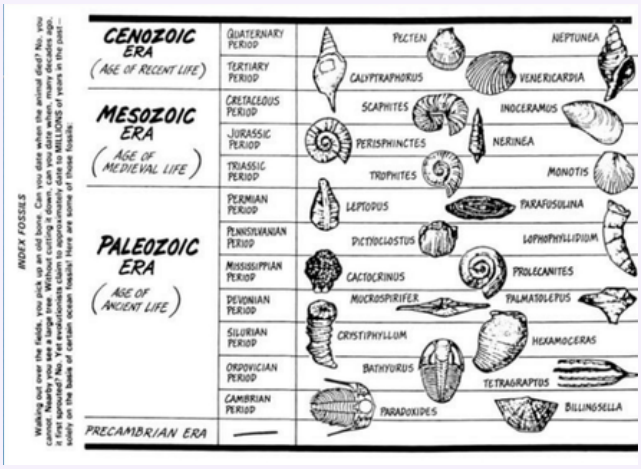
Darwin's OBSERVATIONS:

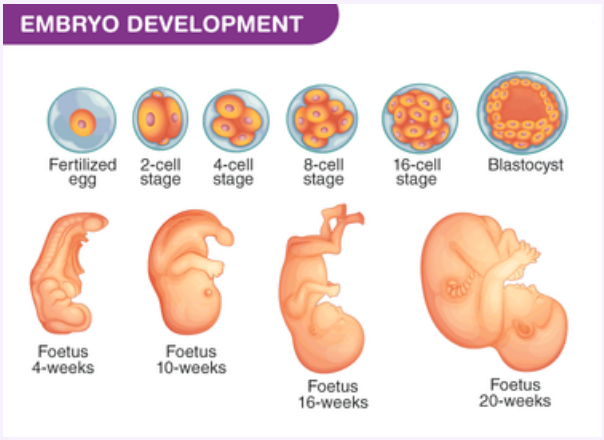
A population changing over time:
Evolution
Occurs in terms of individuals, but defined in population terms:
Natural Selection
Charles Darwin: established a known understanding on evolution by his works.

Each species produces greater offspring than can survive.
The offspring compete with each other for the limited resources available to them.
Every population varies in organisms.
Evolutionary fitness is measured by reproductive success.

The fittest offspring are the most likely to survive & produce second generations.
Fitness varies based on biotic + abiotic factors; different genetic variations can be selected for in different generations.

Evidence of Evolution:





Paleontology:

Revealed the various organisms and evolution's major lines.
Fossils can be dated by:
i. The age of the rocks (where the fossil is found)
ii. The rate of decay of isotopes (carbon-14)
iii. Data geographically

Molecular Biology: The most compelling proof of all is the similarity at the molecular level.

Biogeography

- Study of the distribution of plants + animals in the environment. Scientists have found related species in widely separated wordly regions.

Embryology

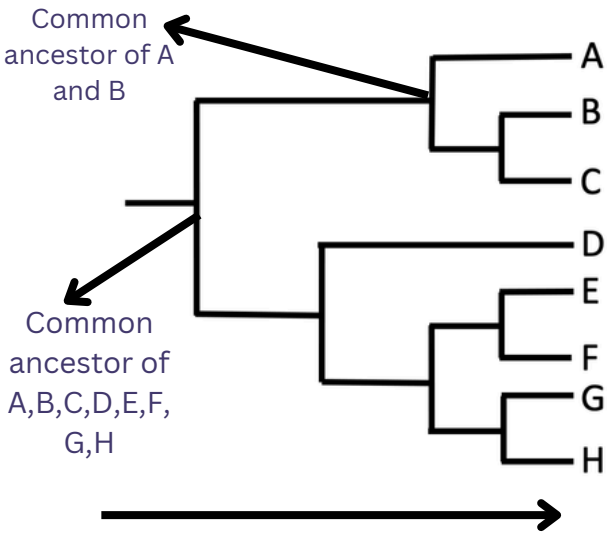
Study of development of an organism: All the vertebrates—(fish, amphibians, reptiles, birds, and mammals) humans—show fishlike features called gill slits.

Morphological homologies

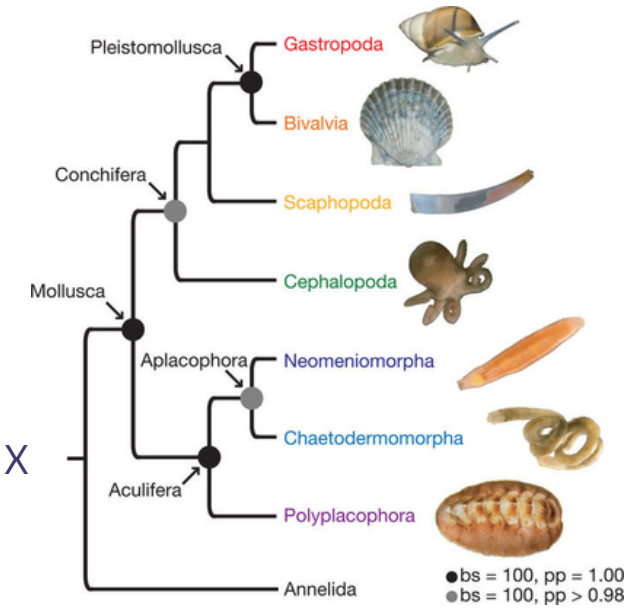
Study of the anatomy of various animals: scientists discovered some animals have similar structures with different functions. Homologous structures point to a common ancestor. Analogous structures evolved independently of one another.

Common Ancestry

Every form of life is derived from some previous one, when 2 or more organisms share the same ancestor, it is known as common ancestry. We study common ancestory through diagrams known as ohylogenetic chart which shows relationships between different lineages and their ancestors. These are built from evidence collected by archaeologists or historians. It can be a bit confusing to read these at first, but once understand the basics it becomes quite easy



Digitalatlasofancientlife.com



kaiserscience.wordpress.com

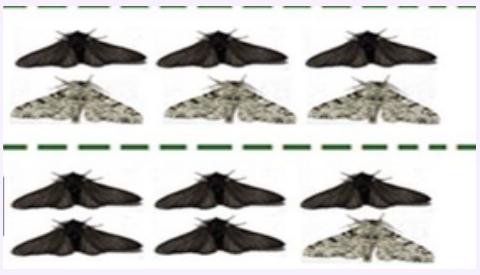
In this tree, X is the common ancestor and for example Plesitomollusca being the common ancestor of Gastropoda and Bivalve

Genetic Variability

Genetic variability refers to the genetic differences present within population of an organism. Genetic variation is crucial in a population since it gives the population a better chance of surviving in case of a disaster. Since if there are different characteristics, some might be able to survive thus continuing the population further.

