AP Biology Review

UNIT I: CHEMISTRY OF LIFE

A. Elements

- All life forms made up of matter
  - All matter made up of **elements**
    - **Elements**
      - Substances that cannot be broken down into smaller substances by chemical means

B. Essential Elements of Life

- 96% of the mass of all living things made up of 4 elements:
  - **Oxygen** (O)
  - **Carbon** (C)
  - **Hydrogen** (H)
  - **Nitrogen** (N)
- Other elements (collectively 4% of biomass)
  - Calcium (Ca)
  - Phosphorus (P)
  - Potassium (K)
  - Sulfur (S)
  - Sodium (Na)
  - Chlorine (Cl)
  - Magnesium (Mg)
- Trace elements
  - IRon (Fe)
  - Iodine (I)
  - Copper (Cu)

C. Subatomic Particles

- **Atom**
  - Smallest unit of an element
  - Building blocks of physical world
- Subatomic PArticles
  - **Protons**
    - Packed with neutrons in nucleus
    - Positively charged
    - Most atoms have same amount of protons as electrons, making them electrically neutral
  - **Neutrons**
    - Packed with protons in nucleus
    - No charge
    - **Isotopes**
      - Same element with different amount of neutrons in nucleus
      - Vary in mass
      - **Radioactive isotopes** decay spontaneously, giving off particles and energy

Electrons

Negatively charged

Spin around nucleus

Very small; effectively massless

Electrons on an atom differ in their amounts of potential energy

Electron's state of potential energy is called its energy level, or **electron shell**

Valence electrons are those in the outermost shell, or **valence shell**

Chemical behavior of an atom is mostly determined by the distribution of electrons in electron shells

Valence shell most important

Elements with full valence shells are chemically *inert*

Atoms with incomplete valence shells can share or transfer valence electrons with certain other atoms

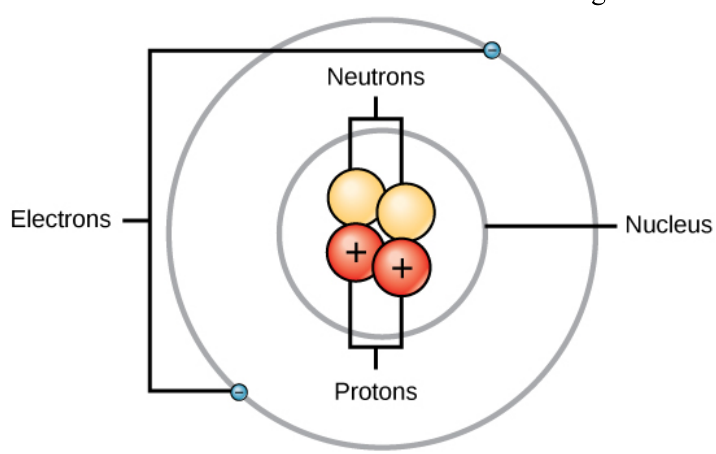
Atoms of different various elements differ in number of subatomic particles

Atomic number=#protons in nucleus

Mass Number= protons+neutrons

Average of all isotopes

Atomic mass+atom's weighted average total mass



D. Compounds

Compound occurs as result of 2 or more individual elements combining in a fixed ratio

Different properties of individual elements

Formed by chemical reaction

Bonds that hold compounds together

Ionic bonds

nonmetal+metal

One or more electrons is transferred from one atom to another

One atom loses electrons (becomes positively charged) while the other gains electrons (becomes negatively charged)

Results from attraction of two oppositely charged ions

Cation has a positive charge

Anion has a negative charge

Cation and anion form to create ionic bond

Covalent bonds

nonmetal+nonmetal

Molecule consists of 2 or more atoms held together by covalent bonds

Formed when electrons are shared between atoms

In **nonpolar covalent** bond, electrons are shared equally

In **polar covalent** bond, electrons are shared unequally

In a **single covalent bond**, one pair of electrons is shared

Double covalent when 2 pairs are shared, etc.

Structural formula used to represent atoms and bonding

Ex. H-H

Molecular formula abbreviates structural formula

Ex. H_2

Electronegativity is an atom's attraction for the atoms in a covalent bond

The more electronegative an atom, the more strongly it pulls shared electrons toward itself

Hydrogen bonds

Hydrogen atom covalently bonds to one electronegative ato is also attracted to another electronegative atom

In living cells, hydrogen bonds are usually oxygen or other nitrogen atoms

Van der Waals Interactions

Weakest

If electrons are distributed asymmetrically in molecules or atoms, they can result in "hot spots" of positive or negative charge

Attractions between molecules that are close together as a result of these charges

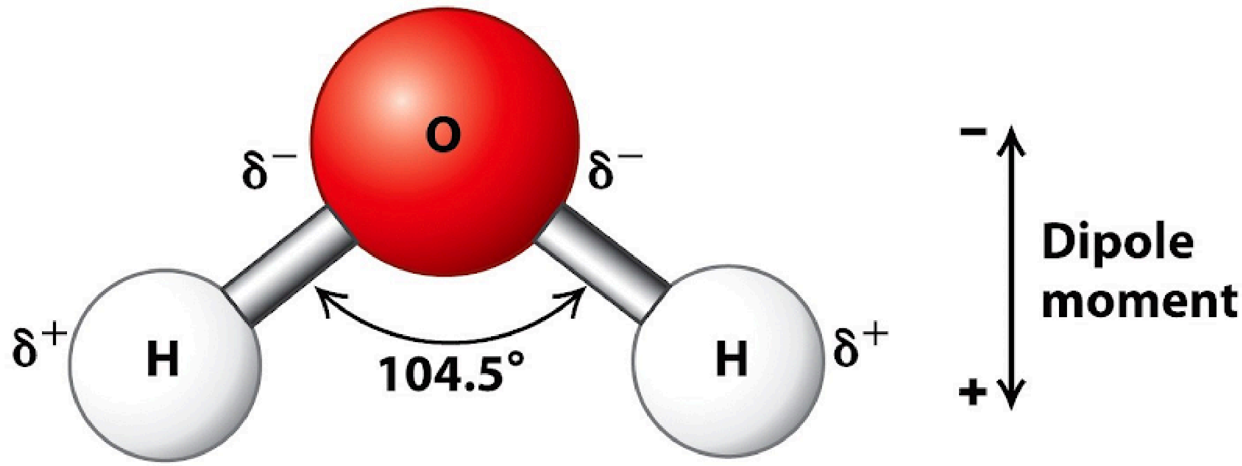
How geckos climb

<u>E. Water: The Versatile Molecule</u>

In water, electrons are not shared equally in the bonds between hydrogen and oxygen

Hydrogen atoms have a partial positive charge while oxygen atoms has a partial negative charge

Water is polar



Hydrogen bonds

- Weak attractions that result of water's polarity
  - Positive end of another polar molecule attracted to oxygen negative charge, and vice versa with the hydrogen end
  - Hydrogen atom covalently bonded to one electronegative atom is also attracted to another electronegative atom
  - Weak Individually, but strong on a larger scale
- Lends watermany special properties
  - **Cohesion**
    - Tendency for water to stick to water
    - Important during transpiration
      - Water evaporates, pulls other water molecules with it, pulling all the way down from leaves to roots
  - **Adhesion**
    - Tendency of water to stick to other substances
    - Cohesion + Adhesion = **capillary action**
      - Allows water to flow up roots/trunks/branches of trees in thin vessels
  - **Surface tension**
    - Results from cohesion of water molecules
    - Ex. water striders can sit on top of water without sinking
  - **High heat capacity**
    - Heat CApacity=ability of a substance to resist temperature changes
    - Keeps ocean temperatures stable
    - Allows organisms to keep constant body temperature, since most life forms are mostly made up of water
    - Heat is absorbed when hydrogen bonds break, released when hydrogen bonds form
  - **High heat of vaporization**
    - Heat a liquid must absorb for 1g to be converted to gas

Evaporative cooling

As a liquid evaporates, its remaining surface cools

How sweat works to cool body down

Expansion on freezing

Lattice structure of ice causes water to expand on freezing

Allows ice to float on top of lakes in winter

Animal life can live beneath ice

Versatility as a solvent

Solution is a liquid that is a homogenous mix of substances

Solvent is the dissolving agent of a solution

Solute is the substance that is dissolved

Aqueous solution is one where water is the solvent

Polarity of water allows it to be a versatile solvent

Can form hydrogen bonds easily

Hydrophobic substances do not dissolve in water, but hydrophilic ones will

F. Acids and Bases

Solution is **acidic** if it contains a lot of H^+

Solution is **alkaline** if it contains a lot of OH^-

Measured on **pH scale**

Logarithmic

Numbered 1-14

Acids 1-7 pH

Bases 7-14 pH

Buffers maintain stable pH

G. Organic Molecules

Organic compound contains Carbon

Inorganic compound does not contain carbon

Carbon often surrounded by hydrogen

Carbon is a versatile atom

Can bind with many elements

Many "slots" to bind with elements

4 valence electrons

Can form 4 covalent bonds

Makes large, complex molecules possible

In molecules with multiple carbons, each carbon bonded to 4 other atoms has a tetrahedral shape

When 2 carbons are formed by a double bond, the atoms joined to the carbons are one the same plane as the carbons

Electron configuration gives it covalent compatibility with other elements

Hydrocarbons consist of only carbon and hydrogen

Can undergo reactions that release a large amount of energy

isomers are compounds with the same molecular formula but different structures/properties

Usually only one isomer is biologically active

Functional groups are the components of organic molecules that are most commonly involved in chemical reactions

Number and arrangement of functional groups give each molecule its unique properties

Functional group	Structure/Molecular formula	Characteristics/properties
Hydroxyl	-OH	Polar due to electronegative oxygen Forms hydrogen bonds with water, helping to dissolve compounds such as sugars
Carbonyl	>C=O	Sugar withcarbony in skeleton=ketose Sugar with carbonyl at end=aldose
Carboxyl	-COOH	Acts as an acid because the covalent bond between hydrogen and oxygen is so polar
Amino	$-NH_2$	Acts as a base
Sulfhydryl	-SH	Helps stabilize protein structure Determines curliness of hair
Phosphate	$-OPO_3^{2-}$	Confers on a molecule the ability to react with water releasing energy
Methyl	$-CH_3$	Affects expression of genes Affects shape/function of sex hormones

Most macromolecules are chains of building blocks called **polymers.** The individual building blocks of a polymer are called **monomer**s

Carbohydrates

Contain carbon, hydrogen, and oxygen in a 1:2:1 ratio

Monosaccharides

Most common are **glucose** and **fructose**

Glucose

Most abundant

Part of food humans eat

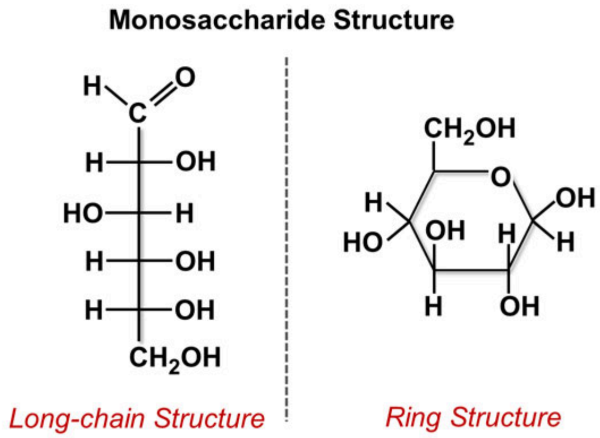
Made by plants during photosynthesis

Broken down to release energy

Fructose

Common sugar in fruits

Can be depicted as either straight or rings



6 carbon-sugars

Formula: $C_6H_{12}O_6$

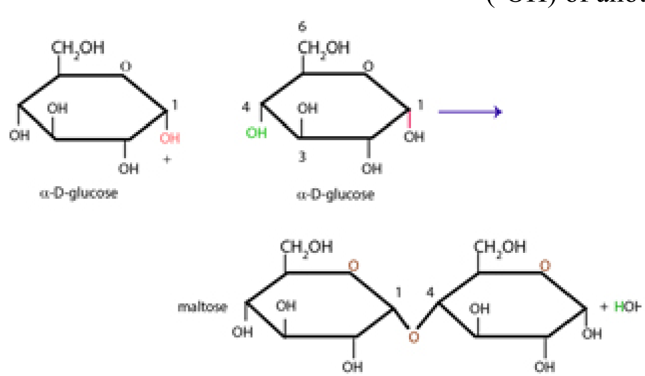
Disaccharides

1 monosaccharide+1 monosaccharide=1 Disaccharide

Formed by **dehydration synthesis**

Aka **condensation**

Hydrogen (-H) from one sugar combines with hydroxyl group (-OH) of another sugar molecule to create water as byproduct



Bond is called **glycosidic linkage**

Broken apart by **hydrolysis**

Reverse of dehydration

Water is used to break apart glycosidic linkage

Polysaccharides

Repeated units of monosaccharides

Most common

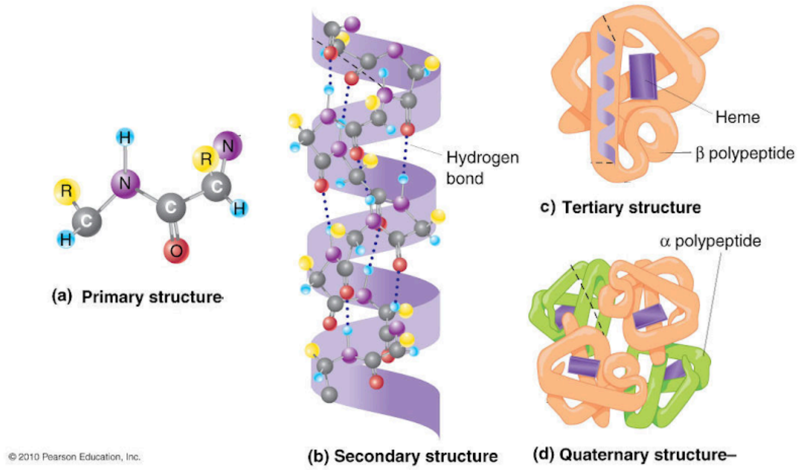
Starch

Stores sugar in plants

- Made up of alpha-glucose molecules
- **Cellulose**
  - Made up of β-glucose molecules
  - Chitin
    - Structural molecule in walls of fungi/arthropod exoskeletons
    - Used as surgical thread since it breaks down in body
- **Glycogen**
  - Stores sugar in animals

Proteins

- **Amino acids**=monomer of proteins
  - 20 kinds of naturally occurring amino acids
- Contain:
  - Carbon
  - Hydrogen
  - Oxygen
  - Nitrogen
- 4 parts of an amino acid centered around a central carbon
  - **Amino group** ($-NH_2$)
  - **Carboxyl group** (-COOH)
  - Hydrogen
  - **R group**
    - Aka **side chain**
    - Interchangeable
    - Vary in composition, polarity, charge, shape depending on specific side chain
    - Polar R groups point outward, hydrophobic R groups point inward
- **Polypeptides**
  - Amino acid + amino acid= **dipeptide**
    - Formed by dehydration synthesis
    - Bond is called a **peptide bond**
    - Multiple amino acids= **polypeptide**
      - Once a polypeptide chain twists and folds on itself, it forms a 3D structure called a protein



Higher protein structure (4 levels total)

- **Primary structure**
  - Linear sequence of amino acids
  - Covalent (peptide) bonds
- **Secondary structure**
  - Protein beings to twist--2 options
    - Forms a coil (alpha-helix)
    - Zigzagging pattern (known as beta-pleated sheets)
  - Shape depends on R-group
  - Formed by amino acids that interact with other amino acids closeby in the primary structure
  - Hydrogen bonds between carbonyl and amino group
  - Interactions between amino and carboxyl groups of protein backbone
  - After secondary structure forms, formerly distant amino acids are now closeby--tertiary structure can form
- **Tertiary structure**
  - Can be both alpha and beta helix/sheets within structure
  - Covalent disulfide bridge often stabilizes structure
  - Bonds between R groups
    - Hydrogen bonds
    - Ionic bonds
    - Disulfide bridges
    - Hydrophobic interactions
- **Quaternary structure**
  - Several different polypeptide chains sometimes interact with each other
  - Same bonds as above, but between peptide chains rather than between R groups
- Mistakes in structure can **denature** a protein
  - Change of shape=change of function

Ex. pH or heat can denature protein

Protein folding can involve **chaperone proteins (chaperonins)**

Help protein fold properly

Make process more efficient

8 kinds of Proteins	
Name	Function
Enzymatic	Selective acceleration of chemical reactions
Defensive	Protection against disease
storage	Storage of amino acids
transport	Transport of substances
hormonal	Coordination of organism's biological activities
receptor	Response of cell to chemical stimuli
contractile/motor	movement
Structural	support

Lipids

Like carbs, consist of carbon, hydrogen and oxygen, but not in a fixed ratio

Do not form polymers

Little-no affinity for water

Hydrophobic due to nonpolar covalent bonds of hydrocarbon

Common examples:

Triglycerides

Glycerol molecule+3 fatty acid chains attached

Fatty acid chain is mostly a long chain of carbons where each carbon is covered in hydrogen; One end of the chain has a carboxyl group (-COOH)

Vary in length and #/location(s) of double bonds

Glycerol is a 3-carbon alcohol with a hydroxyl group attached to each carbon

Fats separate from water because water forms hydrogen bonds with itself while excluding the fats

In order to be made, each of the carboxyl groups of the 3 fatty acids must react with one of the 3 hydroxyl groups of the glycerol molecule via **dehydration synthesis**

bond=**ester linkage**

Saturated fatty acid

No double bond

Carbon chain completely filled ("saturated") with hydrogen

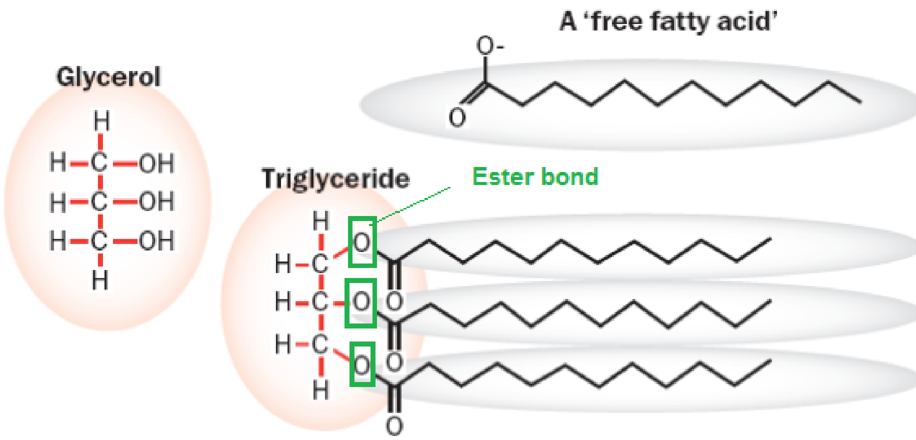
Usually solid at room temp.