The Peppered Moths

genetic variation can be best seen through the peppered moths example. There were 2 different types of moths observed- the dark one with dark coloring allele and the light one with light coloring allele. These two populations were observed in a polluted environment caused by burning of coal. After some time, the light colored moths drastically decreased and the black ones survived and kept reproducing showing how two different characteristics in the moth population allowed the moth population to survive



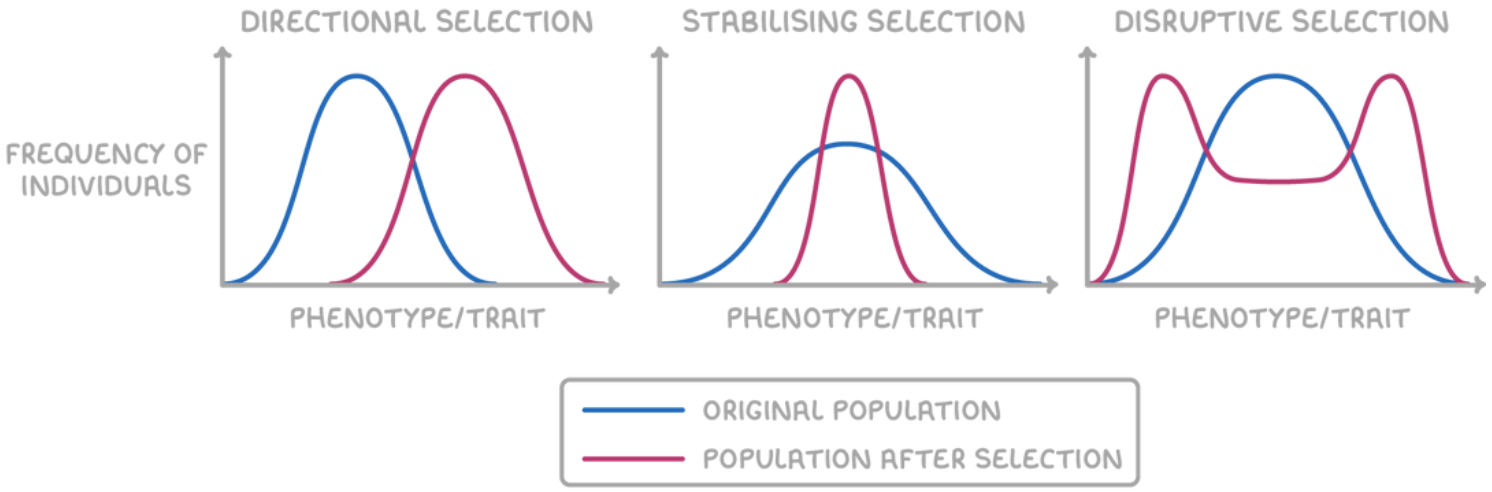
Before and after pollution

Researchgate.net

Types of selection

Directional Selection

- Definition: Favors one extreme phenotype over others, causing a shift in the population's trait distribution in one direction.
- Example: In a population of peppered moths, increased pollution darkens trees, favoring moths with darker coloration, leading to more dark-colored moths over generations.
- Effect: Shifts the average trait value in a particular direction.



amazonaws.com

Stabilizing Selection

- Definition: Favors intermediate phenotypes, reducing the number of extreme traits.
- Example: Human birth weights—very low and very high birth weights have higher mortality rates, so average birth weights are selected for.
- Effect: Reduces variation by favoring the "average" phenotype, keeping the population more consistent.

Disruptive Selection

- Definition: Favors both extreme phenotypes over the intermediate phenotype, potentially leading to speciation.
- Example: In a habitat with both dark and light rocks, mice with either dark or light fur may survive better than those with intermediate fur color, leading to two distinct color groups.
- Effect: Increases variation by favoring multiple distinct phenotypes and can lead to the development of two separate populations.

Species

Reproductive Isolation Definition

Mechanisms that prevent different species from interbreeding and producing fertile offspring. Types: Prezygotic Barriers: Prevent fertilization (e.g., geographic, temporal, behavioral isolation). Postzygotic Barriers: Prevent the survival or fertility of hybrid offspring. Example: Different frog species may have distinct mating calls, so they only attract mates from their own species.

Divergent Evolution

- Definition: The process by which related species evolve different traits, often due to different environmental pressures or niches.
- Example: Darwin's finches, which evolved different beak shapes depending on their specific food sources on the Galápagos Islands.
- Result: Leads to increased diversity as species adapt to various environments.

Gradualism

- Definition: The theory that evolution occurs slowly and steadily through the accumulation of small genetic changes over long periods.
- Example: The slow development of the modern horse from small, multi-toed ancestors over millions of years.
- Contrast with Punctuated Equilibrium: Proposes continuous, slow change rather than sudden shifts.

Punctuated Equilibrium

- Definition: A model of evolution where species remain stable for long periods, with brief, rapid bursts of change due to environmental shifts or mutations.
- Example: Fossil records showing long intervals with little change, followed by sudden appearance of new traits.
- Contrast with Gradualism: Suggests that evolutionary change can occur in short, intense periods rather than gradually.

Adaptive Radiation

- Definition: A process in which a single ancestral species diversifies into multiple new species, each adapted to a different niche.
- Example: The radiation of mammals after the extinction of dinosaurs, filling various ecological roles as herbivores, carnivores, and omnivores.
- Result: A burst of speciation and increased biodiversity as species evolve to exploit different environments.