Unsaturated fatty acid

Double bond along carbon chain, causing a bend

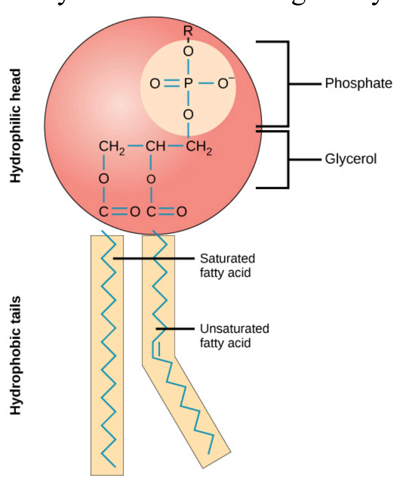
Bend allows triglyceride to become LESS dense, making it liquid at room temperature

Polyunsaturated fatty acid has multiple double bonds within the fatty acid, causing many bends



Phospholipids

2 fatty acid "tails" + 1 negatively charged phosphate "head"



Tails are hydrophobic, while head is hydrophilic (negative charge on head attracts polar water)

Amphipathic molecule (molecule that is both polar and nonpolar)

In water, phospholipids self-assemble into a "bilayer arrangement"

Hydrophobic tails face towards interior

Found in cell membranes

Steroids

Cholesterol

4-ringed molecule dispersed throughout membrane

- Maintains membrane stability
  - Increases membrane fluidity at lower temperatures by disrupting close packing
  - Decreases fluidity at high temperatures through its constant movement

Nucleic Acids

- Contain carbon, hydrogen, oxygen, nitrogen, and phosphorous
- Structure
  - Nitrogenous base
  - Pentose sugar
  - Phosphate group
  - Portion of nucleotide w/o phosphate group is called nucleoside
- Store, transmit, and help expres hereditary information
- monomer=nucleotides
- Amino acid sequence of a polypeptide is programmed by a unit of inheritance called a gene
  - Made up of DNA
- **Deoxyribonucleic acid (DNA)**
  - sugar=deoxyribose
  - Contains genetic/hereditary information
  - Provides directions for its own replication
  - Directs synthesis of messenger RNA (mRNA), and through mRNA, controls protein synthesis
    - Occurs on ribosomes
- **Ribonucleic acid (RNA)**
  - sugar=ribose
  - Essential for protein synthesis
- 2 families of nitrogenous bases
  - Pyrimidines
    - Single 6-membered ring
    - Ex.
      - Cytosine
      - Thymine (only DNA
      - Uracil (only RNA)
  - Purines
    - 6-membered ring fused to a 5-membered ring
    - Ex.
      - Adenine
      - Guanine
- Nucleotide Polymers
  - Nucleotide polymers linked together to build a polynucleotide

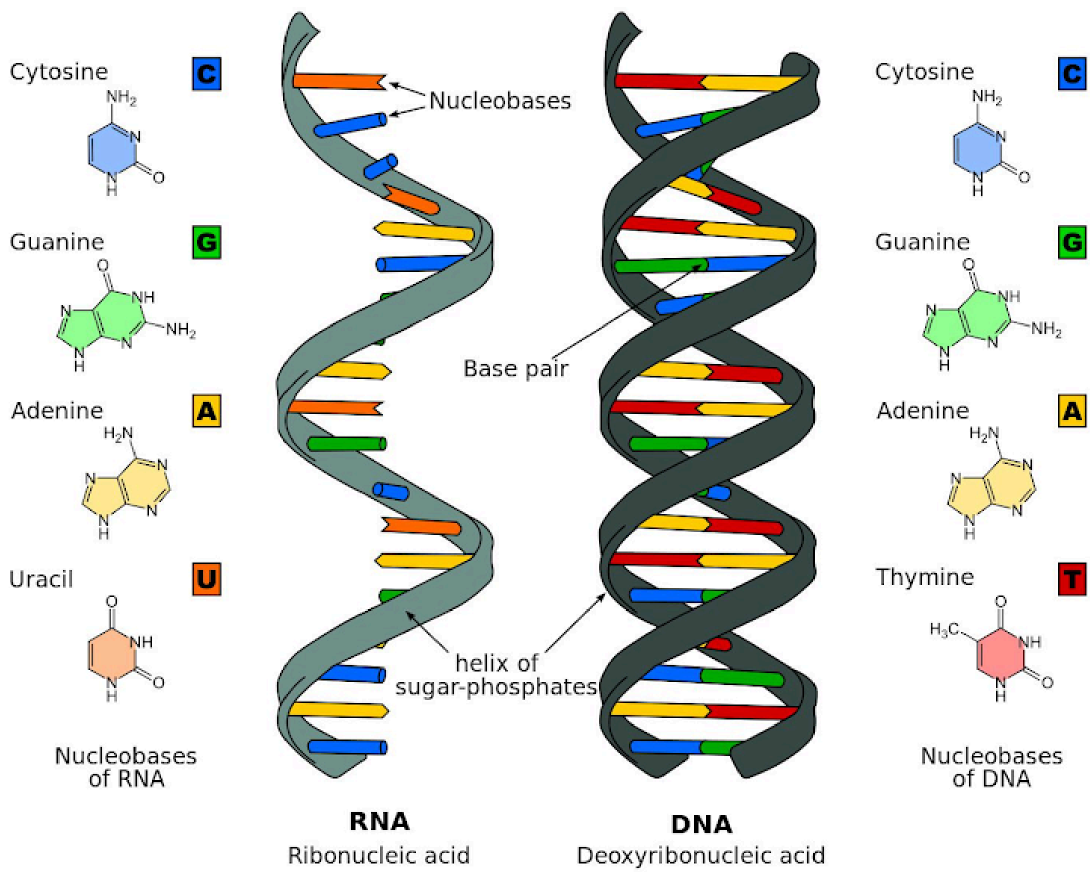
Adjacent nucleotides are joined by covalent bonds that form between the -OH group on the 3’ carbon of one nucleotide and the phosphate on the 5’ carbon on the next

- Links create a backbone of sugar-phosphate units with nitrogenous bases as appendages

RNA molecules usually exist as single polypeptide chains

DNA molecules have 2 polynucleotides spiraling around an imaginary axis, forming a double helix

- Two backbones run in opposite 5’→3’ directions from each other (**antiparallel)**
- One DNA molecule contains many genes
- Nitrogenous bases pair up and form hydrogen bonds
    - Adenine-Thymine
    - Guanine-Cytosine
    - Complementary base pairing
    - In RNA, thymine is replaced by uracil, so A and U pair



Macromolecule	Monomer	Polymer	Linkage Bond

Carbohydrates	Monosaccharide (ex. Glucose)	Polysaccharide (ex. Starch, glycogen, cellulose)	Glycosidic linkage
Proteins	Amino Acid (Ex. Glycine)	Polypeptide (ex. actin)	Peptide bond
Nucleic Acids	Nucleotides (ex. Adenine, thymine, guanine, cytosine)	DNA or RNA	Sugar-phosphate phosphodiester bonds
Lipids	Not a true polymer, but often contains chains of carbons with hydrogens	Triglycerides, Phospholipids, cholesterol	Ester bonds

F. Origins of the Earth

Alexander Oparin and **J. B. S. Haldane** proposed that the primitive atmosphere contained the following gases:

Methane (CH_4)

Ammonia (NH_3)

Hydrogen (H_2)

Water (H_2O)

No free oxygen (O_2)

No oxidation/reduction

Rocks do not release oxygen through weathering

Gases collided, producing chemical reactions that eventually led to the organic molecules we know today

Substantial support until 1953

1953, **Stanley Miller** and **Harold Urey** simulated the conditions of primitive Earth in a lab,

Put theoried gases into flask, struck them with electrical charges to simulate lightning, and organic compounds similar to amino acids appeared

Current theory of the origin of life suggests 4 main stages

1. Formation of amino acids
2. Monomers form polymers
3. Enclosure of small organic molecules into larger ones
4. Self-replicating molecules that can direct synthesis of other organic substances

Energy sources for early organic synthesis

Lightning

Volcanic eruptions

RNA world hypothesis

Original life-forms were simple molecules of RNA

RNA not restricted to double helix
RNA capable of replicating and passing genes
Complex organic compounds must have formed via dehydration synthesis
Organic compounds then used as food by cells
Simple cells evolved into complex cells

Heterotrophs
living organisms that rely on organic molecules for food
Aka consumers

Autotrophs
Organisms that make their own food
Most commonly via photosynthesis
Aka producers

UNIT II: Cells

A. Living Things

All living things are composed of **cells**
According to cell theory, the cell is life's basic unit of structure and function
Cell is the smallest unit of living material that can carry out all the activities necessary for life
Why not be a GIANT CELL?
Specialization
Must maintain high surface area:volume ratio to allow cellular exchanges across the membrane!

B. Types of Cells and Organelles

Invention of electron microscopes allowed scientists to figure out the exact functions of cells

Prokaryotic cells
Only in domains Bacteria and Archaea
Smaller
Simpler
Circular DNA
In **nucleoid region**
NO NUCLEUS
Cell wall
Made up of peptidoglycans that surround a lipid layer called the **plasma membrane**
Filled with semi-fluid cytosol
Have ribosomes
Can have flagella
Long projections used for motility
May have a thick **capsule** outside their cell wall to give them extra protection
No membrane-bound organelles

Eukaryotic cells
More complex

- Organized into smaller structures called organelles
- DNA in nucleus bounded by a membranous nuclear envelope
- Cytoplasm between plasma membrane and nucleus

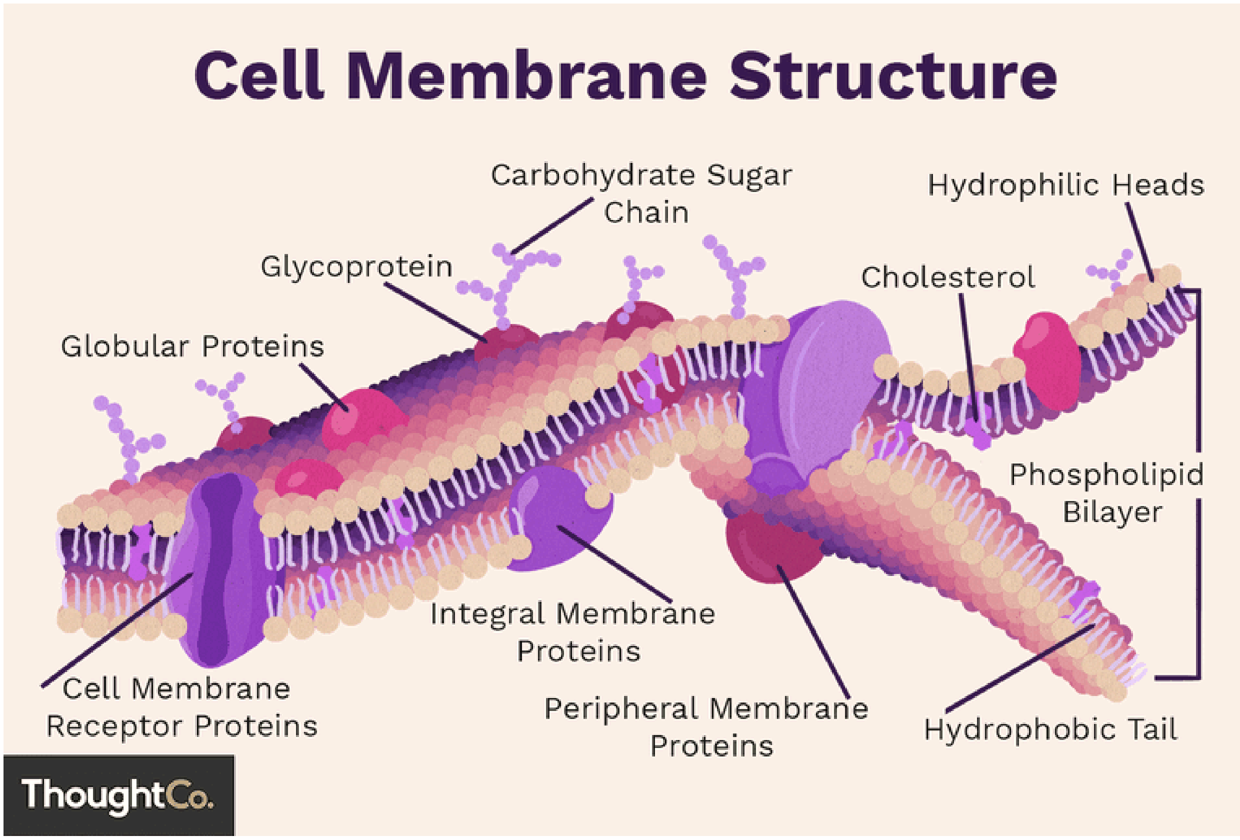
C. Organelles

- Each organelle has its own special task
- **Plasma Membrane**
    - Outer envelope
    - Complex
    - Phospholipid bilayer
    - Encloses vacuole
    - Regulates movement in/out of cell
    - Flexible due to weak bonds holding it together
        - Higher fluidity when more phospholipids have double bonds (causing a bend in the tail) since the molecules aren't as packed
    - Semipermeable
        - Only small hydrophobic molecules can pass through unaided
        - Anything large/hydrophilic must pass through active/passive transport
        - Water can't move through easily due to its polarity
    - **Fluid-mosaic model**
        - **Peripheral proteins** are loosely associated with the lipid bilayer
            - Located on inner/outer surface of membrane
        - **Integral proteins** are firmly bound into the plasma membrane
            - Amphipathic to allow anchoring
            - Some extend all the way through the membrane
        - Membrane peppered with different proteins/carb chains
    - **Adhesion proteins**
        - membrane proteins form junctions between adjacent cells
    - **Receptor proteins**
        - Serve as docking sites for arrivals at the cell
        - Ex. hormones
    - **Transport proteins**
        - Form pumps that use ATP to actively transport solutes across the membrane
        - Hydrophilic channel that certain molecules/ions can use as a tunnel
        - Specific for substance it moves
    - Carrier Proteins
        - Bind to molecules and change shape to shuttle them across the membrane
    - **Channel proteins**
        - Selectively allow the passage of ions/molecules
    - **Cell surface marker**
        - Exposed on cellular surface
        - Play a role in cell recognition/adhesion
        - Ex. glycoproteins
    - **Carbohydrate side chains**

Attached to surface of some proteins
Found only on outer surface

Cholesterol

Maintain fluidity (see pg. 11)
Unsaturated fats also lend membrane fluidity by increasing space between phospholipids due to bend



Nucleus

Largest organelle of cell
Directs what goes on in cell
Responsible for cell's ability to reproduce
Home of hereditary information (DNA)
DN organized into large structures called chromosomes
Most visible structure of nucleus id nucleolus, which is where rRNA is made and ribosomes are assembled

Ribosomes

Sites of protein synthesis
Manufacture all proteins required/secreted by the cell
Consists of RNA and other proteins
Bind messenger RNA and transfer RNA to synthesize proteins
Round structures consisting of 2 subunits:te large subunit and the small subunit
Composed of RNA and proteins
Can either be free floating or attached to the **endoplasmic reticulum (ER)**

Endoplasmic Reticulum (ER)

- Continuous channel that extends into many regions of the cytoplasm
- Lipid proteins synthesis/transport
- **Rough ER**
  - Attached to nucleus
  - Studded with ribosomes
  - Proteins generated here are trafficked to/across plasma membrane, or used to build Golgi bodies, lysosomes, or the ER.
- **Smooth ER**
    - Lacks ribosomes
    - Makes:
      - Lipids
      - Hormones
      - Steroids
    - Breaks down toxic chemicals

Golgi Bodies

- Process proteins
- Once the ribosomes on the rough ER have completed synthesizing proteins, the Golgi bodies modify, process, and sort the products
- packaging/distribution centers for materials destined to be sent out of cell
- Package final products into **vesicles**
  - Carry products to plasma membrane
- Involved in production of lysosomes

Mitochondria

- "PoWeRhOUsE oF ThE cElL"
- Responsible for converting the energy from organic molecules into useful energy for the cell
- Energy molecule in the cell is **adenosine triphosphate (ATP)**
- Unique oblong shape and characteristic double membrane consisting of an inner portion and an outer portion
- Inner membrane forms folds called **cristae**
  - Separates innermost area (called the matrix) from the intermembrane space
  - Outer membrane separates the intermembrane space from the cytoplasm
  - Production of ATP done on the cristae

Mitochondria Structural Features

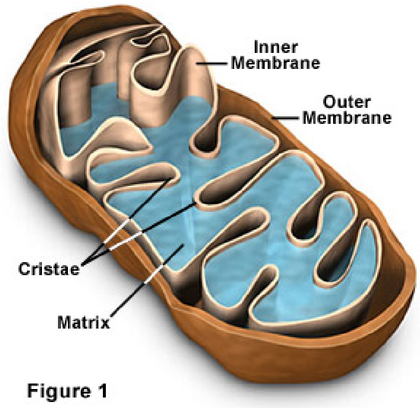


Figure 1

Lysosomes

Tiny sacs that carry digestive enzymes

Break down old/worn out organelles/debris/large ingested particles

Cells clean-up crew

Keep cytoplasm clear of unnecessary flotsam

Sometimes contain hydrolytic enzymes that function only at an acidic pH, which is enclosed inside the lumen of the lysosome

Centrioles

Small. Paired, cylindrical structured often found within **microtubule organizing centers (MTOCs)**

Most active during cellular division

When cell is ready to divide, centrioles produce microtubules, which pull the replicated chromosomes apart and move them to opposite ends of the cell

Common in animal cells but not in plants

Vacuoles

Latin for "empty cavity"

Fluid-filled sacs that store water/food/wastes/salts/pigments for later use/removal

Larger in plant cells

Peroxisomes

Breakdown of long fatty acids through beta-oxidation

Cytoskeleton

Network of fibers that maintain cell shape

Most important:

Microtubules

Made up of protein tubulin

Participate in cellular division/movement

Integral part of centrioles/cilia/flagella

Microfilaments

Important for movement

Composed of protein actin

- Actin monomers joined together and broken apart as needed to allow microfilaments to grow and shrink
- Assist during cytokinesis/muscle contraction/formation of pseudopodia extension during cell movement

Cilia and Flagella

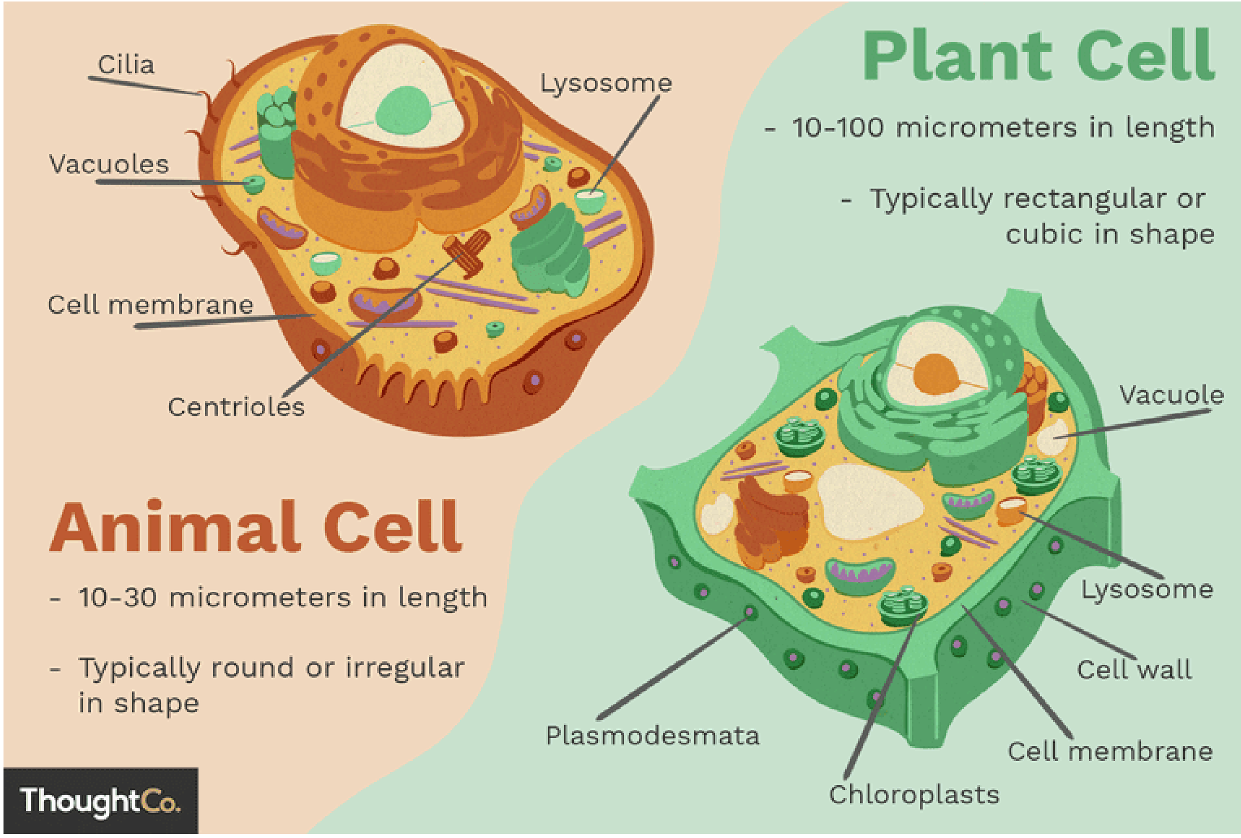
- Allow motion in single-celled organisms
- In respiratory tract, cilia sweep constantly back and forth to keep out pathogens/dust
- Every sperm cell has flagellum, enabling it to swim through the female reproductive organs to fertilize the waiting ovum

Extracellular matrix

- Molecules secreted by cell
  - Mostly glycoproteins or other carb/containing molecules, esp. collagen
- Provides structure/biochemical support

Plant Cells vs. Animal Cells

- Plant have **plasmodesmata**
  - Connections between plant cells that allow communication amongst them
- Plant cells have **cell wall**
  - Rigid layer of cellulose
  - Outside of plasma membrane
  - Provides support for cell
  - Prevents lysis
- Plant cells have **chloroplasts**
  - Contain chlorophyll, making them green
  - Involved in photosynthesis
- In plants, most of cytoplasm taken up by enlarged vacuole that crowds out other organelles
  - Contains **cell sap** in mature plants
  - Full vacuole means plant is not dehydrated
- Plants do not contain centrioles



Structural Characteristics of Different Cell Types			
Structure	**Prokaryote**	**Plant Cell**	**Animal Cell**
Cell Wall	Yes	Yes	NO
Plasma Membrane	Yes	Yes	Yes
Organelles	NO	Yes	Yes
Nucleus	NO	Yes	Yes
Centrioles	NO	NO	Yes
Ribosomes	Yes	Yes	Yes

D. Transport Across the Plasma Membrane

Ability to travel across the plasma membrane depends on (1) semipermeability of the plasma membrane and (2) the size and charge of the molecules that want o get through

Lipid-soluble substances can cross the membrane easily due to the phospholipid tails of the membrane

“Like dissolves like”

Facilitated transport

Substances must pass through a specific channel protein instead of directly through the membrane due to its hydrophilic/charge/etc.