Convergent evolution

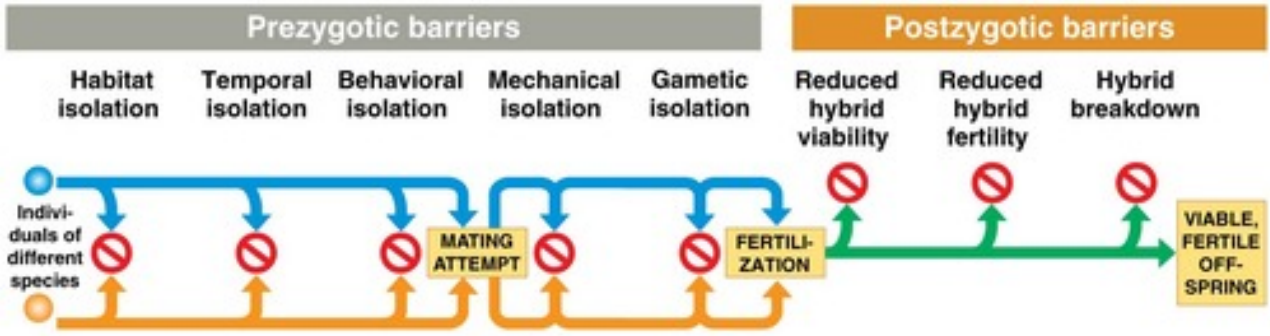
- the process of unrelated species independently developing similar traits
- due to similar environmental pressures
- ex: bats (mammals) and butterflies (insects) - wings

Pre-zygotic Barriers

- "pre-zygote": **barriers that prevent fertilization**
- mating barriers: habitat isolation, temporal isolation
- zygote barriers: behavioral isolation, mechanical isolation, gametic isolation

Post-zygotic Barriers

- "post-zygote": **barriers that inhibit hybrid speciation**
- reduced hybrid viability (do not compete development)
- hybrid sterility (not fertile)
- hybrid breakdown (F1 gen. is fertile, but later gen. are not)



Allopatric Speciation

- Populations are geographically separated by physical barriers

Sympatric Speciation

- Occurs within the same geographic location, i.e. through reproductive isolation

Causes of Evolution

There are five main causes of evolution:
natural selection, sexual selection, mutation, gene flow,
& genetic drift

Natural Selection

- environmental pressures selecting on genetic variation
- ex: tree trunks turn brown, causing brown beetles to have a higher chance of surviving predators than green beetles

Sexual Selection

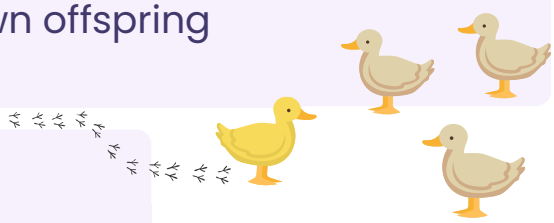
- non-random mating
- ex: female birds only choose to mate with pink male birds, causing the population to be predominantly pink

Mutation

- random appearance of a new gene in a gene pool
- ex: a mutation in light-colored moths caused the appearance of dark-spotted (peppered) moths

Gene Flow

- movement of genes (immigration and emigration)
- ex: yellow ducks immigrate into a brown duck population and mate to produce yellow-brown offspring



Genetic Drift

- random chance events
- ex: an entire anthill is flooded, killing most of ant population and leaving only a small random assortment of survivors

I thought these graphics might make it more fun/memorable but feel free to remove them :)

Hardy Weinberg Equilibrium

Hardy Weinberg is used to calculate the frequencies of **alleles** and **genotypes**. As shown below "p" represents dominant alleles. When you see a p^2 it is representative of homozygous dominant genotypes(RR). Secondly "q" represents recessive alleles and therefore q^2 is representative of homozygous recessive genotypes(rr). Finally 2pq represents heterozygous genotypes(Rr)

Hardy-Weinberg Equations

$p^2 + 2pq + q^2 = 1$

$p + q = 1$

p = frequency of the dominant allele in a population

q = frequency of the recessive allele in a population

inspirit.com

Example Problem

Say green eyes are a recessive trait of fruit flies and 9% of fruit flies in a population have green eyes. Find the frequency of the homozygous dominant genotype.

1. If 9% of the population is homozygous recessive for green eyes that means q^2=0.09
2. If q^2=0.09 then using algebra q=0.3
3. Using the Hardy-Weinbery equation p+q=1 p+(0.3)=1 p must=0.7
4. If p=0.7 then p^2(heterozygous dominant) must be 0.7^2
5. p^2=0.49 or 49%

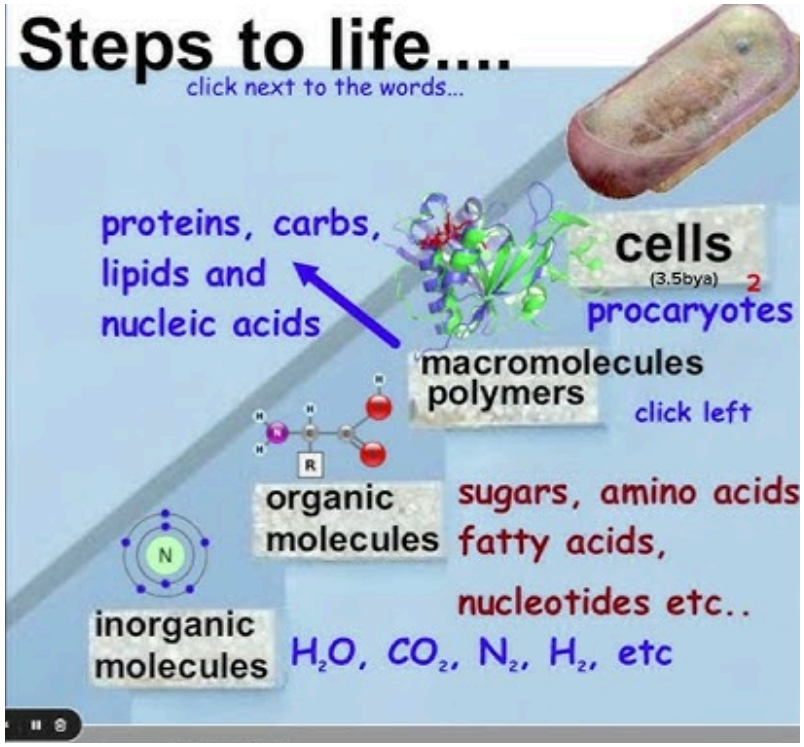
note that Hardy-Weinberg only works for populations with two alleles(dominant/recessive)

https://youtu.be/7S4WMwesMts?feature=shared Good Video Review

Origins of Life

There are many theories on the origins of life, however, for AP Bio there is one main one to know. It is said that the Earth formed 4.6 billion years ago but it was not until 3.9 billion years ago that life was first formed. It is mostly believed that non-living precursors such as gases in the ocean caused the formation of life. These gases are said to have contained inorganic molecules like methane, ammonia, hydrogen, and water. Colliding together, these gases formed compounds necessary for life.