Depends on a number of proteins that act as tunnels through the membrane
Ex.:**Aquaporins** are water specific-channels

Simple transport: Simple and facilitated diffusion

Diffusion

A substance will move down its concentration gradient

Simple Diffusion

If the diffusion molecule is hydrophobic, the nonpolar molecule can drift through the membrane unaided

Facilitated Diffusion

Diffusion of a substance requires the help of a channel protein

Called **passive transport** when that substance is moving down its concentration gradient

No energy required

At **Dynamic equilibrium**, as many molecules cross the membrane in one direction as the other

Osmosis

Process where water is diffused

Water always moves from areas where it is more concentrated to where it is less concentrate

Water moves to dilute solid particles

In both diffusion and osmosis, the final result is that the solute concentrations are the same on both sides of the membrane. The only difference is that in diffusion that membrane is usually permeable to the solute, and in osmosis it is not

Tonicity describes osmotic gradients

A **Isotonic** solution, the solute concentration is the same inside as outside

No net water movement

A **hypertonic** solution has more total dissolved solutes than the cell

Cell loses water

A **hypotonic** solution has less total dissolved solutes than the cell

Cell gains water

Cell walls help maintain water balance

A plant cell in a hypotonic solution swells until the wall opposes uptake, becoming turgid/firm; while an animal cell in a hypotonic solution will lyse/burst since their membrane are not as string

Plant cells experience lethal plasmolysis in a hypertonic environment

Plant cells become flaccid in an isotonic environment

Water potential(Ψ) is the measure of potential energy in water and describes the eagerness of water to flow from an area of high water potential to an area of low water potential

Affected by pressure potential Ψ_p and solute potential Ψ_s

Equations on AP sheet

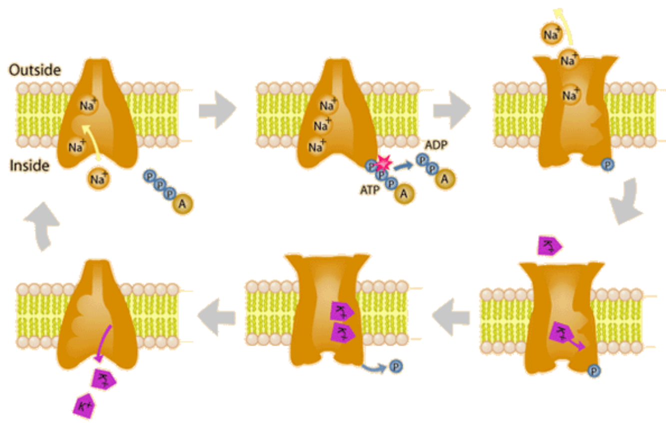
ACtive Transport

Allows a substance to move against its concentration gradient by using energy to help it along

Performed by specific proteins along membrane

Ion Pumps

- Membrane potential=voltage difference across a membrane
    - Voltage created by difference in the distribution of positive/negative ions across a membrane
- 2 combined forces (electrochemical gradient) drive diffusion of ions across a membrane
- Electrogenic pump is a protein that generates voltage across a membrane
- Ex.: **Sodium-potassium pump**
    - Pushes out 3 Na^+ and brings in two K^+
    - Depends on ATP



- Cotransport occurs when active transport of a solute indirectly drives transport of other solutes

PRimary active transport directly uses ATP to transport something

Secondary active transport occurs when a substance is moved across its concentration gradient by using the energy captured from the movement of another substance passively moving along its concentration gradient

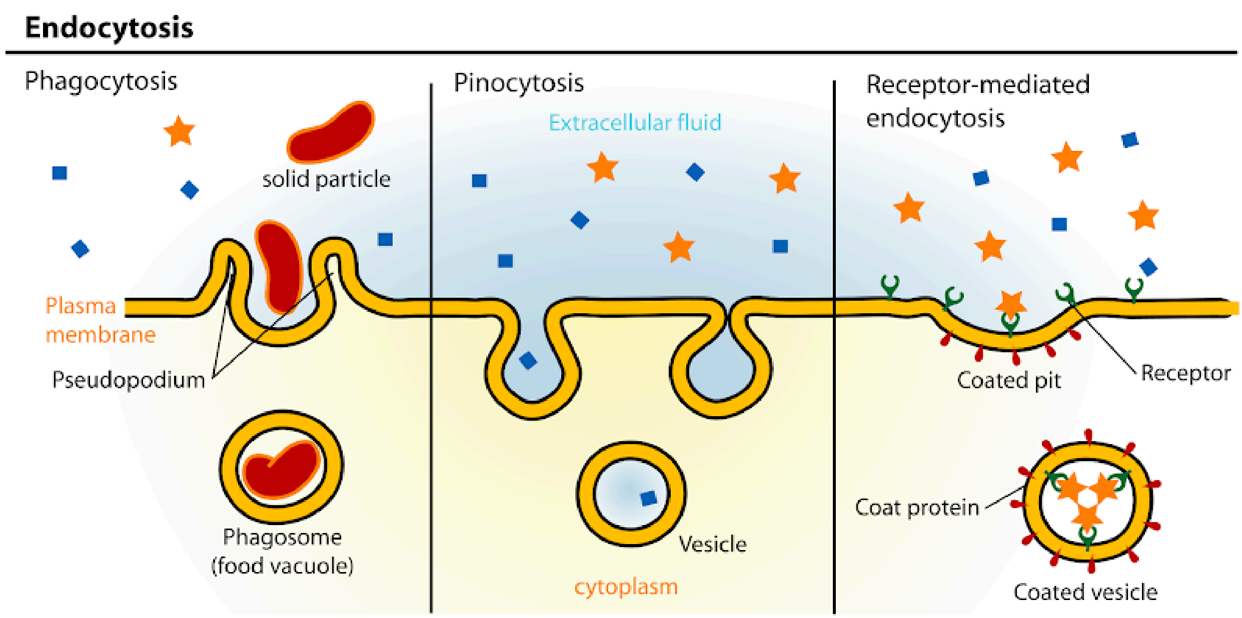
Endocytosis

- When the particles that want to enter a cell are too large to be transported by a channel protein, the cell uses a portion of the membrane to engulf that substance
    - Membrane forms a pocket, pinches in, and eventually forms a vacuole/vesicle
- 3 types
    - **Pinocytosis**
        - Ingests liquids
    - **PHagocytosis**
        - Ingests solids
    - **receptor -mediated endocytosis**

Cell surface receptors work with endocytic pits that are lined with a protein called clathrin

When a ligand binds to one of these receptors, it is brought into the cell by invagination (“folding in”) of the cell membrane

Vesicle forms around incoming ligand and carries it to cell’s interior



Exocytosis

Large particles transported out of cell ex. Waste, specific secretion products (like hormones)

`fusion of a vesicle with plasma membrane

Reverse endocytosis

Bulk Flow

One-way movement of fluids brought about by pressure

Ex. movement of blood through a blood vessel

Dialysis

Diffusion of solutes across a selectively permeable membrane

Cell Junctions

Result of cells in close contact with each other

Allow neighboring cells to form strong communication connections/nutrient flow

Fastens cells to each other

Provide contact between neighboring cells or cell and extracellular matrix

3 types

Desmosomes

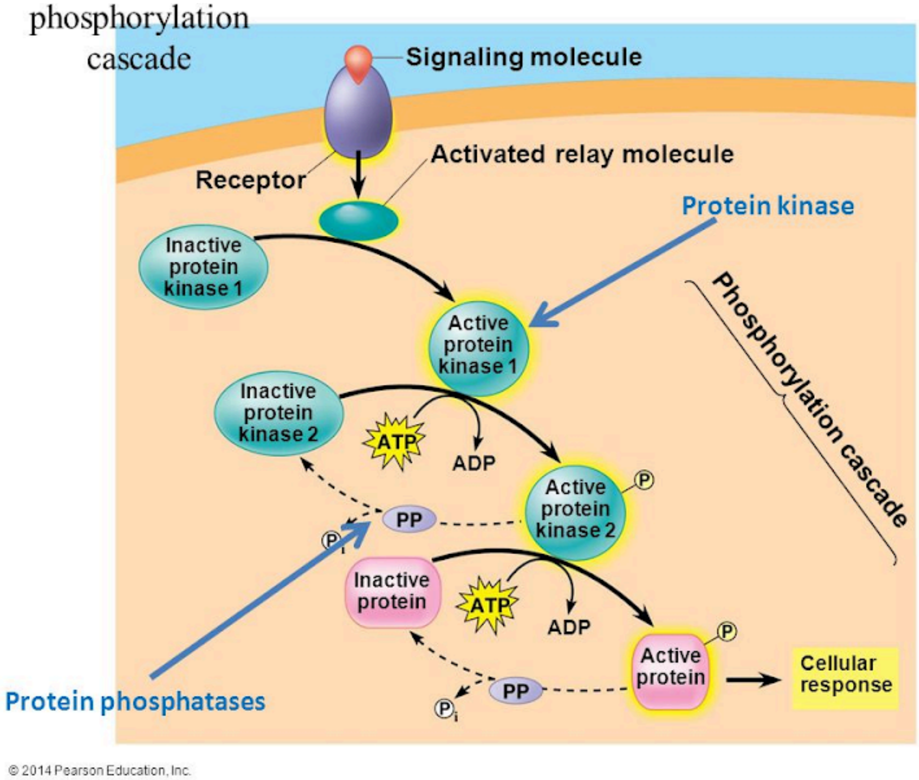
Hold adjacent animal cells tightly together

Pair of discs associated with the plasma membrane of adjacent cells+intermediate filaments within cells that are also attached to discs

Gap junctions
Protein complexes that form channels in membranes and allow communication between cytoplasm of adjacent animal cells for the transfer of small molecules/ions
Tight junctions
Tight connections between membranes of adjacent animal cells
So tight that there is no space in between cells
Seal off body cavities
Prevent leaks

Cell Communication
- Involves transduction of stimulatory/inhibitory signals from other cells/organisms/environment
- **Quorum sensing** is when unicellular organisms make their numbers known to other members of their species
- **Taxis** is the movement of an organism in response to a stimulus
  - positive=movement towards stimulus
  - negative=movement away from stimulus
  - **Chemotaxis** is movement in response to a certain chemical
    - Ex.:
      - Bacterial can control flagella rotation to avoid repellents/find food
      - Used by neutrophils to respond to an infection
- Signalling can be short range (nearby cells) or long range (throughout organism)
  - Done by cell junctions/ligands
- Cell's response to an extracellular signal sometimes called the "output signal"
- **Signal transduction** is the process by which an external signal is transmitted to the inside of a cell
  - 1. RECEPTION
    - A signalling molecule binding to a specific receptor
    - Intracellular or extracellular
    - Even the same signal can have different effects in cells with different proteins and pathways
    - Pathway branching and "cross-talk" further help the cell coordinate incoming signals
  - 2. TRANSDUCTION
    - Activation of a signal transduction pathway
    - AMPLIFICATION
      - Phosphorylation cascade
        - one enzyme (kinase) phosphorylates another, causing a chain reaction leading to the phosphorylation of thousands of proteins
        - At each step, the number of activated products is much greater than in the preceding step

phosphorylation cascade



Scaffolding proteins are large relay proteins to which other relay proteins are attached; increase signal transduction efficiency by grouping together different proteins involved in the same pathway

RESPONSE

Affect gene expression

Change enzymatic activity

Apoptosis

Programmed cell suicide

Components of cell chopped up and packaged into vesicles which are digested by scavenger cells

Mostly done by caspases (main proteases (enzymes that cut up proteins) that carry out apoptosis)

Can be triggered by extracellular ligand, DNA damage, or proteins misfolding in ER

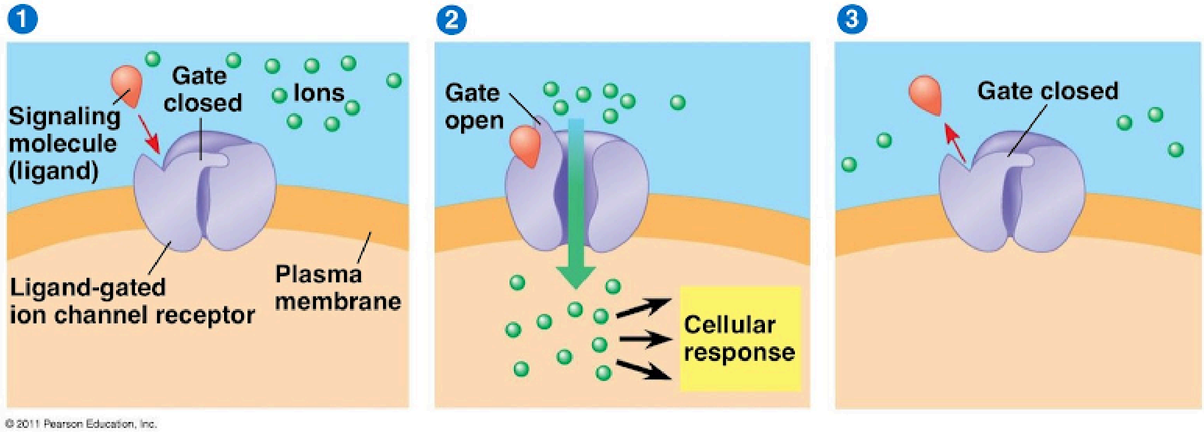
Apoptosis evolved early in animal evolution

Essential for development and maintenance if all mammals

3 classes of membrane receptors

Ligand-gated ion channels

Ion channel is opened upon binding to a specific ligand

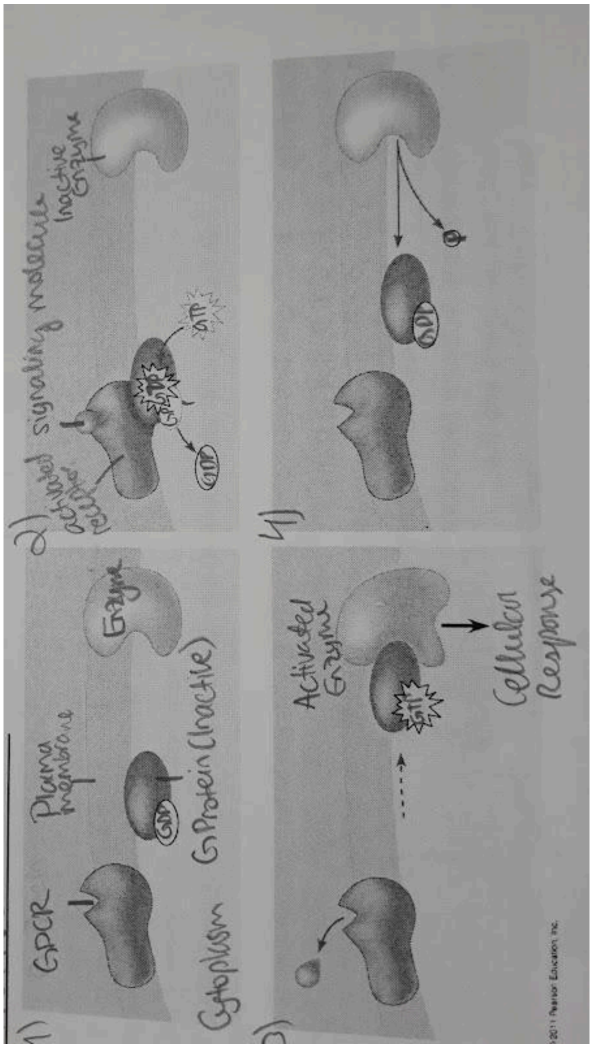


Catalytic receptors

- Aka **enzyme-linked receptors**
- Enzymatic active site on the cytoplasmic side of the membrane
- Initiated by ligand binding on the extracellular surface

G-protein coupled receptor

- Largest family of cell-surface receptors
- A GPCR is a plasma membrane receptor that works with the help of a G protein
  - G protein acts as an on/off switch
    - If GDP is bound to the G protein, the G protein is inactive
    - Signal stopped by hydrolyzing GTP

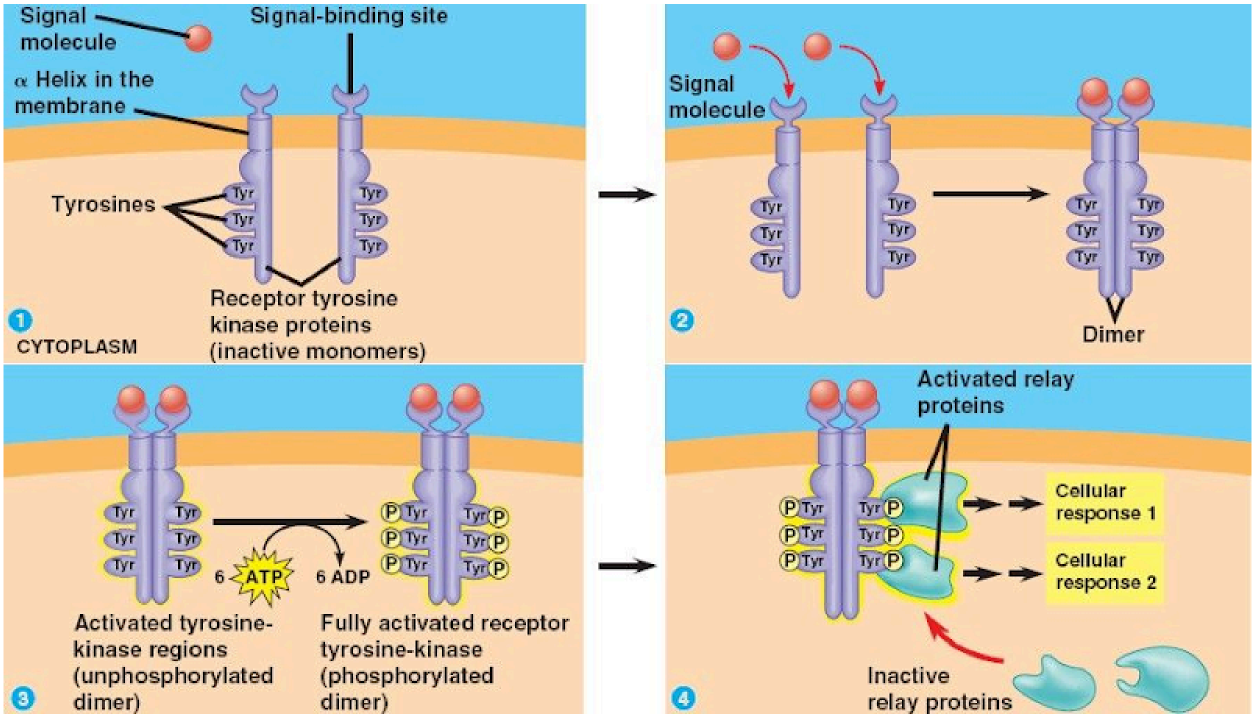


Receptor Tyrosine Kinases

Membrane receptors that attach phosphates to tyrosines

Can trigger multiple signal transduction pathways at once

Abnormal functions of RTKs associated with many types of cancer



Intracellular receptors

Small or hydrophobic messengers can readily cross the membrane and activate receptors in cytoplasm

Ex. steroid/thyroid hormones of mammals

Secondary messengers diffuse easily into cell

Can activaate a phosphorylation cascade

Can act as a transcription factor, turning on many genes

Signal transduction in eukaryotic cells usually involves many cells and complex regulation

Bacterial cells use a much simpler, 2-component regulatory system in transduction pathways

In plants

No nervous system, but can product several proteins found within them ex. Neurotransmitter receptors

Can generate electrical signals in response to environmental stimuli

Some plants can also use chemicals to communicate with nearby plants

UNIT III: CELLULAR ENERGETICS

A.Bioenergetics

Glucose, starch, and fat all energy-rich, but the bonds must be broken in order for the energy to be released

First Law of Thermodynamics: Energy cannot be created or destroyed. The sum of energy in the universe is constant.

Second Law of Thermodynamics: Energy transfer leads to less and less organization. The universe tends towards **entropy**

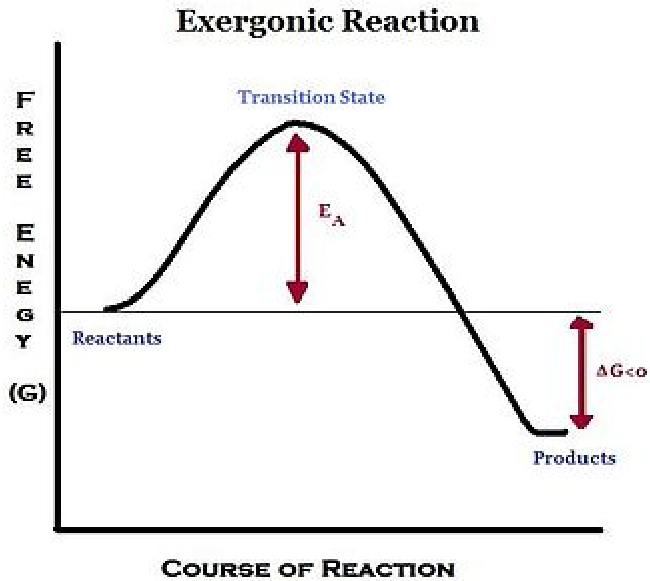
Types of Reactions

Exergonic

Products have less energy than the reactants

Energy is given off during the reaction

Ex. oxidation of molecules in mitochondria

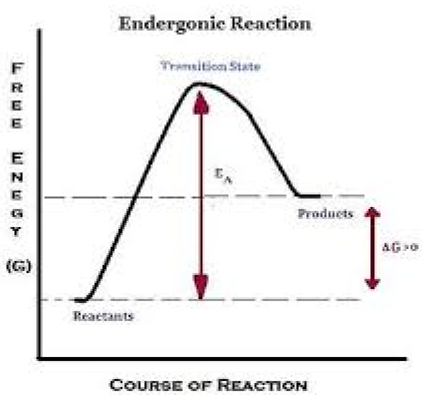


Endergonic

Require an input of energy

Products have more energy than reactants

Ex. plants' use of CO_2 and water to form sugars



<u>B. Gibbs Free Energy</u>

$\Delta G=\Delta H-T\Delta S$

T=temperature

H=**enthalpy** (measure of energy in a thermodynamic system)

S=entropy

Change in the Gibbs free energy of a reaction determines whether the reaction in favorable (spontaneous, negative) or unfavorable (nonspontaneous, positive)

Used to figure out if, without adding energy, the reactants will stay as they re or be converted to products

Spontaneous Reactions

Occur without a net addition of energy

$\Delta G<0$=exergonic

$\Delta G>0$=endergonic

Only occur if energy is added

Activation Energy

Even though exergonic reactions release energy, the reaction still needs energy to start off with

Reactants must first go into **transition state** before turning into products

Activation energy is the energy needed to achieve the transition state

Bonds must be broken before new bonds can form

C. Enzymes

Biological catalysts that speed up reactions

Accomplished by lowering activation energy and helping transition state form

Lowers activation energy by:

Orienting substrate correctly

Straining substrate bonds

Providing favorable microenvironment

Bonding to substrate

Do NOT change the energy of the starting point or the ending point of the reaction. Only lower activation energy

Enzyme Specificity

Each enzyme catalyzes only one kind of reactions

Enzyme are usually named after the molecules they target

Replace suffix of substrate with -*ase*

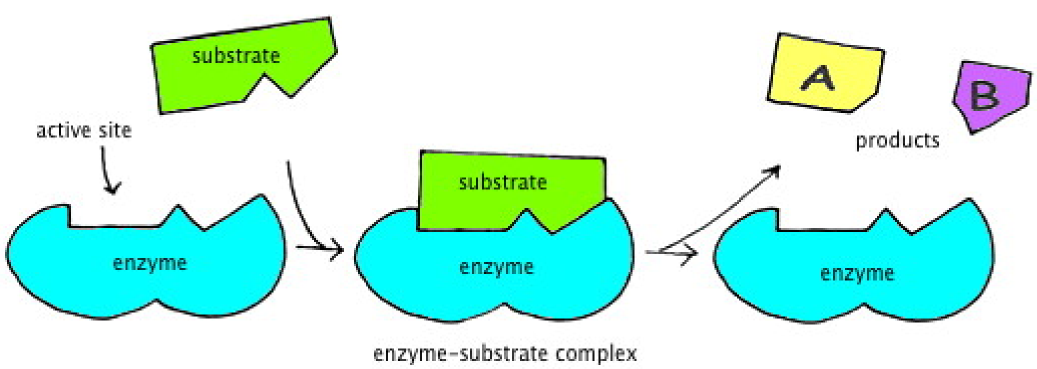
Ex. maltose catalyzed by maltase

Substrates are the targeted molecules (reactant)

Enzyme-Substrate Complex

Enzyme brings about transition state by helping the substrate(s) get into position

Accomplished through **active site**



Once the reaction has occurred, the enzyme is released from the complex and restored to its original state

Now the enzyme is free react with other substrates again

Induced fit

Enzyme slightly changes shape to accommodate the shape of substrates

Sometimes certain factors are necessary for this process

Cofactors sometimes aid induced fit and also help catalyze reactions

Nonprotein helpers of enzymes

Ex. vitamins

Factors affecting reaction rates

Temperature

Although the rate of reaction increases with temperature, it only does so up to a point, because too much heat can denature an enzyme

Q_{10}

Measure of sensitivity of a physiological process of enzymatic reaction rate

$$Q_{10} = \left(\frac{R_2}{R_1}\right)^{\left(\frac{10}{T_2 - T_1}\right)}$$

Temp must be celsius or kelvin

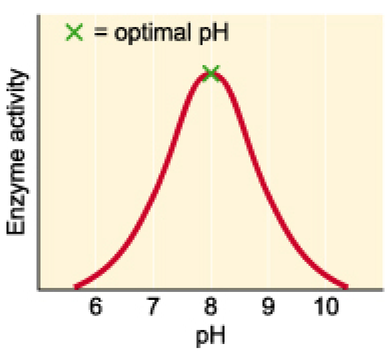
Same unit for T_1 and T_2

Two reaction rates (k_1 and k_2) must have same unit

Reaction rates with $Q_{10}=1$ are temperature independent

pH

Most enzyme's ideal pH is 7



Enzyme Regulation

Cell can control enzymatic reactions by regulating the conditions that change the shape of the enzyme

Can be turned off/on by things that bind to them

Some bind at active site

Some bin at **allosteric sites** (non-active sites)

Competitive inhibition

If a substance has the exact complementary shape to the active site, it can compete with the substrate and block it from getting into the active site

If there is enough substrate available, it will out-compete the inhibitor and the reaction will occur

As substrate is used up, inhibitor out-competes the substrate and less reaction will occur

Allosteric inhibitors/Non Competitive inhibition

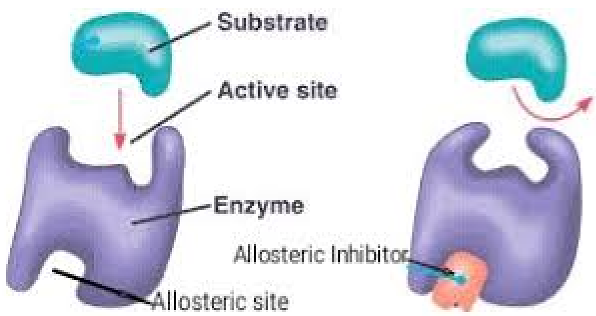
Binds to an allosteric site

Distorts shape of enzyme so it cannot function until the inhibitor is removed

Substrate can still bind if active site is intact, but the enzyme will not be able to catalyze the reaction

Activators can also be used to stabilize the enzyme's active state

Inhibitors stabilize the inactive state



Enzymes can also be controlled by negative feedback mechanisms

Product of reaction the enzyme is helping is also an allosteric inhibitor

Prevents a cell from wasting resources by synthesizing more of a product than is needed

D. Reaction Coupling

ATP consists of a molecule of adenosine bonded to 3 phosphates

Carries enormous amount of energy within phosphate bonds

When a cell needs energy, it splits off the 3rd phosphate, forming adenosine diphosphate (ADP) and one loose phosphate (P_i) in the process

$ATP \rightarrow ADP + P_i + \text{energy}$

ATP is relatively neat and easy to form

Sources

Cellular respiration

Sugar turned into ATP

In plants, sugar is made by **photosynthesis**

In animals, sugar is taken from food consumed

E. Photosynthesis

$6CO_2 + H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Chloroplast structure

Stroma=inner fluid-filled region

grana=structures inside stroma that look like stacks of coins

thylakoids=”coins” of grana

Contain chlorophyll, a light-absorbing pigment that drives photosynthesis

Chlorophyll *a*

Chlorophyll *b*

Carotenoids

Pigments gather light, but are not able to excite electrons, only one molecule in the **reaction center** can

Contains enzymes involved in photosynthesis

2 reaction centers:

Photosystem I (PS I)

p700

Photosystem II (PS II)

P680

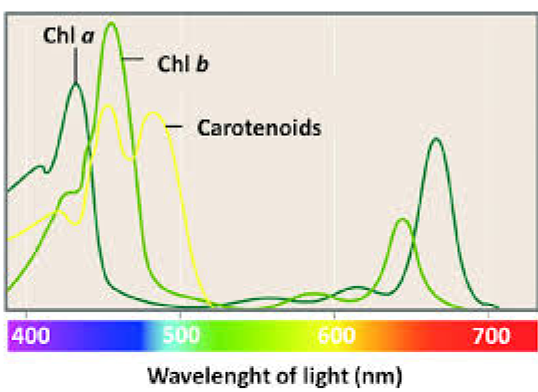
Both comprised of a Light harvesting complex, where a photon of light is passed like a wave between pigments and a Reaction center complex, which contains chlorophyll-a and uses light energy to “boost” and electrons and pass onto primary electron acceptor

Absorption spectrum measures how well a certain pigment absorbs electromagnetic radiation

Opposite of emission spectrum

Chlorophyll *a* and *b* absorb blue and red light but reflect green (reason why plants are usually green)

Carotenoids absorb light at blue-green end, and reflect red light



Light reactions

When a leaf captures sunlight, the energy is sent to p680 of photosystem II

Sidenote: it may seem weird that the light reaction starts off in PSII and not PS I but its only called PS I because it was discovered first

Activated electrons trapped by p680 and passed down to molecule called the primary acceptor, and then they are passed down to carriers in the electron transport chain

Photolysis

To replenish electrons in the thylakoid, water is split into O^-, $2H^+$, and electrons

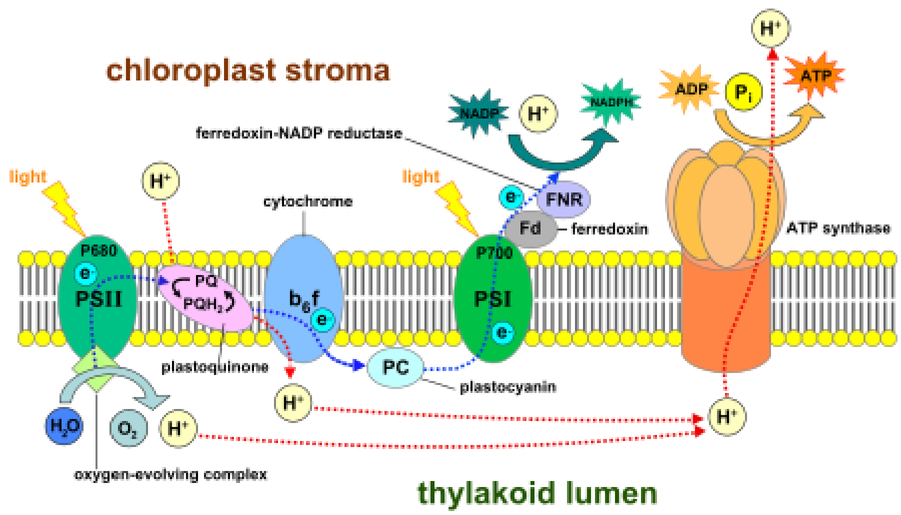
Water is split again into hydrogen ions (used for ETC) and Oxygen (released)

As the energized electrons from PSII travel down the ETC, they pump H^+ into the thylakoid lumen

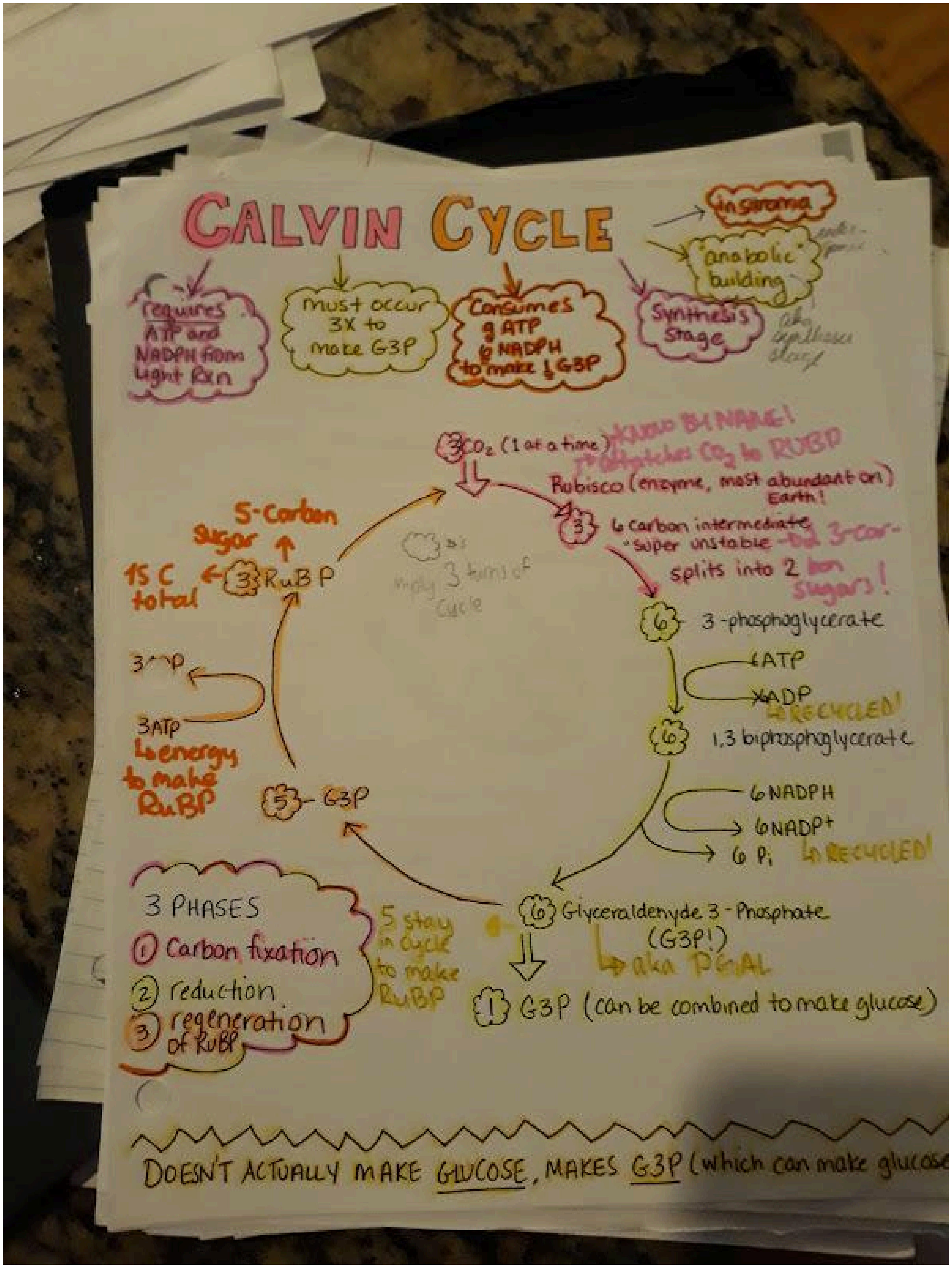
Proton gradient is created

As hydrogen ions move back into the stroma through ATP synthase along their concentration gradient, ATP is created

After the electrons leave PS II, they enter PSI, where they are passed through a second ETC until they reach the final electron acceptor $NADP^+$ to make NADPH



Dark cycle on sketch notes below



F. Cellular Respiration

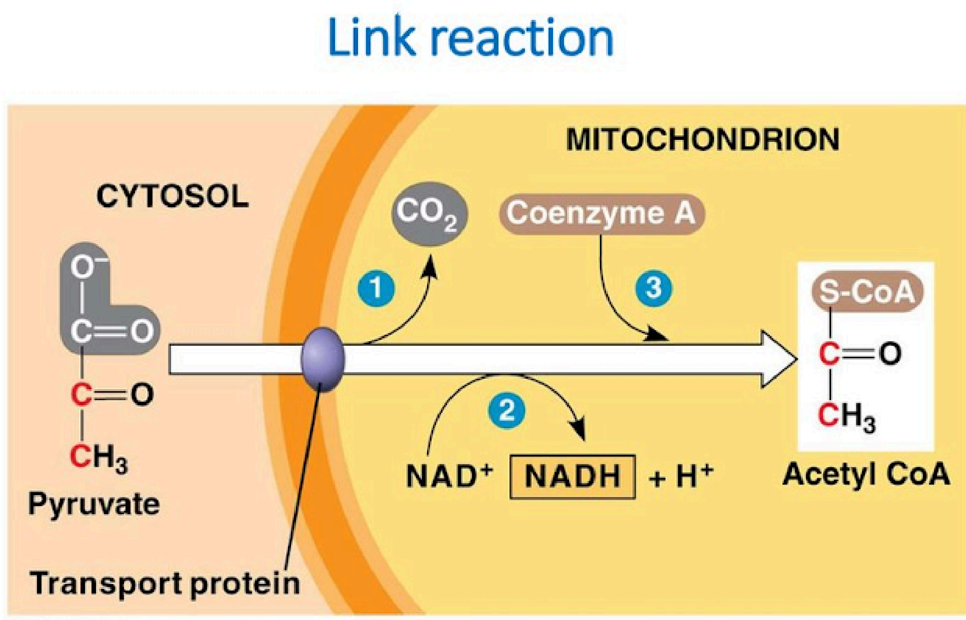
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