Compounds can't just form life just like that. This is why the **RNA-world hypothesis** was suggested. It is believed these compounds formed RNA and RNA was able to replicate and pass on genomes. Then through evolution came the complex life forms we know of today.



APBio Ch 18:Origins and History of Life(Winnie Sloan)

Unit 7

Natural Selection

1. How does natural selection drive evolution?

A) Individuals evolve during their lifetime.
B) Beneficial traits increase over generations.
C) Environmental changes cause mutations.
D) All individuals adapt equally.

2. Which scenario illustrates genetic drift?

A) Darker moths survive predation.
B) A volcano reduces population size.
C) Antibiotic resistance develops in bacteria.
D) Wolves migrate between two populations.

3. Which ensures Hardy-Weinberg equilibrium?

A) Frequent mutations occur in populations.
B) Population is small and isolated.
C) No gene flow between populations.
D) Selection favors certain traits.

Unit 7

Natural Selection

4. Which are homologous structures?

A) Bat wings and insect wings.
B) Whale fins and penguin wings.
C) Human and whale forelimbs.
D) Monkey tails and shark tails.

5. The first cells on Earth were likely

A) Ribosomes
B) Anaerobic Prokaryotes
C) Eukaryotes
D) Amino Acids

4. Changes in mating rituals can lead to which...

A) Genetic Drift
B) Gene Flow
C) Speciation
D) Bottleneck effect

4. The reason eukaryotes have prokaryote features is attributed to...

A) Endosymbiosis B) Speciation
C) Adaptive radiation D) Cambrian Explosion

Answer key:
1) B 2) B 3) C 4) C 5) B 6) C 7) A

Unit 8

Ecology

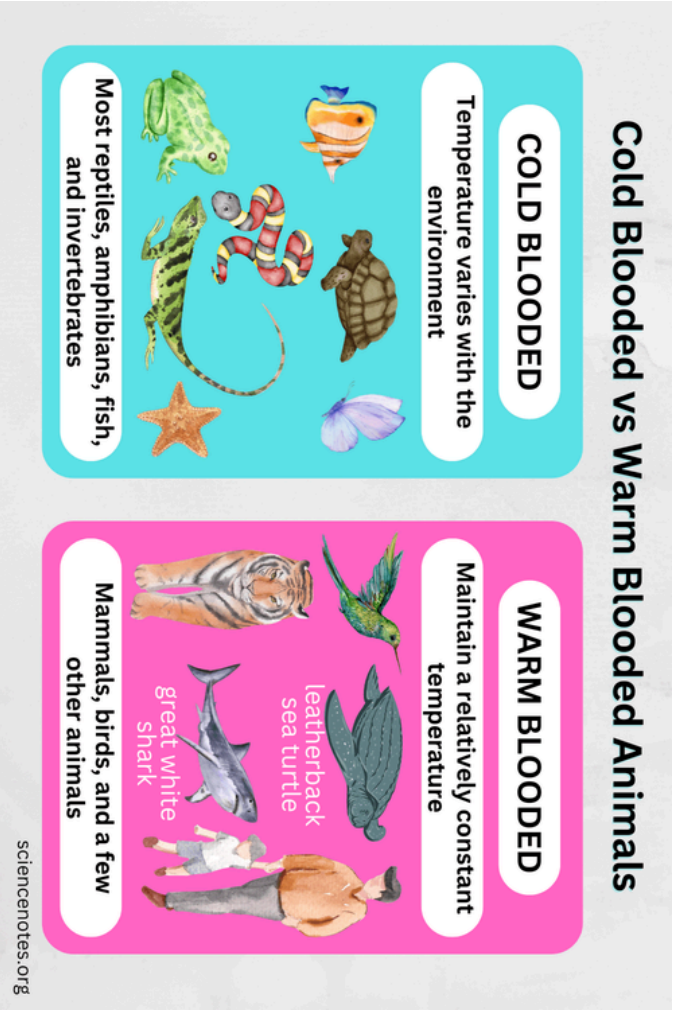
Interacting with the Environment

Endotherms: Warm-blooded animals that maintain body temperature independent of the environment.

- **Generate their own body heat** through **metabolism** (i.e. cellular respiration)
- Body temperature is stable, no matter the external conditions
- Mammals and Birds

Ectotherms: Cold-blooded animals that **use external sources of heat** to regulate body temperature

- Ex. Staying warm using sunlight
- Do not produce their own body heat
- Reptiles, Amphibians, Fish, Invertebrates



Types of Learning

Imprinting: Rapid learning that occurs during a **critical period** of life, such as early development

- Animals learn things necessary for survival
- Ex. Baby geese following their mother

Habituation: Loss of response to a stimulus after repeated exposure to it

- Allows animals to focus on more important stimuli in their environment

How Animals Communicate

Pheromones

Pheromones are **chemical signals** that one animal uses to trigger a response from another animal. This usually facilitates communication **within one species.** They are usually **olfactory** (able to be smelled). Examples:

- Marking territory with urine
- Sex pheromones between males and females

Social Behavior

Agonistic Behavior: Aggressive and threatening behavior/rituals

- Between two animals that are in **competition** for something (e.g. food)

Dominance Hierarchies: Members of a population have a **social structure** where some individuals are dominant to others

- can be based on size

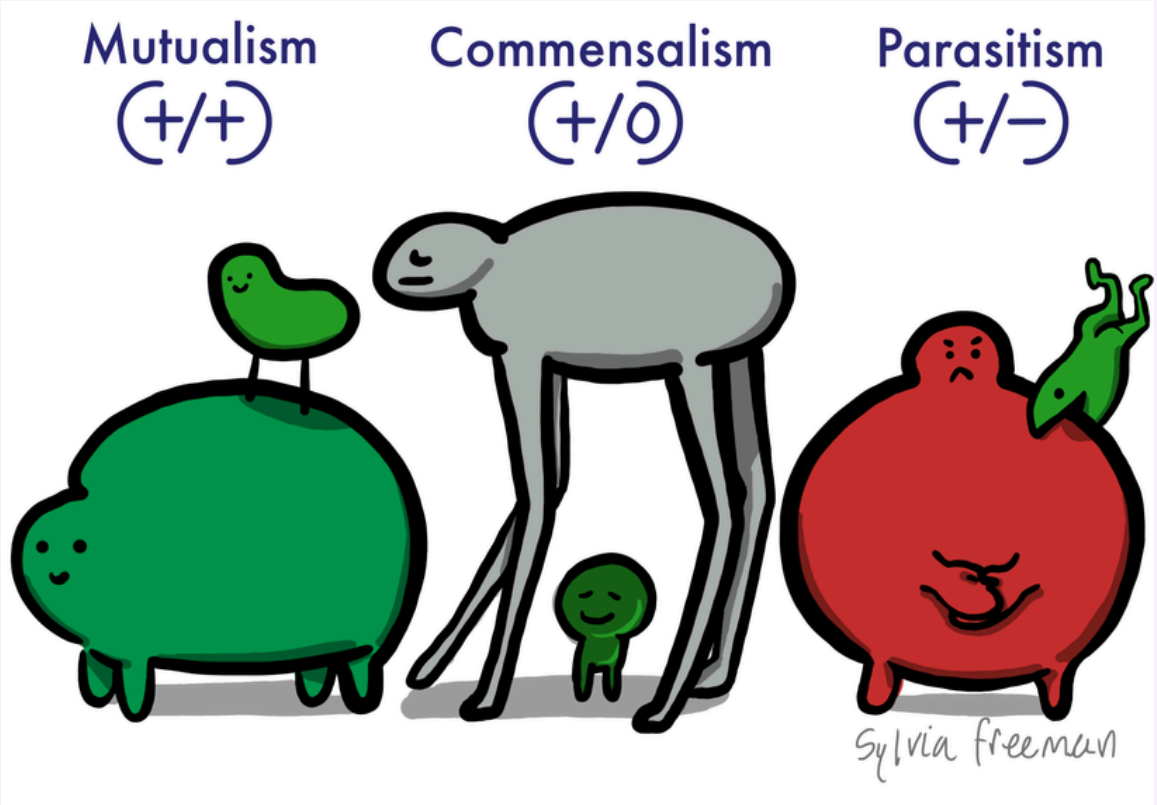
Altruistic Behavior: Behavior that harms the individual performing it, but **benefits the colony as a whole**

- Ensures the survival of the rest of the population
- Ex. In a population of squirrels, one guards the colony for predators
- Indirectly **increases fitness** of colony

Territoriality: Animals establish territories in environment for their colony

- Protect themselves against other members of species
- Ex. Wolves forming territories for their pack

Symbotic Relationships:



1. Mutualism: both organisms win/benefit from eachother, e.g lichen components.
2. Commensalism: in which an organism lives off the other with no harm to said organism, e.g., the remora.
3. Parasitism: where an organism harms its host, e.g; leeches, who feed on the blood of other animals.

Plant Behaviors:

Photoperiodism: when plants flower in response to a change in their received daylight/darkness amounts.

Tropism: turning in response to a stimulus

3 Plant Tropisms:

1. Phototropism: refers to the way plants react to sunlight, e.g bending toward light.

Gravitropism: refers to the way plants respond to gravity. E.g: roots; positive gravitropism, (growing downward into the Earth.) Stems: negative gravitropism (they grow up, away from the pull of gravity),

Thigmotropism: response of touch in a plant. For example, ivy growing around a post or trellis.

Ecology

The study of interactions between organisms and their environment, including both **biotic** (living) and **abiotic** (non-living) factors.

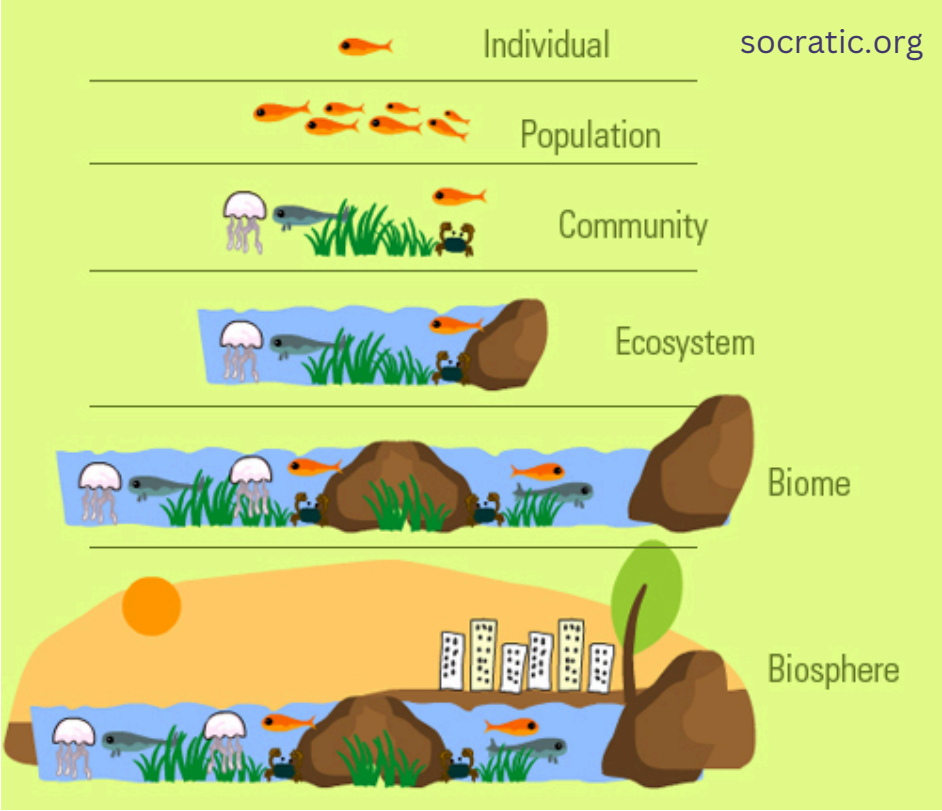
Hierarchy in Ecology

Population

- Definition: A group of individuals of the same species living in the same area and capable of interbreeding.
- Example: A population of wolves in a specific national park.