Aerobic respiration: ATP made in the presence of oxygen
Anaerobic respiration: ATP made without presence of oxygen
1. GLYCOLYSIS

  Glucose is split
  Glucose 6-carbon; when it is split it makes 2 3-carbon pyruvates
  Creates 2 ATP (net)
  NADH created from the transfer of electrons to NAD^+
  Occurs in cytoplasm
  Glucose + 2 ATP + 2 NADh ⟶ 2 Pyruvate + 4 ATP + 2ND

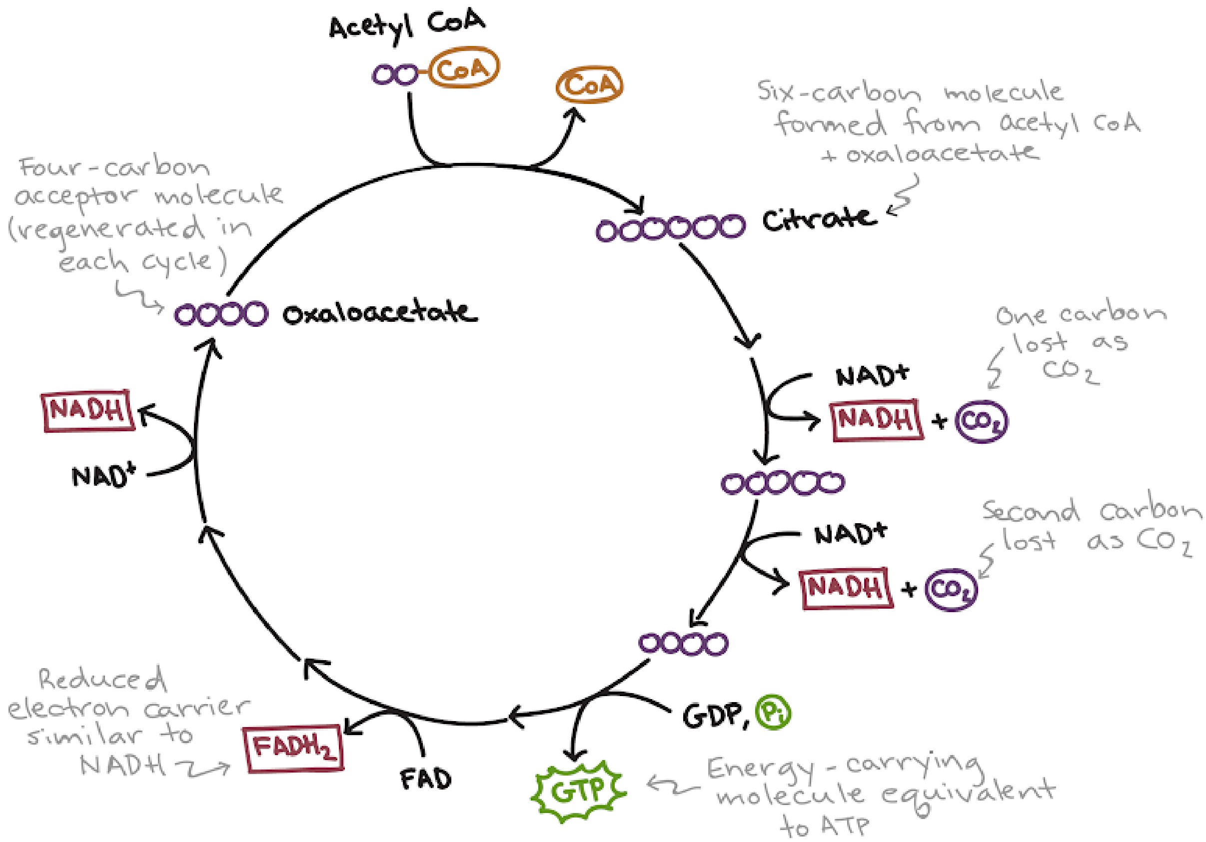
2. FORMATION OF ACETYL CoA

  2Pyruvate + 2 Coenzyme A + 2 NAD^+ ⟶ 2 Acetyl-CoA + $2CO^2$ + 2 NADH
  Extra carbons leave cell as CO_2



3. CITRIC ACID CYCLE

  Aka Krebs cycle
  Each acetyl coa will enter Krebs cycle on at a time, and all carbons will be turned into CO_2 eventually
  Acetyl CoA combines with oxaloacetate (4-carbon) to create citric acid
  Active transport into mitochondria via cotransport with oxygen
  citric eventually gets turned back into oxaloacetate



3 types of energy produced:

1ATP

3 NADH

1 $FADH_2$

Atthis point there are 4 ATP, 10 NADH, and 2 $FADH_2$ total

4. OXIDATIVE PHOSPHORYLATION

As electrons are removed from a molecule of glucose, they carry with them as much of the energy that was originally stored within their bonds

These electrons are then transferred to readied carrier molecules--NADH and $FADH_2$

Electron carriers shuttle electrons down to **electron transport chain**, and the resulting NAD^+ and FADH can be recycled to be used again

Hydrogen atoms are split

$$H_2 \longrightarrow 2H^+ + 2e^-$$

High-energy electrons are passed down a series of protein carrier molecules that are embedded in the cristae

Some proteins include NADH dehydrogenase and cytochrome C

The electrons travel down the electron transport chain until they reach the final acceptor, oxygen

Oxygen pulls the electrons through the chain due to its electronegativity and then combines with them and hydrogen to create water

Allows For a gradual release of energy rather than a sudden, explosive one

Chemiosmosis

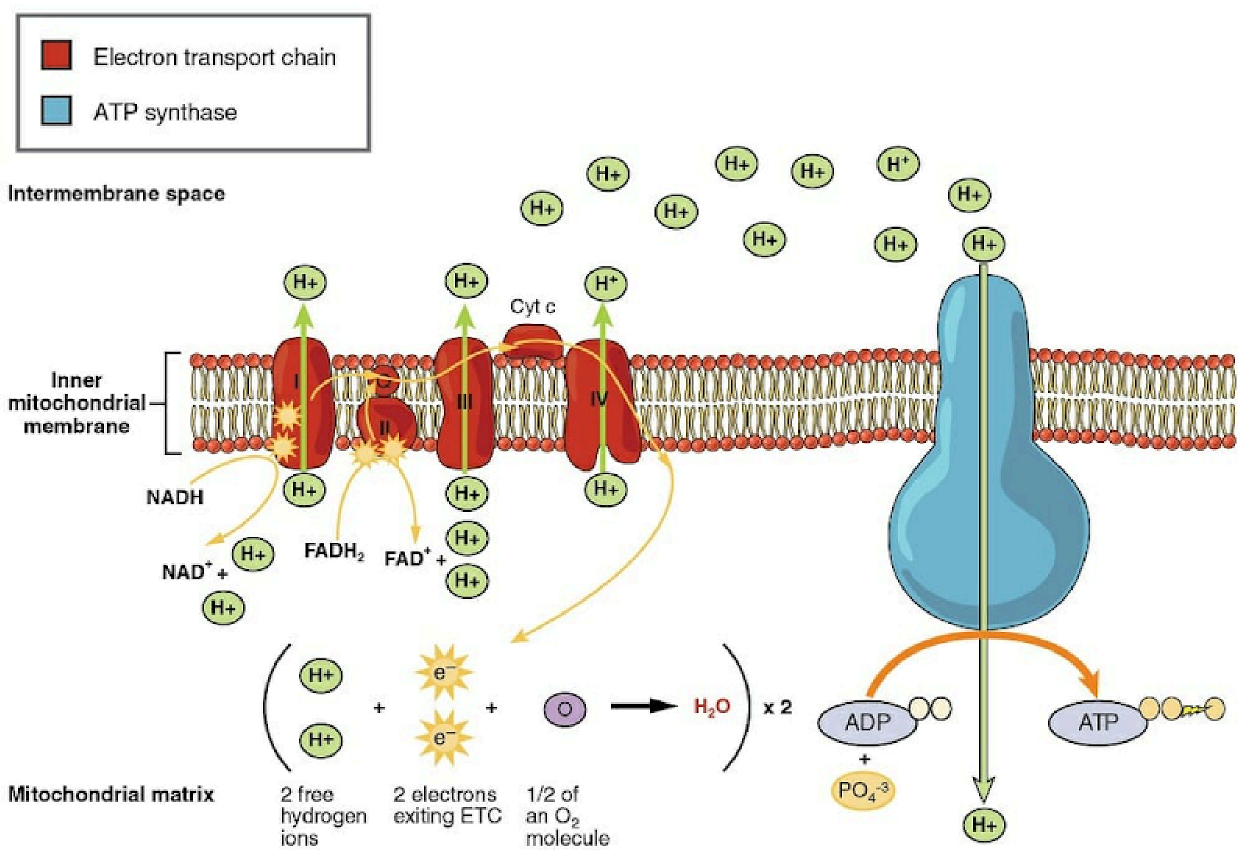
The energy released from the ETC is used to pump hydrogen ions across the inner mitochondrial membrane from the matrix into the intermembrane space

Creates **pH/proton gradient**

Potential energy created from gradient is responsible for the production of ATP

Flow back in through ATP synthase and this movement provides the energy necessary to produce ATP

$ADP + P_i \longrightarrow ATP$

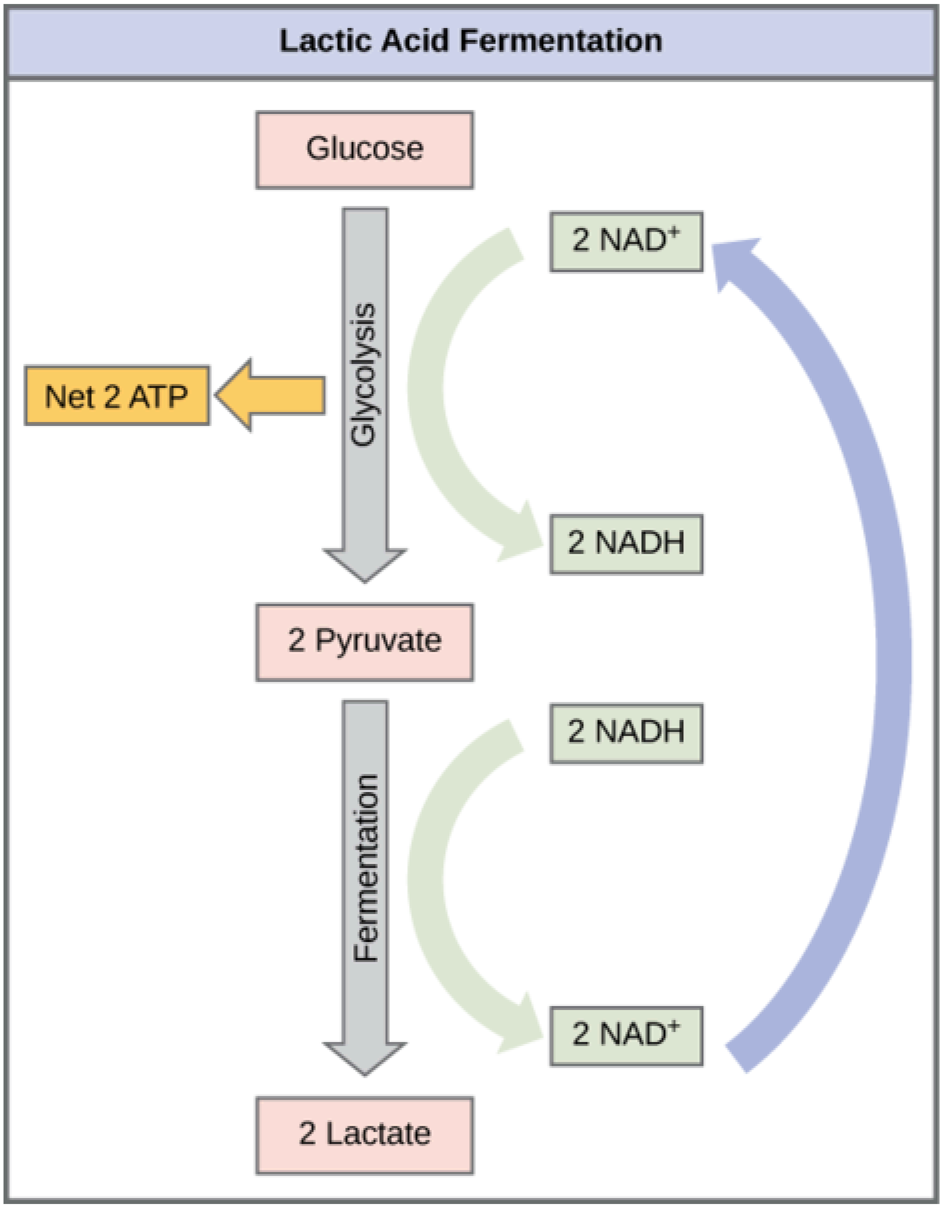


Stages of Aerobic Respiration				
Process	Location	Main Input	Main Output	Energy Output per glucose

Glycolysis	Cytoplasm	1 Glucose	2 pyruvates	2 ATP 2 NADH
Formation of Acetyl-CoA	As pyruvate is transported into the mitochondria	2 pyruvates 2 coenzyme A	2 Acetyl-CoA	2 NADH
Citric Acid Cycle	Matrix of mitochondria	2 Acetyl-CoA oxaloacetate	oxaloacetate	6 NADH 2 $FADH_2$ 2 ATP
Oxidative Phosphorylation	Inner mitochondrial membrane	10 NADH 2 $FADH_2$ 2 O_2	Oxygen 2 NADH (x1.5) 8 NADH (x2.5) 2 $FADH_2$ (x1.5)	3 ATP 20 ATP 3 ATP
				Overall Net: 20 ATP

G. Fermentation

- In anaerobic environments, cellular respiration doesn't work
  - No ETC, so electron carriers are useless
  - No Acetyl CoA or Citric Acid cycle
  - Only glycolysis can occur
- Glycolysis produces 2 pyruvate and 2 NADH
  - In order to recycle NADH, pyruvate takes its electrons, creating lactic acid in muscles or ethanol in yeast
    - Both products are unfortunately toxic
  - ATTP created through substrate-level phosphorylation
- Common in bacteria
  - In some, an ETC may exist, but SO_4 is the electron acceptor instead of o_2, creating H_2SO_4 as a byproduct



UNIT IV: MOLECULAR BIOLOGY

A.Molecular Structure of DNA

- Made up of repeated units of **nucleotides**
  - Each nucleotide has:
    - 5-carbon sugar
      - Pentagon shaped
      - Called deoxyribose
      - Linked to phosphate and nitrogenous base
    - Phosphate
    - Nitrogenous base
      - Adenine
        - Purine (double-ringed)
      - Guanine

Purine

Cytosine

Pyrimidine (single-ringed)

Thymine

Pyrimidine

Purines always pair up with pyrimidines to keep DNA width consistent

Nucleotides linked together by **phosphodiester bonds** that make up the sugar-phosphate backbone

Double helix structure discovered by scientists **Watson, Crick, and FRanklin**

Nobel prize earned for discovery

Franklin used X-Ray crystallography in its discovery

Base pairing (*Chargaff's Rules*)

Each base can only bond with a specific complementary base

A-T

C-G

Specific rations of each nucleotides in the same species

Complementary strands

Strands are antiparallel

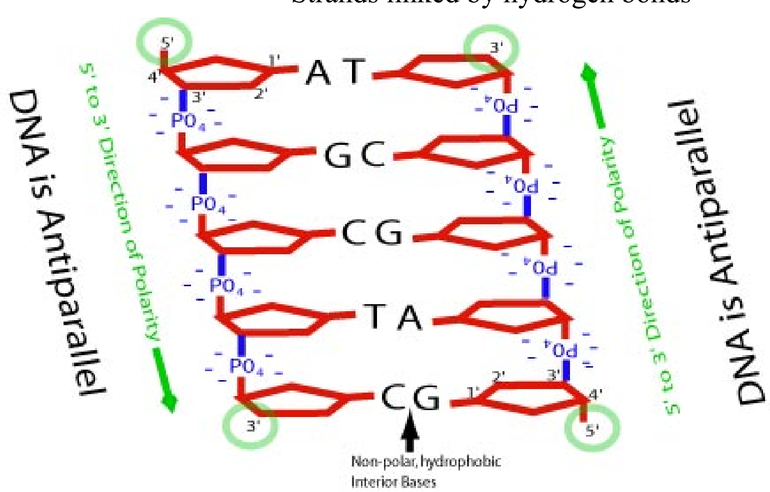
Run in opposite directions

5' and 3' end named after carbons that end them

5' has phosphate group

3' has hydroxyl group

Strands linked by hydrogen bonds



B. GEnome Structure

Genetic code is the sequence of the base pairs

Gene codes for a specific protein

Prokaryotes: single DNA molecule

Eukaryotes: multiple DNA molecules

An species entire DNA sequence is its **genome**

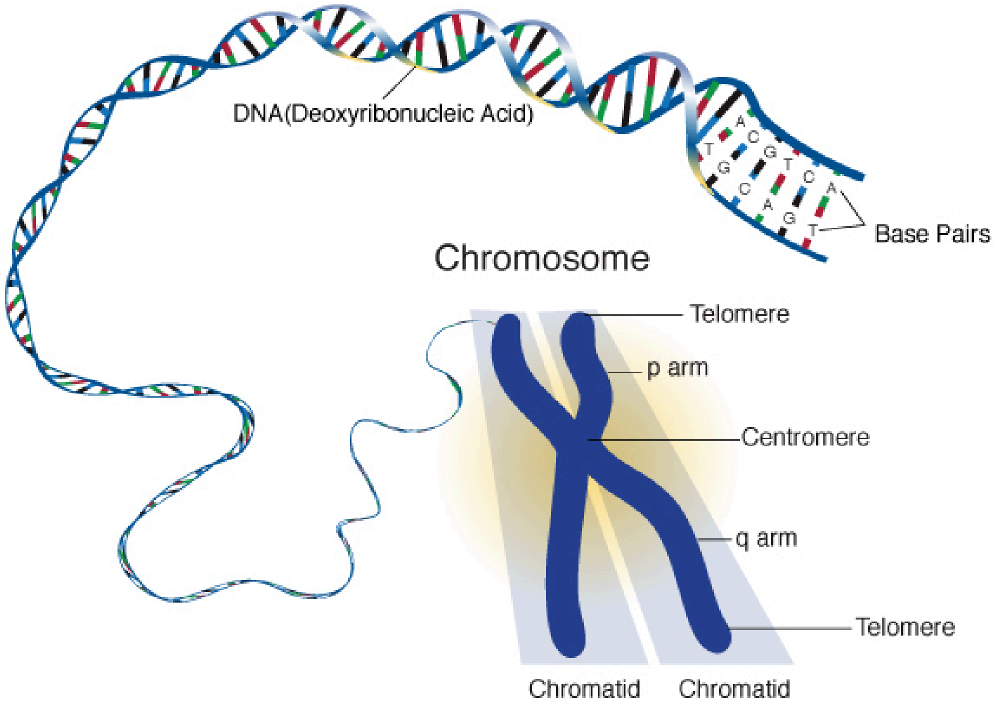
Chromosome is each separate chunk of DNA