Community

- Definition: All the populations of different species that live and interact in a specific area.
- Example: In a forest, the community includes trees, birds, insects, fungi, and mammals interacting.



Ecosystem

- Definition: A community of living organisms (biotic factors) interacting with their non-living environment (abiotic factors) in a specific area.
- Example: A coral reef, including fish, algae, water, sunlight, and sand.

Biosphere

- Definition: The global sum of all ecosystems, including all areas on Earth where life exists (land, water, and atmosphere).
- Example: The Earth itself, encompassing all living organisms and the environments they inhabit.

Food Chain

Producers (Autotrophs)

Organisms that produce their own food through photosynthesis (using sunlight) or chemosynthesis (using chemical energy).

Decomposers

Organisms that break down dead organisms and recycle nutrients back into the ecosystem.

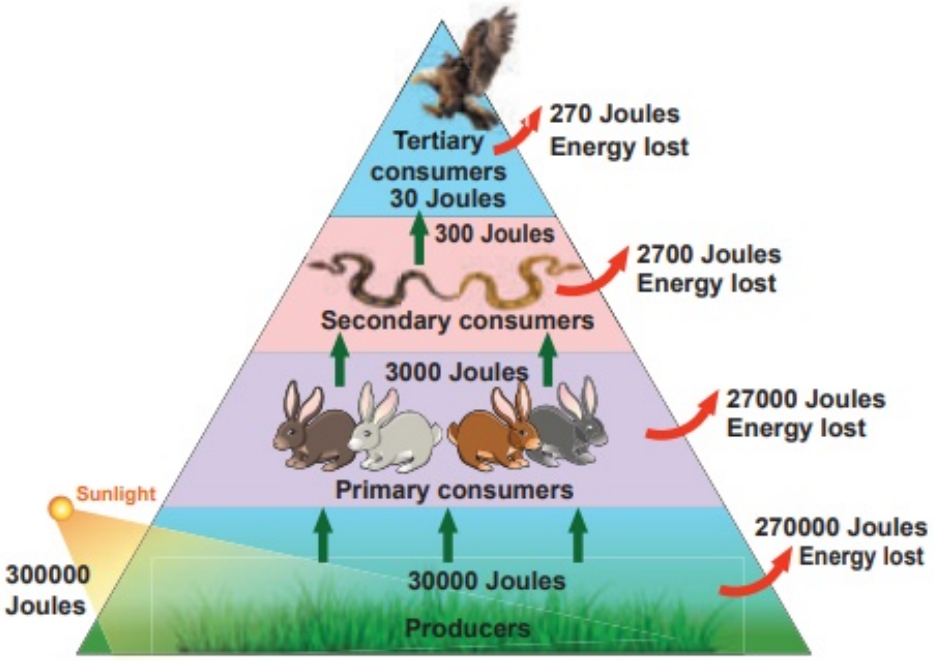


Figure 15: Ten percent law

brainkart.com

Consumers (Heterotrophs)

- Organisms that rely on consuming other organisms for energy.

Types

- **Primary Consumers**: Herbivores that eat producers (e.g., rabbits, deer).
- **Secondary Consumers:** Carnivores that eat herbivores (e.g., snakes, frogs).
- **Tertiary Consumers**: Top predators that eat secondary consumers (e.g., hawks, sharks).
- **Omnivores:** Organisms that eat both plants and animals (e.g., bears, humans).

Keystone Species

- A species that plays a critical role in maintaining the structure and stability of its ecosystem. Its removal can lead to ecosystem collapse.

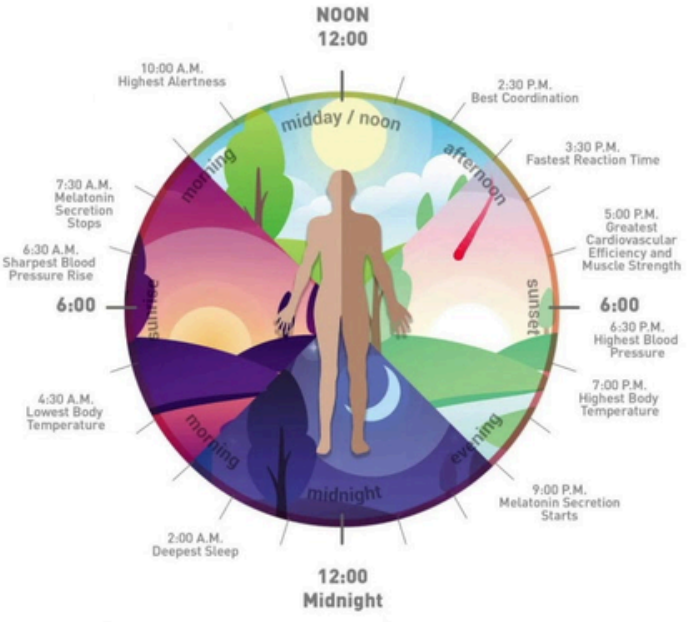
10% Rule (Energy Transfer)

- Definition: Only about 10% of the energy from one trophic level is passed to the next. The rest is lost as heat, used for metabolism, or left undigested.
- Example:
  - 1000 kcal of energy in producers → 100 kcal in primary consumers → 10 kcal in secondary consumers → 1 kcal in tertiary consumers.

Circadian Rhythm

Circadian rhythm is the internal clocks/cycles of an organism in relation to time, driven by biochemical mechanisms.

- Ex: roosters, humans, plants



Bioaccumulation

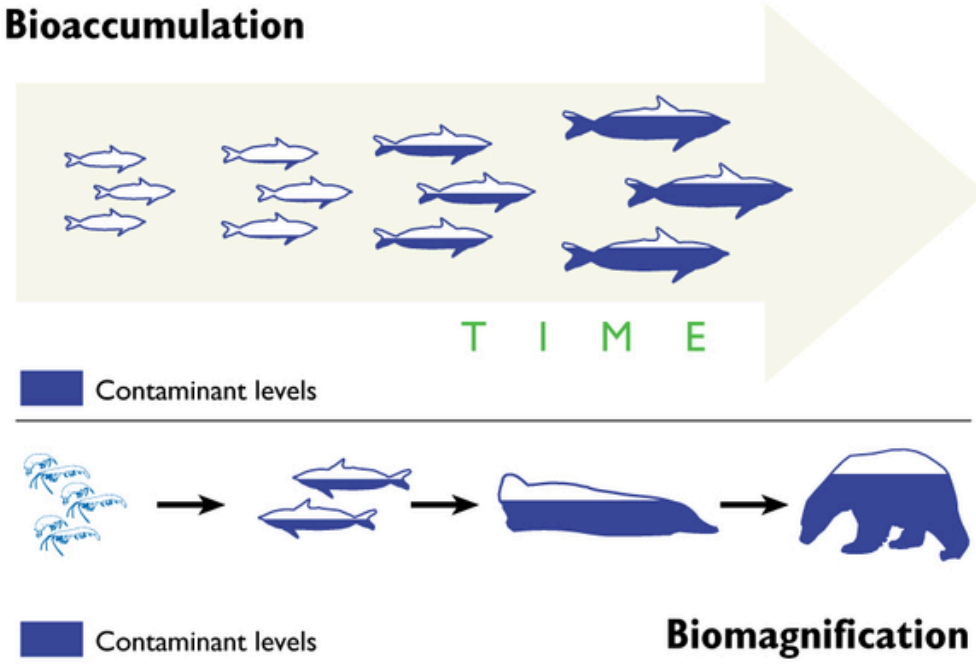
Bioaccumulation is the <u>buildup</u> of chemicals in an organism over time.

- Accumulation occurs within a <u>single organism</u>
- As it lives longer, it consumes more of the chemical

Biomagnification

Biomagnification is the <u>increase in concentration</u> in each organism going up the food chain.

- Magnification occurs because the larger an animal is/the more food it consumes, the more chemicals it also consumes



Simpson's Diversity Index

Simpson's Diversity Index is an equation used to measure the diversity of ecosystems. It takes into account:

- number of species ("richness")
- relative abundance of each species ("evenness")

The values of D range from 0 to 1. The closer to 1, the higher the diversity.

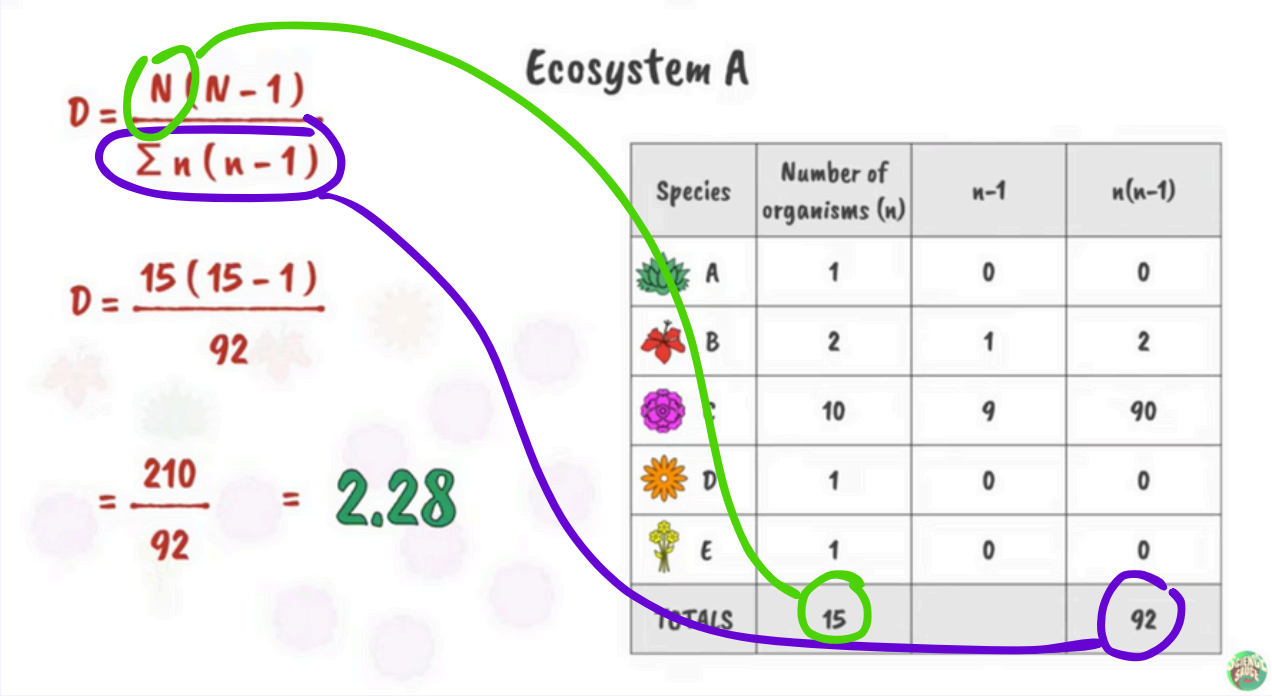
$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

D = Biodiversity (higher means more diverse)

N = Total number of organisms

n = Number of organisms of each species

Example Problem



Science Sauce: "Simpson's Diversity Index Explained." https://www.youtube.com/watch?v=7DOuku8876I

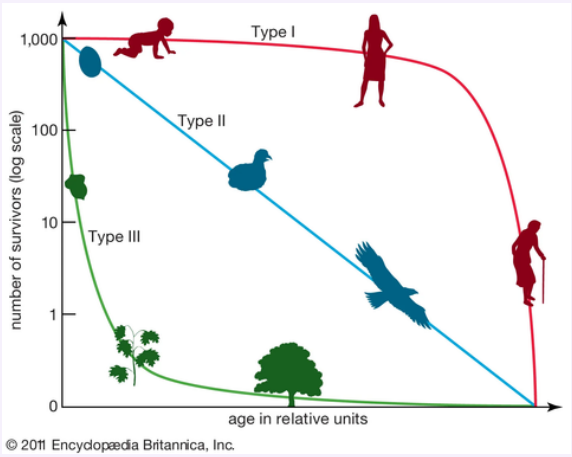
Population and Density

A **population** is a group of individuals of the same species living in a defined area, interacting with each other and their environment. **Population density** shows the number of individuals per unit of area or volume, which can help to assess resource availability, competition, and interactions.