Prokaryotes have one circular chromosome, and eukaryotes have linear chromosomes chromosomes wrapped around proteins called histones, and histones are bunched in groups called a **nucleosome**

How Tightly DNA is packaged depend on the section of DNA and what is going on in the cell at the time

Euchromatin is extremely loose genetic material

Heterochromatic is extremely tight genetic material with inactive genes



C. DNA Replication

First step is to unwind the double helix by breaking the hydrogen bonds

Accomplished by an enzyme **helicase**

Single stranded Binding PRotein hold the strands apart

Origin of replication=place where replication process begins; short stretch of DNA with specific nucleotide sequence

Exposed DNA now forms a *y*-shaped **replication fork**

DNA replication begins at specific sites called **origins of replication**

Topoisomerase cuts and rejoins the helix to prevent tangling and relieve tension

DNA polymerase III adds nucleotides to freshly built strand

Can only add nucleotides to the 3' end

RNA primase adds a short strand of RNA nucleotides called an **RNA primer**

Primase synthesizes RNA primer

After replication, the **DNA Polymerase I** removes the RNA primer and replaces it with DNA

Leading strand

Synthesized continuously

5' to 3'

Replicated towards fork

Lagging strand

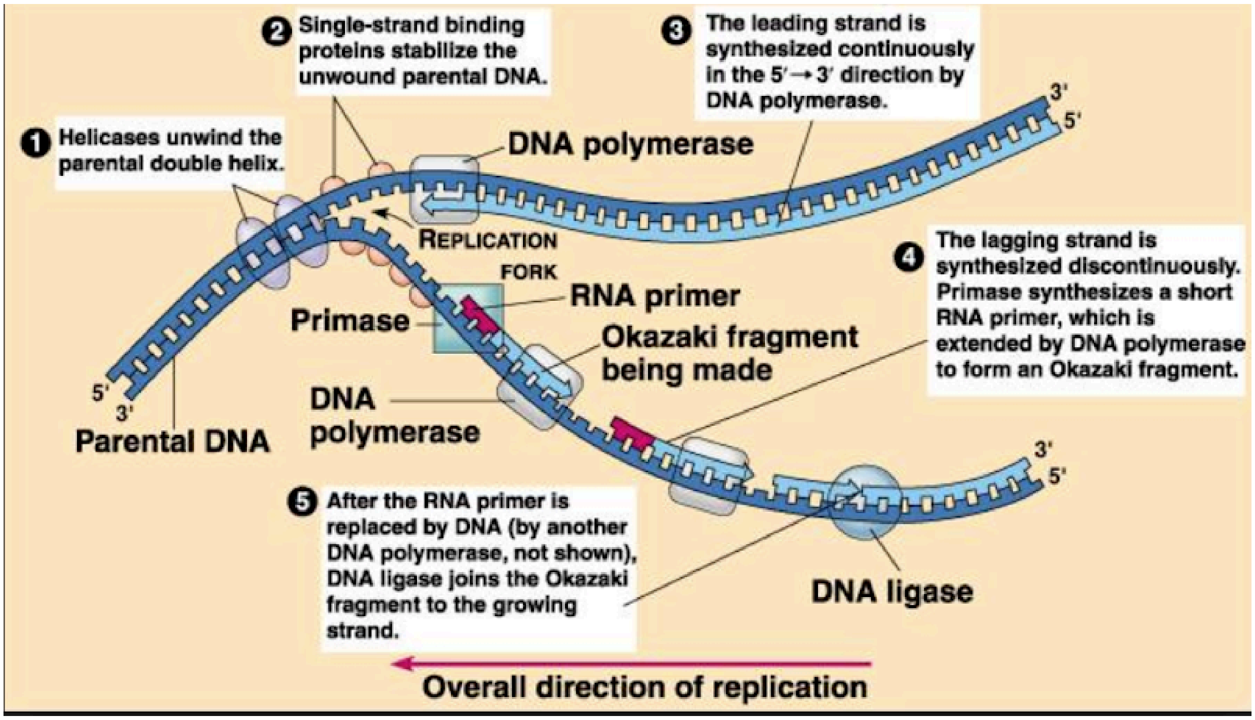
Made in pieces called **Okazaki fragments**

3' to 5'

Replicated Away from fork

Must be made in pieces since nucleotides can only added to 3' end

Fragments linked together by **DNA ligase** to produce a continuous strand



DNA proofreading and repair

DNA polymerase in charge of repair synthesis

Nuclease removes damage

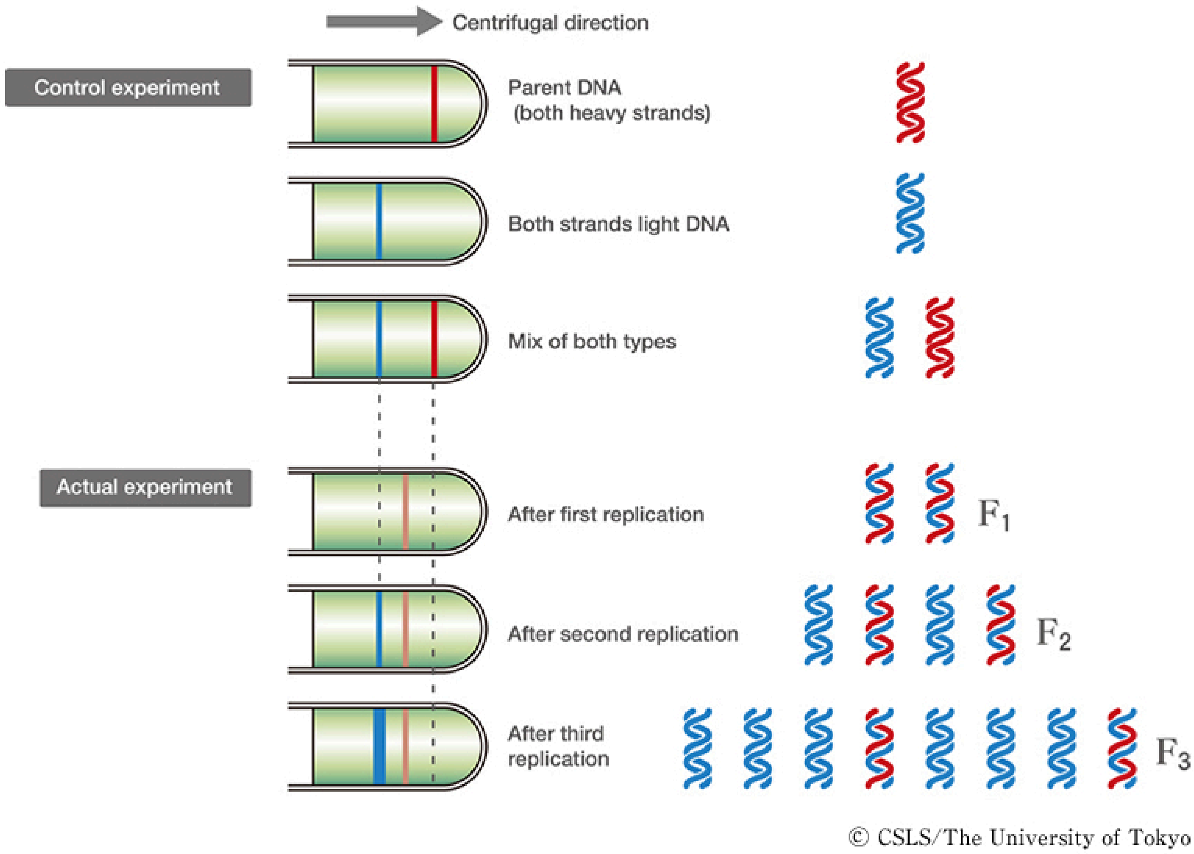
Ligase seals newly repaired strands

Repair enzymes detect damage

Replicates **semiconservatively** because each new molecule is comprised of ½ of the original strand

Semiconservative model proved by Meselson and Stahl's experiments

Created "heavy" template DNA using N15, measured weights of replicated DNA by looking at the layers that formed, semiconservative model was the only one that fit



A few bases at very end cannot be replicated because the DNA polymerase needs to bind

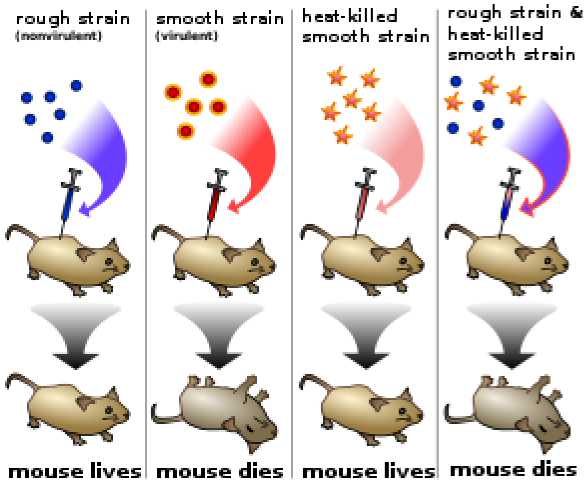
Every time replication occurs the chromosome loses a few base pairs

Genome has compensated for this over time by putting bits of unimportant/less important DNA at the ends of a molecules called **telomeres**

Key history

Protein originally thought to be the carrier of genetic material due to its higher variety and specific functions

Griffiths want to find out what substance causes transformation



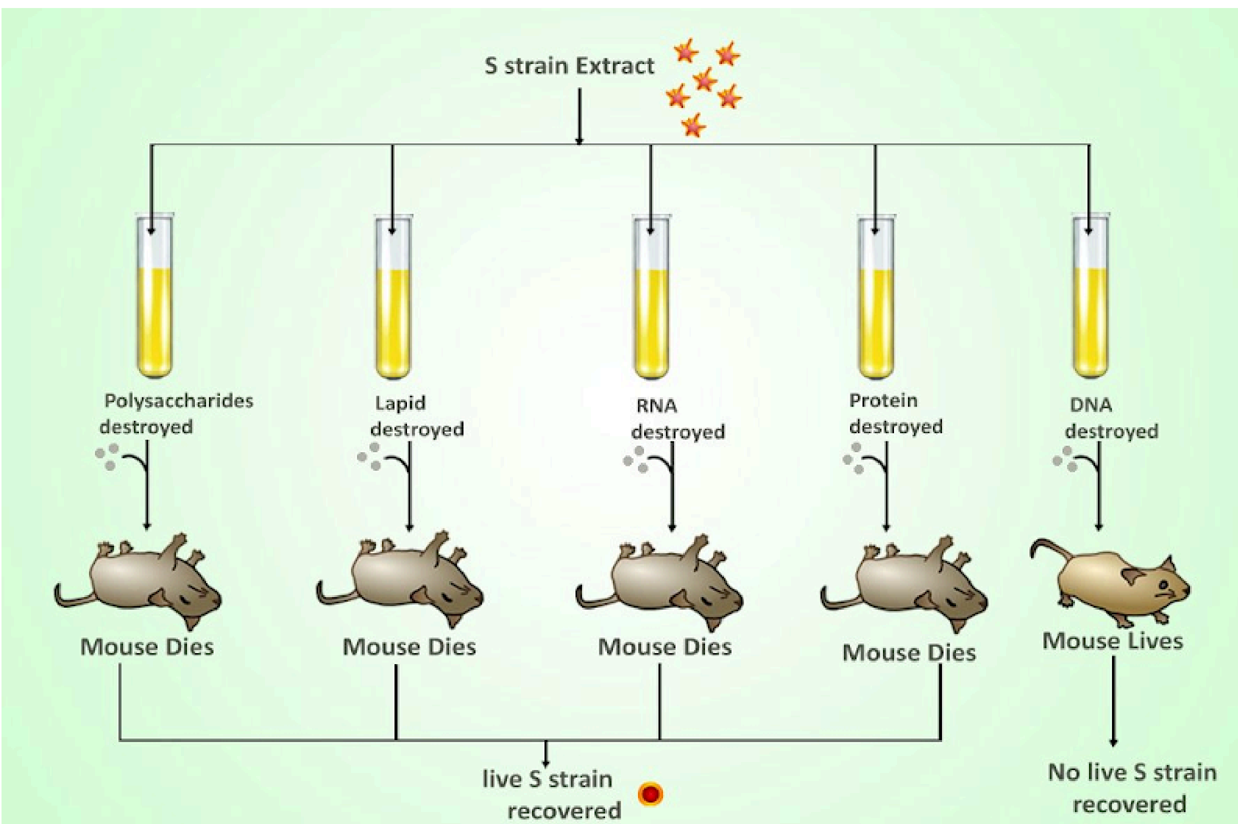
R bacteria had been transformed into pathogenic S bacteria by unknown substance

Avery, MacLeod, and McCarty isolated various cellular components from a dead virulent strain of bacteria

Followed up on a previous experiment by Griffiths and added each of these cellular components to a strain of living non-virulent bacteria

Only the component of the deadly bacteria was able to change the second bacteria into a deadly strain capable of reproducing

DNA must be responsible for passing traits and it is inheritable



Hershey-CHase

Used bacteriophages and labelled protein parts of some with radiolabeled sulfur and labelled the DNA parts of other viruses with radiolabeled phosphorus

Bacteriophages inject genetic material into cell so more genetic material will be created

When viruses infected bacteria, only the labelled DNA was inside, but they were still able to replicate and make progeny viruses

E. coli were infected by the phage, and there was more and more P that entered. They concluded that DNA carried the genetic information to produce DNA and proteins

Central Dogma

DNA's main role is directing the manufacture of molecules that actually do the work in the body

DNA expression:

1. Turn into RNA
2. Send RNA out into the cell and often gets turned into a protein

Transcription turns RNA into DNA

Takes place in nucleus (except in prokaryotes)

Translation turns RNA into a protein

Takes place in cytoplasm

RNA

Single stranded

5-carbon sugar is ribose instead of deoxyribose

Uses **uracil** instead of thymine

major types of RNA

Messenger RNA (mRNA)

Temporary version of DNA that gets sent to ribosome

Ribosomal RNA (rRNA)

Produced in nucleolus

Makes up part of ribosomes

Transfer RNA (tRNA)

Shuttles Amino acids to the ribosomes

Responsible for bringing the appropriate amino acids into place at the appropriate time

Done by reading message carried by mRNA

Interfering RNA (RNAi)

Small snippets of RNA that are naturally made in the body or intentionally created by humans

siRNA and miRNA can bind to specific sequences of RNA and mark them for destruction

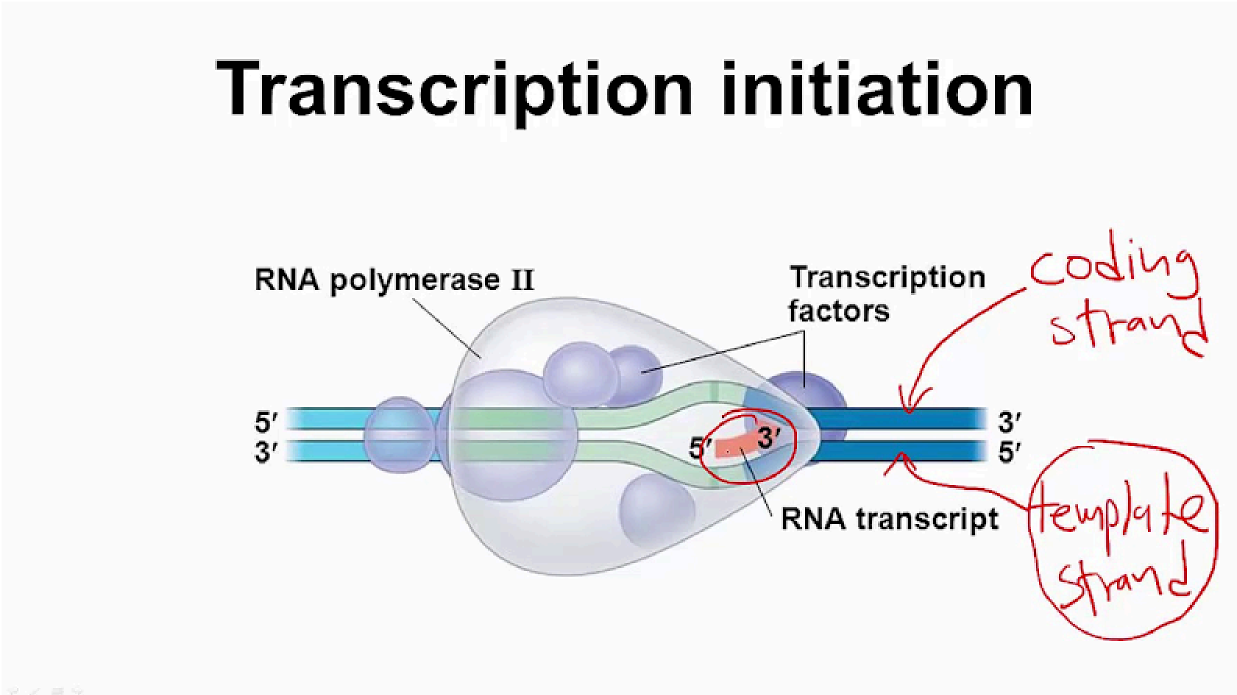
Transcription

RNA copy of DNA code

pre-mRNA synthesis

Only a specific section is copied into mRNA

- Occurs as-needed on a gene-by-gene basis
- Exception: prokaryotes will transcribe a recipe that can be used to make several proteins
    - Called **polycistronic** transcript
    - Eukaryotes tend to have one gene that gets transcribed to one mRNA and translated into one protein
        - **Monocistronic** transcript
- 3 steps: initiation, elongation, termination
    - initiation
        - Unwind and unzip DNA strands using helicase
        - **Transcription initiation complex**
            - Transcription factor proteins+RNA polymerase
            - Forms at promoter
        - Transcription only occurs as-needed to conserve resources
    - ELongation
        - Begins at special sequences of the DNA strand called **promoters**
        - Free RNA nucleotides inside the nucleus used to create mRNA
            - RNA polymerase used to construct mRNA
        - Strand that serves as the template is called **antisense strand, the non-coding strand, or the template strand**
        - Strand that lies dormant is the **sense strand, or the coding strand**
        - Rna polymerase build RNA only to 3’ side
            - Doesn’t need primer
        - Promoter region is “upstream” of the actual coding part of the gene
        - Official starting point if **start site**
        - RNA strand is complementary to template DNA strand
    - TErmination
        - Once termination sequence is reached, it separates from the DNA template, completing the process of transcription



RNA processing

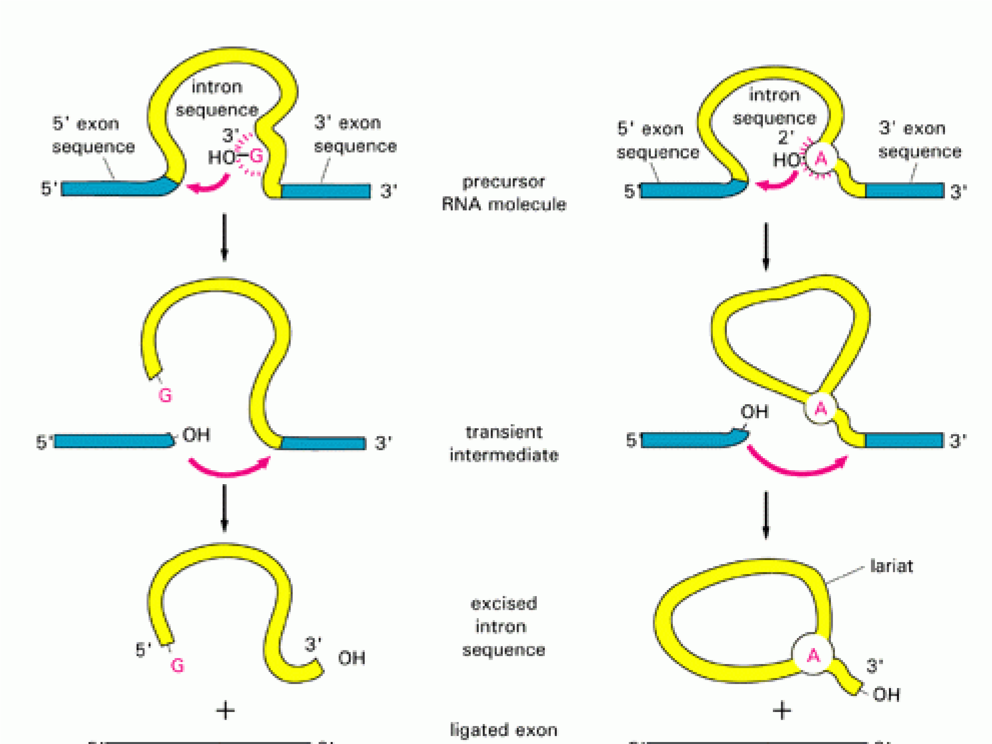
In eukaryotes the RNA must be processed before it can leave the nucleus