Demography and Survivorship

Demography is the statistical study of population changes over time, focusing on factors like **birth rates, death rates, and age structures. Survivorship curves** graphically represent the proportion of individuals surviving at each life stage:

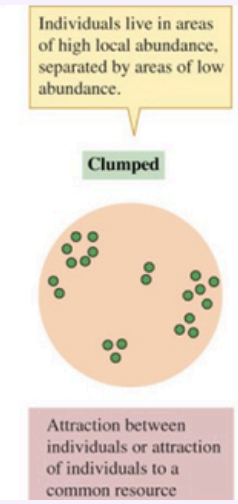
- **Type I**: High survival in early/midlife, with a steep decline in old age (e.g., humans).
- **Type II:** Constant mortality rate across life stages (e.g., squirrels).
- **Type III**: High mortality early in life, with survivors reaching adulthood (e.g., plants, fish).



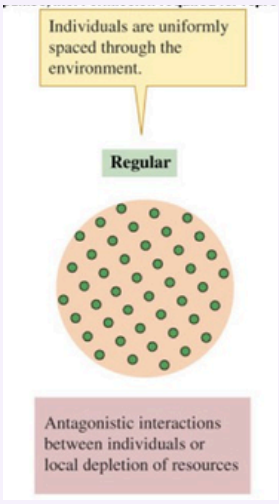
Britannica.com

Dispersion Patterns

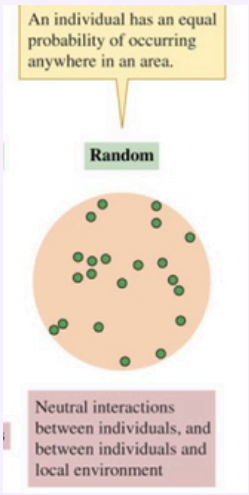
Wordpress.com



Clumped: Individuals gather near resources or for social reasons (e.g., herds).



Uniform: Even spacing due to territorial behavior (e.g., nesting birds)



Random: No specific pattern, often with evenly distributed resources (e.g., wildflowers).

Limiting Factors

- **Density-Dependen**t: Increase effects with population size (e.g., competition, disease).

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Britannica.com

- **Density-Independent**: Impact regardless of size (e.g., weather, natural disasters).

Population Growth

Exponential growth- happens when resources are unlimited, and the population grows at its maximum rate. The formula is:

$$dN/dt=rmaxN$$

Where:

- **dN/dt**: Change in population size over time.
- **rmax:** Growth rate (birth rate minus death rate).
- **N**: Current population size.

This equation shows that the growth rate is proportional to the population size (N), meaning the larger the population, the faster it grows. This results in a "**J-shaped**" curve on a graph.

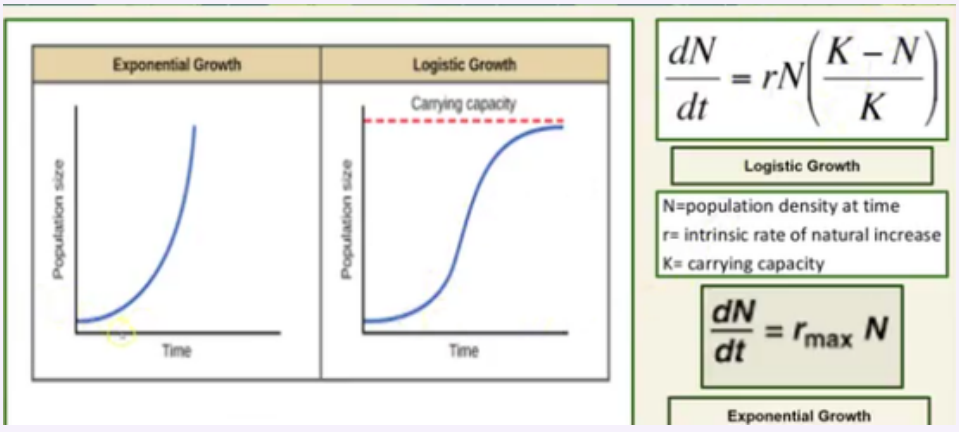
Logistic growth considers resource limitations, where growth slows as the population approaches the carrying capacity (K). The formula is:

$$dN/dt=rmax(K-N/K)N$$

Where:

- **dN/dt**: Change in population size over time.
- **rmax**: Growth rate.
- **N**: Current population size.
- **K:** Carrying capacity.

This results in an "**S-shaped"** curve on the graph



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Unit 8

Ecology: Review Questions

1. **What type of behavior can describe when a squirrel guards its colony to protect it against predators?**

A) Altruistic Behavior B) Antagonistic Behavior
C) Dominance Hierarchies D) Imprinting

2. Which of the following is *not* true about pheromones?

A) Sensed using olfactory receptors
B) Used to mark territory
C) Used for communication
D) Occurs between members of different species

3. Agonistic behavior occurs between ___.

A) Two animals in competition B) A parent and child
C) An animal and its environment D) Endotherms and ectotherms

4. What is habituation?

A) Using external sources of heat to regulate body temperature
B) A rapid form of learning during development
C) Loss of response to recurring stimulus
D) A type of altruistic behavior

Unit 8

Ecology: Review Questions

5. A human goes about their daily routine without any evident affliction of bacteria on them. Which symbiotic relationship is this an example of?

A) Parasitism B) Commensalism C) Bonding D) Mutualism

6. A population rapidly loses its nutrients and resources from a fatal wildfire accident. Many habitats and assets are lost. Animal life plummets. What type of population growth is this?

A) Deforestation B) Photonic

C) Logistic D) Exponential

7. Which of the following rules does the following exemplify: 1000 kcal of energy in producers → 100 kcal in primary consumers → 10 kcal in secondary consumers → 1 kcal in tertiary consumers.

A) Keystone Rule B) Omnivore Rule

C) Food Chain Rule D) 10% Rule

Answer key:
1) A 2) D 3) A 4) C 5) B 6) C 7) D