Freshly transcribed RNA is called hnRNA (heterogenous nuclear RNA) and it contains both coding regions and noncoding regions

Regions that express the code will be turned into protein are **exons**

Non-coding regions in the mRNA are **introns**

- Introns removed by **spliceosome**
  - Spliceosome made up of many snRNPs
    - snRNPs made up of ribozyme+small nuclear RNA
      - ribozyme=RNA catalyst that can copy RNA strands
  - Spliceosome identifies ends of an intron
  - Folds chromosome
  - Spliceosome cuts out the intron and binds the two exons together
  - Non i prokaryotic cells



3 properties of RNA that allow it to function as an enzyme

Single stranded

Functional groups that act as catalysts

Hydrogen bonds with other nucleic acids

Introns allow more genetic diversity

More possibilities for crossover

Alternate splicing can yield new protein varieties

Methyl cap added to 5' end

Helps mRNA leave nucleus

Allows attachment to ribosome

Modified guanine

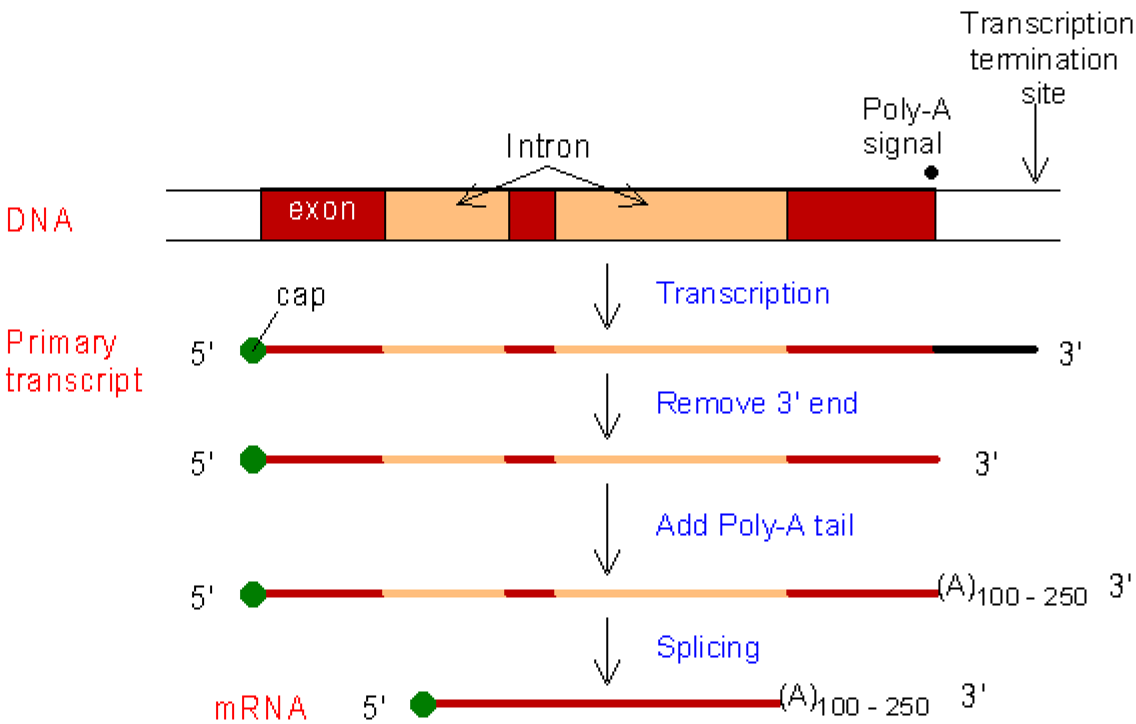
poly-A tail added to 3' end

Protects mRNA from endonucleases in cytoplasm, which can only attach to 3' end

50-250 adenine

No cap or tail in prokaryotic cells since they have no nucleus

mRNA leaves nucleus through nuclear pore



TRanslation

- Process of turning mRNA into a protein
- mRNA nucleotides will be read in the ribosome in groups of three
    - Group of three nucleotides=**codon**
        - Each codon corresponds to a particular amino acid
- mRNA attaches to the ribosomes to initiate translation and "waits" for the amino acids to come to the ribosome
- 3 sites on ribosome
    - E=exit site
    - P=polypeptide storage/exit
    - A= place where tRNA brings in amino acid
- 1.mRNA attaches to mRNA binding site on small subunit. tRNA attaches onto A site
- 2. Large subunit attaches via GTP
    - 1st tRNA is in P site
    - 2nd tRNA comes in A site
- 3. rRNA in large subunit catalyzes a peptide bond between amino acids
- 4. 1st rRNA moves to exit site
    - 2nd tRNA moves to P site
    - New tRNA comes in through A site
    - Steps 1-4 repeats until stop codon is reached
    - As mRNA moves through ribosome, other ribosomes can attach to it at the same time (as long as mRNA has not degraded, especially on 5'cap

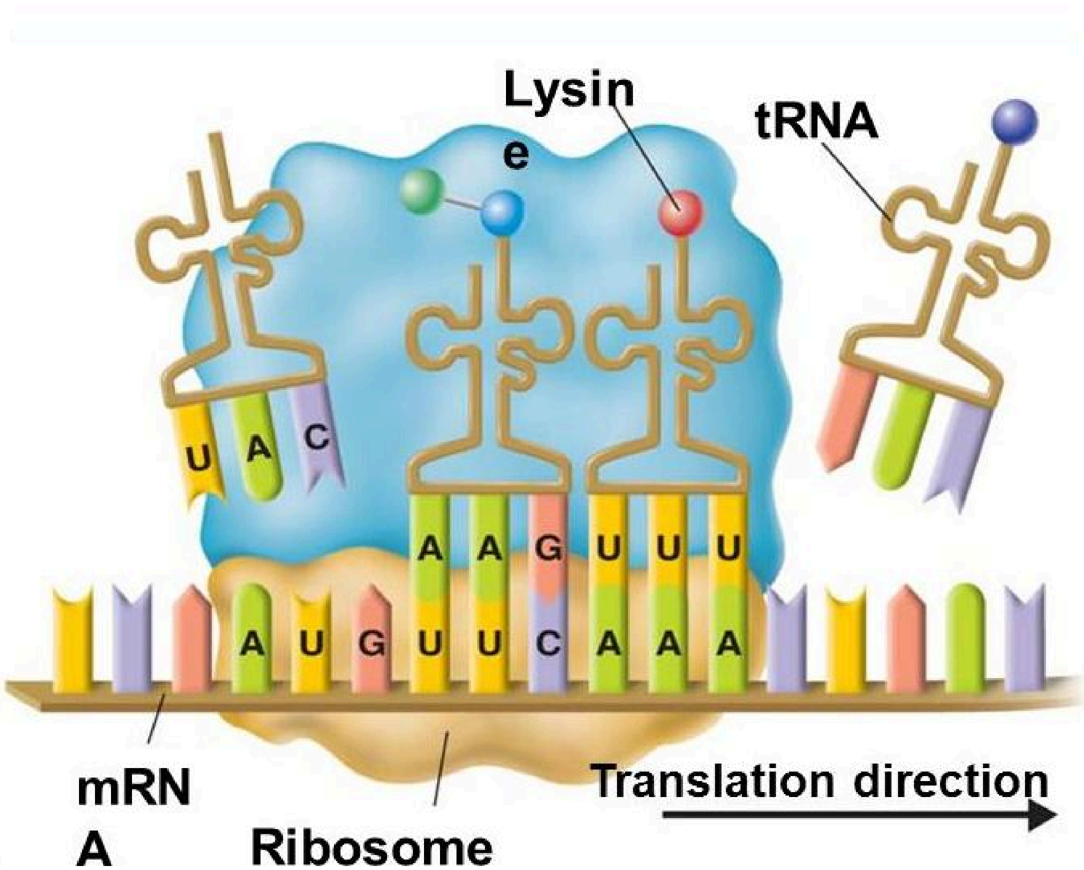
5. Release factor adds water to end of polypeptide; polypeptide detaches and exits through P-site tunnel
6. small/large subunit/mRNA disassemble and disassociate; process of translation can start over again

tRNA carries amino acid

- Attaches to RNA via anticodon (complementary base pair to codon)
- **Wobble pairing** on third nucleotide (flexible bonds)
- Each tRNA becomes charged and enzymatically attaches to an amino acid in the cell's cytoplasm and "shuttle" it to the ribosome
- Charging enzymes require ATP

3 phases:

- Initiation
    - 3 binding sites:
        - **A site**
        - **P site**
        - **E site**
    - Start codon is AUG (methionine)
    - TATA box=specific promoter for initiation
    - RNA polymerase binds to a specific location on promoter
    - Transcription factors attach to promoter to help guide RNA polymerase
- Elongation
    - As each amino acid is brought to the mRNA, it is linked to its neighboring amino acid by a peptide bond and eventually forms a full protein
- Termination
    - Synthesis of a polypeptide ended by **stop codons**

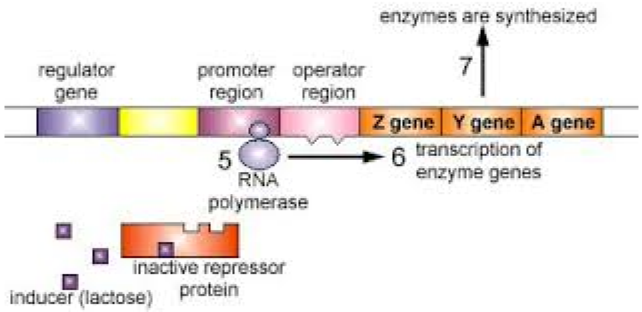


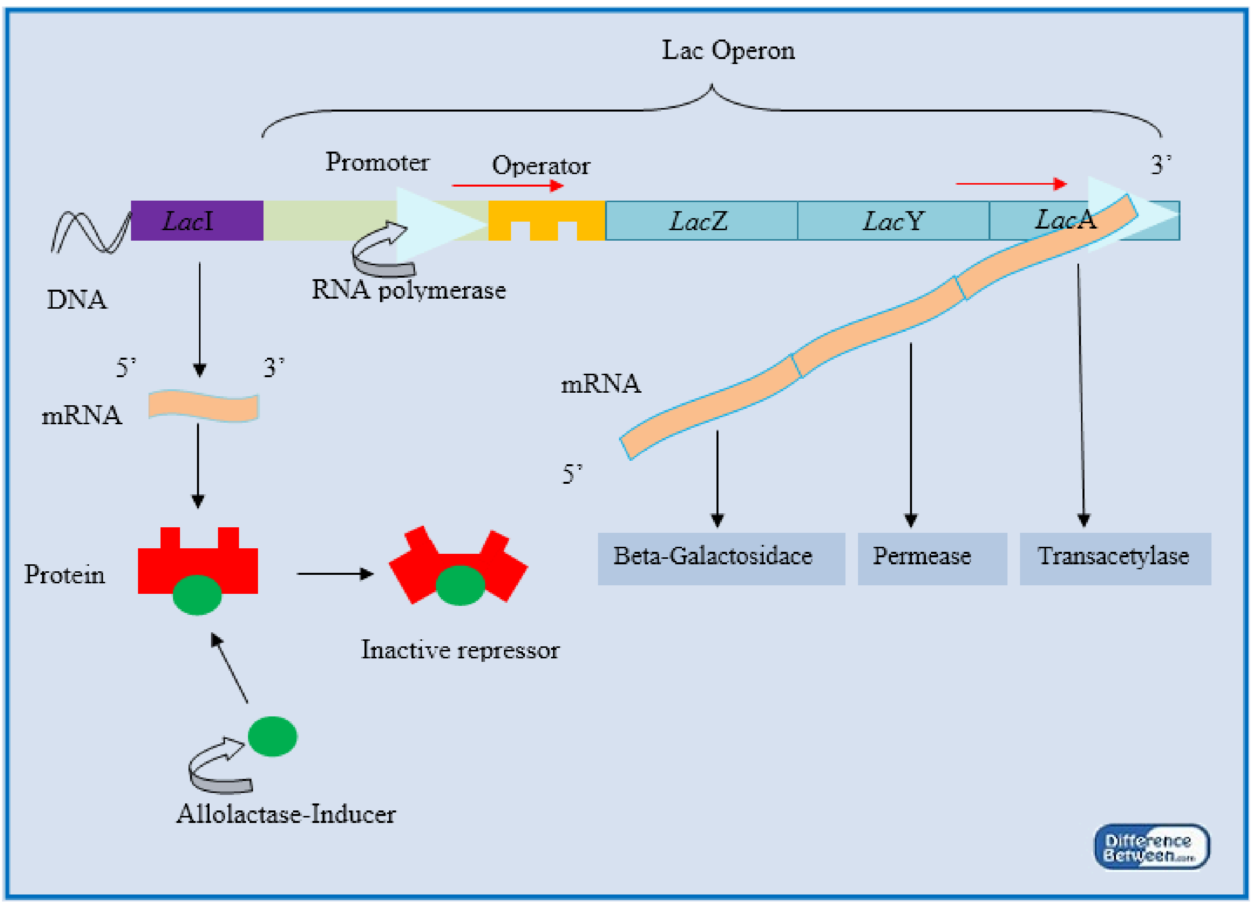
- Gene Regulation
  - Pre-transcriptional regulation
    - **Transcription factors** can either encourage or inhibit the unwinding of DNA and the binding of RNA polymerase
  - **Operons**
    - Bacteria only
    - **Structural genes**
      - Code for enzymes in a chemical reaction
      - Genes will be transcribed at the same time to produce particular enzymes
    - **PRomoter gene**
      - Region where RNA polymerase binds to begin transcription
    - **Operator**
      - Controls whether transcription will occur
      - Where repressor/inducer binds
    - **Regulatory gene**
      - Codes for a specific regulatory protein called to repressor
      - Repressor capable of attaching to the operator and blocking transcription
      - If repressor binds to the operator, transcription will not occur

If repressor does not bind to the operator, RNA moves along operator and transcription occurs

inducible=presence of molecule turns gene on

repressible=presence of molecule turns gene off





Chromatin Modification

Histone acetylation

Acetyl groups added to histones

Looser Chromatin

Access for transcription increased

DNA methylation

Methyl groups added to bases

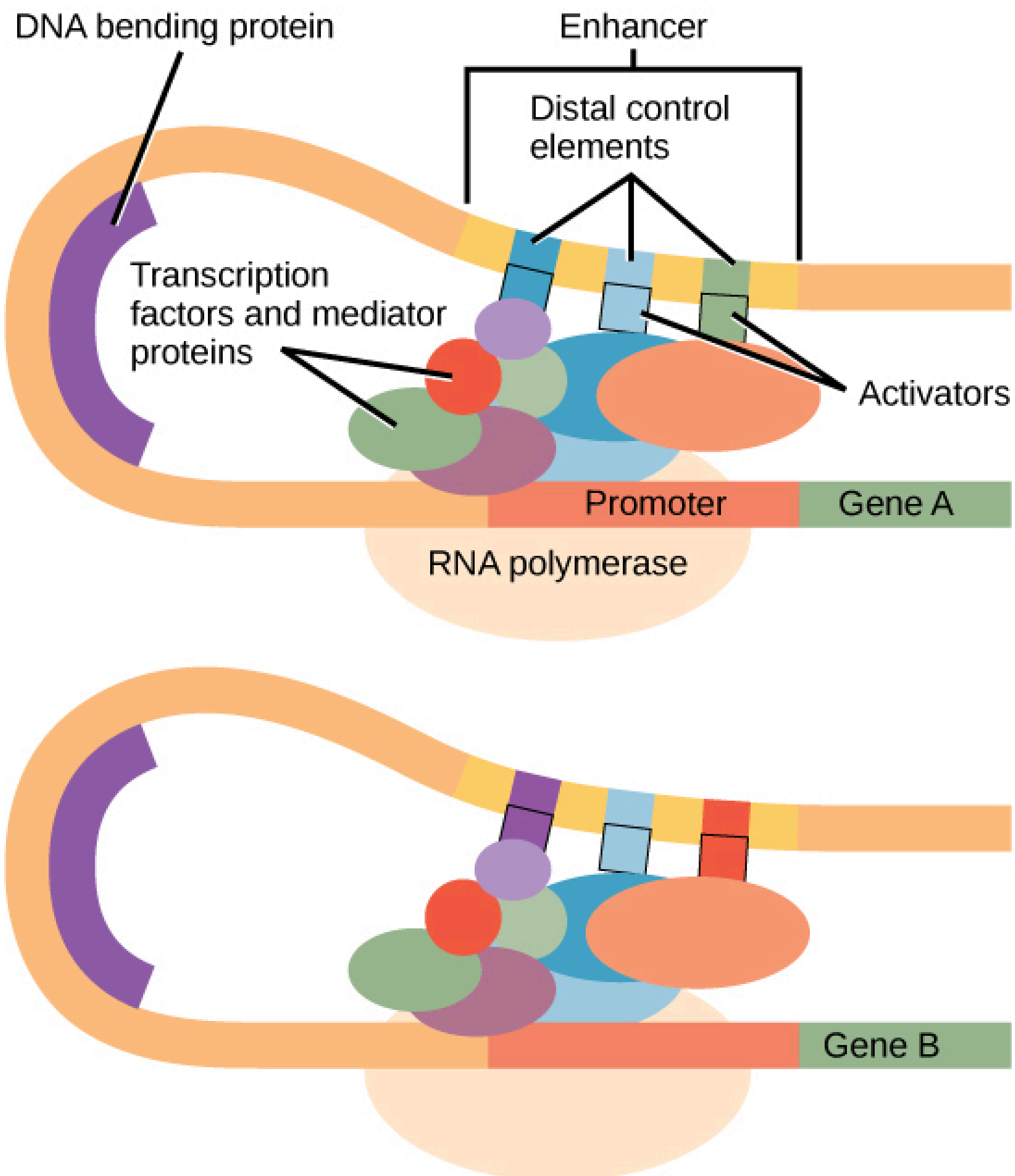
Silences gene

Tightens chromatin

Enhancers

Upstream of promoter

Bends DNA



Post-transcriptional regulation

Occurs when the cell creates an RNA but then decides that it should not be translated into a protein

RNAi molecules bind to an RNA via complementary base pairing

Creates double-stranded RNA, signalling that RNA should be destroyed, preventing it from being translated

Post-translational regulation

Protein has already been made, but doesn’t need it yet, so it is deactivated

Mutations

Mutation is an error in the genetic code

Occur because DNA is damaged in cannot be repaired or because DNA is repaired incorrectly

Caused by chemicals or radiation

Can also occur when a DNA polymerase or an RNA polymerase makes a mistake

RNA polymerases have proofreading abilities, but RNA polymerases do not

Error in DNA not a problem unless that gene is expressed AND the error causes a change in the gene product

Base Substitution

Point mutations result when a single nucleotide is replaced for another

Nonsense mutation

Cause original codon to become a stop codon, which results in early termination of protein synthesis

Missense mutation

Cause original codon to be altered and produce a different amino acid

Silent mutations

codon that codes for the same amino acid is created and therefore does not change the corresponding protein sequence

Frameshift mutations

insertions/deletions result in the gain or loss of DNA or a gene

Can have devastating consequences during translation

results in a change in the sequence of codons used by the ribosome

Duplications

Extra copy of genes

Caused by unequal crossing-over during by meiosis or chromosome rearrangements

,ay result in new traits as one copy may evolve a new function

Inversions

Changes occur in the orientation of chromosomal regions

May cause harmful effects if the inversion involves a gene or an important regulatory sequence

Translocation

2 different chromosomes break and rejoin in a way that causes the DNA sequence to be lost, repeated, or interrupted

D. Biotechnology

Recombinant DNA generated by combining DNA from multiple sources to create a unique DNA molecule that is not found in nature

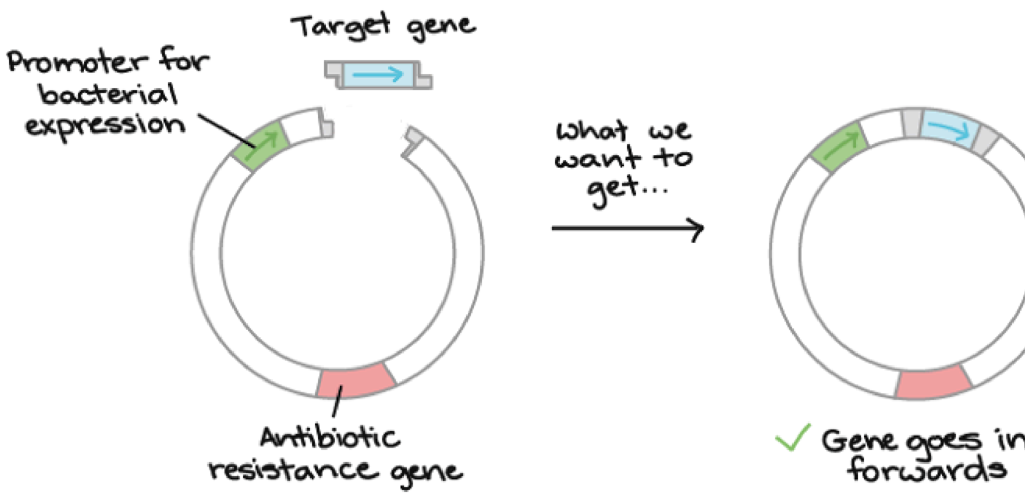
Ex. introduction of a eukaryotic gene of interest into a bacterium for production

Polymerase Chain Reaction (PCR)

- Enables the creation of billions of copies of genes within a few hours
- DNA polymerase, DNA, and lots of nucleotides added in a small PCR tube
- **Thermocycler**
  - PCR machine that heats, cools, and warms PCR tubes many times
  - Each time the machine is heated, the hydrogen bonds break, separating the double-stranded DNA (Denaturation)
  - As it cools, primers bind to the sequence flanking the region of the DNA we want to copy, primers can form hydrogen bonds with ends of target sequence (Annealing)
  - When it is warmed, polymerase binds to the primers on each strand and adds nucleotides on each template strands (extension)
  - REPEAT exponentially

Transformation

- **Transformation:** process of giving bacteria foreign DNA
  - Genes of interest (vectors) placed into small circular DNA molecule called a **plasmid**
    - Plasmid usually codes for antibiotic resistance
    - Small ring of DNA found in bacteria that is replicated separately form the chromosomal DNA
    - Not in all bacteria
  - 1. Extract the plasmid
  - 2. Add a restriction enzyme that will cut the ring open
    - Restriction enzymes usually used to cut up foreign DNA, but are used by scientists for this purpose
    - Cuts palindromes, leaving “sticky ends”
    - Always cut at the same nucleotide sequence
  - 3. Cut a piece of human DNA with same restriction enzyme
    - Reverse transcriptase must be used to process DNA since prokaryotes do not have RNA processing to remove introns
      - DNA transcribed and mRNA is processed, and then reverse transcriptase turns mRNA back into DNA
    - Reverse transcriptase also used by retroviruses
    - Problems: vector may be too big, and there is no direct way to force the plasmid to accept the vector
  - 4. Mix the cut plasmids with the cut human DNA-some will align right due to their sticky ends
    - Ligase used to glue ends back together
  - 5. Allow bacteria to take plasmid back in
    - Heat shock/electric shock used to change membrane so plasmid can re-enter easily
  - 6. Allow to reproduce



Not all bacteria will be transformed, can be tested by using antibiotic resistance

Allows the safe mass-production of proteins used for medicine

Important role in the study of gene expression

Transfection: putting a plasmid into a eukaryotic cell, rather than a bacteria cell

Gel Electrophoresis

DNA fragments can be separated according to their molecular weight using **gel electrophoresis**

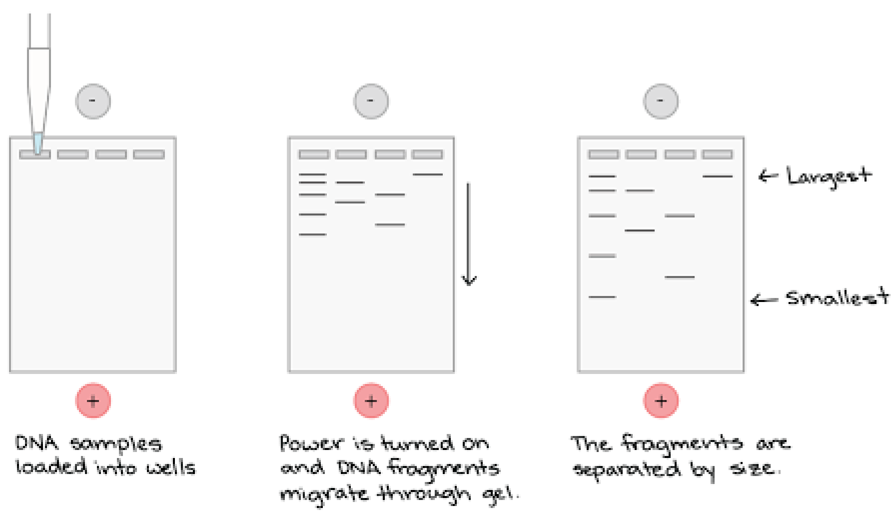
DNA put into wells on negative end, and when a current is run through the gel, the DNA moves across gel according to their weight

Because DNA and RNA are negatively charged, they migrate through the gel toward the positive pole of the electrical field

Smaller fragments move faster and farther

Restriction enzymes used to create a molecular fingerprint

Places where enzymes cut and thus the sizes are unique for each person



Stem cells also very important in biotechnology since they can turn into many different kinds of cells, but it is controversial due to harvesting methods

- Totipotent cell: capable of giving rise to any type of cell or a complete embryo
- Pluripotent cell:capable of giving rise to different cell types

<u>UNIT V: CELL REPRODUCTION</u>

Cell division

- Mechanism to replace dying cells
- Small part of life cycle of a cell
- Some types of cells are nondividing
  - Usually highly specialized cells derived from a less specialized type of cell
  - Made as needed, but cannot replicate themselves
  - Ex. red blood cells
- Multicellular organisms depend on cell division for:
  - Development from a fertilized cell
  - Growth
  - Repair

Binary Fission

- Used by prokaryotes
- Chromosome replicates at origin of replication and the two daughter chromosomes actively move apart
- Plasma membrane pinches inward, dividing cell into two
- Mitosis likely evolved from binary fission
  - Certain protists exhibit cell division that seem intermediate between binary fission and mitosis

<u>A. Interphase</u>

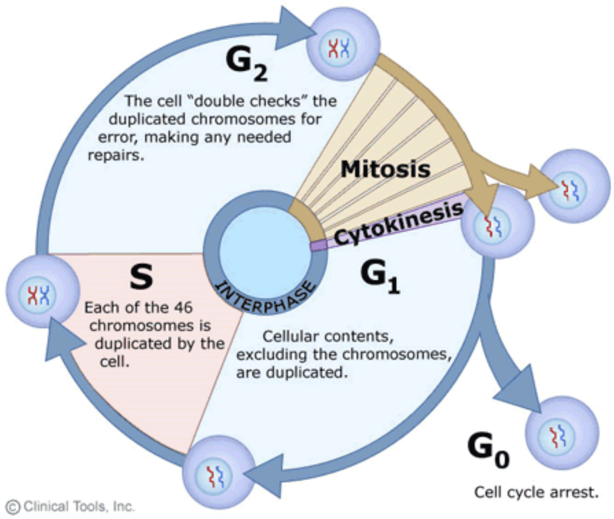
Time span from one cell division to another

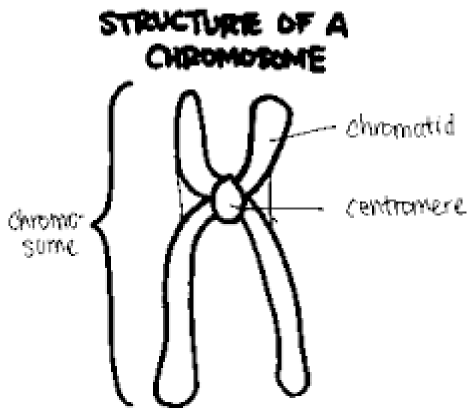
Cell carries out regular activities

All the proteins/enzymes the cell needs to grow are produced in interphase

3 Phases:G_1, S, G_2

- G_1
  - Cell produces all enzymes required for replication
  - G=”Gap” or “growth”
- S
  - Cell replicates genetic material
  - Every chromosome in nucleus is duplicated
    - Sister chromatids created, held together by centromere
  - To be called a chromosome, they each need to have their own centromere; once chromatids separate, they will be “chromosomes”





CEll cycle checkpoints

Checkpoints highly regulated by **cyclins** and **cyclin-dependent kinases (CDKs)**

To induce cell cycle progression, CDK binds to a regulatory cyclin. Once together, the complex is activate

Can affect many proteins in cell

Causes cell cycle to continue

To inhibit cell cycle progression, CDKs and cyclins are kept separate

Separated via dephosphorylation

MEtaphase Checkpoint

Chromosome spindle attcachment

G_1 Checkpoint

Check for:

Nutrients

Growth factors

DNA damage

Can put cell into G_0 is it doesn't need to divide

G_2 checkpoint

Check for:

Cell size

DNA replication

Make sure cell division is happening properly in cells

Stops progression if cell is not ready to progress to next stage

In eukaryotes, checkpoint pathways mainly function ay phase boundaries

When DNA damage is detected, cell will not progress until damage is fixed, or apoptosis is started

CAncer can result from a mutation in a protein that normally controls progression, resulting in unregulated cell division

Oncogenes are genes that cause cancer

Normally required for proper growth and regulation of he cell cycle

Mutated versions can cause cancer

proto-oncogene=normal, healthy oncogene

- DNA change that makes a proto-oncogene excessively active
  - Converts it to an oncogene, which may promote excessive cell division and cancer

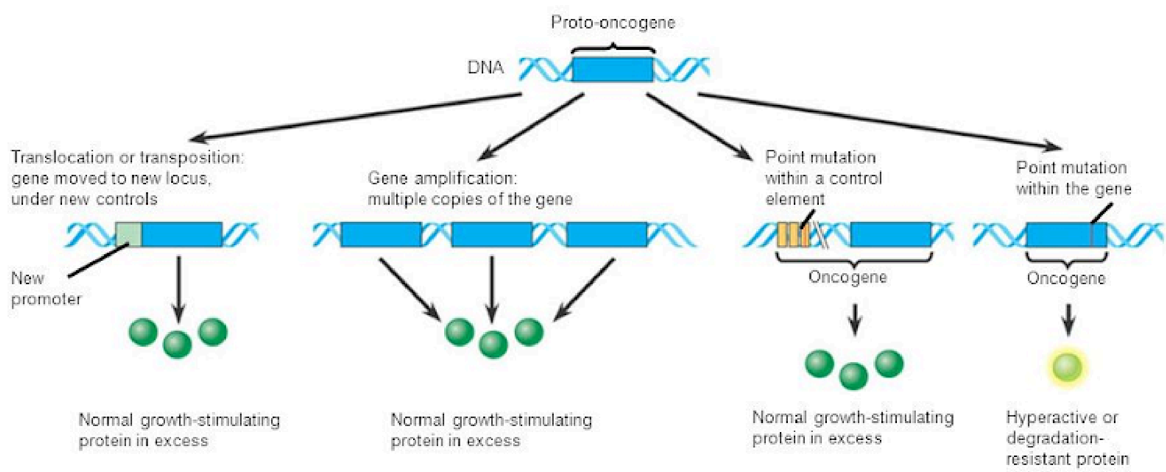


Figure 19.11

Tumor suppressor genes

Produce proteins that prevent the conversion of normal cells into cancer cells

Detect damage within cell and work with CDK/cyclin complexes to stop cell growth until damage can be repaired

Can trigger apoptosis is damage is too severe to be repaired

In order for a cell to become a cancer cell. It must simultaneously override checkpoints, grow in an unregulated way, and avoid cell death

Stop cell division

Density-dependent inhibition

Anchorage dependency

B. Mitosis

Prophase

Disappearance of the nucleolus and nuclear envelope

Chromosomes thicken and become visible

Now called **chromatin**

Centrioles in microtubules organizing centers (MTOCs) start to move away from each other towards opposite poles of the cell

Centrioles spin out system of microtubules known as **spindle fibers**

Spindle fibers attach to **kinetochore** located on centromere of each chromatid

Metaphase

Chromosomes begin to line up along equatorial **metaphase plate**

Moved along by spindle fibers attach to kinetochores on each chromatid

Anaphase

Sister chromatids of each chromosome separate at the centromere and migrate to opposite poles

Pulled apart by shortening microtubules

Non-kinetochore tubules elongate cell

Telophase

Nuclear membrane forms around each set of chromosomes

Nucleoli reappear

Cytokinesis

Cytoplasm splits in half

Cell splits along **cleavage furrow**

Cell membrane forms along each new cell, split into distinct daughter cells

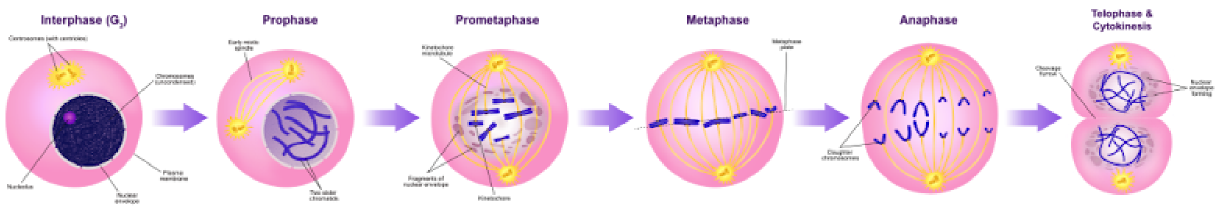
In plant cells, a cell plate forms down the middle instead of a cleavage furrow

Interphase

Cells re enter initial phase, and are ready to start the cycle over again

Chromosomes become invisible again

Genetic material goes back to being chromatin



- Purpose of mitosis
    - Produce daughter cells that are identical copies of parent cell
    - Maintain proper number of chromosomes from generation to generation
- Occurs in almost every cell except for sex cells
- Involved in growth, repair, and asexual reproduction

<u>C. Haploid vs. Diploid</u>

- **Diploid cell** has 2 sets of chromosomes
    - Most eukaryotic cells have 2 full sets of chromosomes: one for each parent
    - Shown by "2*n*"
- **Haploid cell** has only one set of chromosomes
    - Shown by "*n*"
- **Homologous chromosomes** are duplicate versions of each chromosome
    - Similar in size and shape
    - Express same traits, but may have different alleles
- Gametes
    - Sex cells
    - Haploid
        - Offspring will get one gamete from each parent, creating a diploid zygote/offspring

<u>D. Meiosis</u>

- Production of gametes
- Limited to sex cells in **gonads**
    - gonads=sex organs
    - **Testes** in males and **ovaries** in females
    - Made up of **germ cells**
- Produces haploid cells which then combine to restore the diploid (2*n*) number during fertilization
- 2 rounds of cell division: **meiosis I** and **meiosis II**
- Just like in mitosis, double-stranded chromosomes are formed during S phase of interphase
- **Meiosis I**
    - **Prophase I**
        - Nuclear membrane disappears
        - Chromosomes becomes visible
        - Centrioles move towards opposite ends of cell
        - **Synapsis**
            - Chromosomes line up side-by-side with their homologs (counterparts)

2 sets of chromosomes come together to form a **tetrad** (aka **bivalent**) consisting of 4 chromatids

Crossing over

Exchange of segments between homologous chromosomes

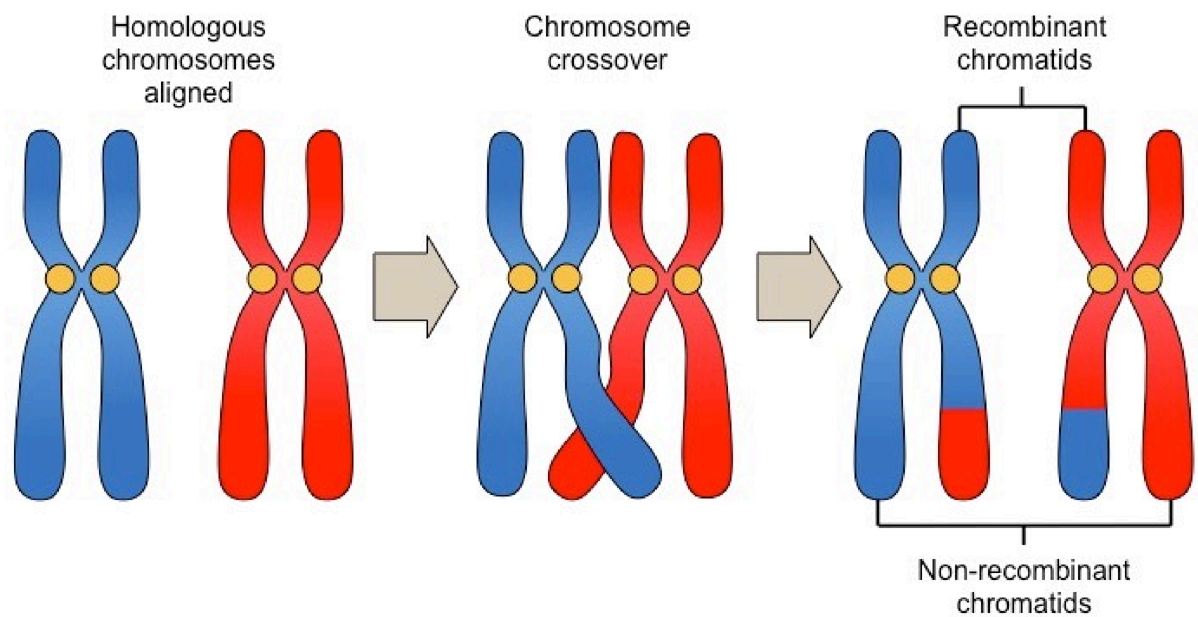
Genetic variation

Begins in Prophase I as homologous chromosomes line up gene by gene

Produces recombinant chromosomes (DNA combined from each parent)

Homologous portions of two nonsister chromatids trade placed

Chromatids that are farther apart are more likely to cross over



Metaphase I

Tetrads line up along metaphase plate

Random alignment--more genetic variation

Offspring will be a combination of all 4 grandparents

ANaphase I

Each pair of chromatids within a tetrad separates and moves to opposite poles

Chromatids DO NOT separate at centromere

Telophase I

Nuclear membrane forms around each set of chromosomes

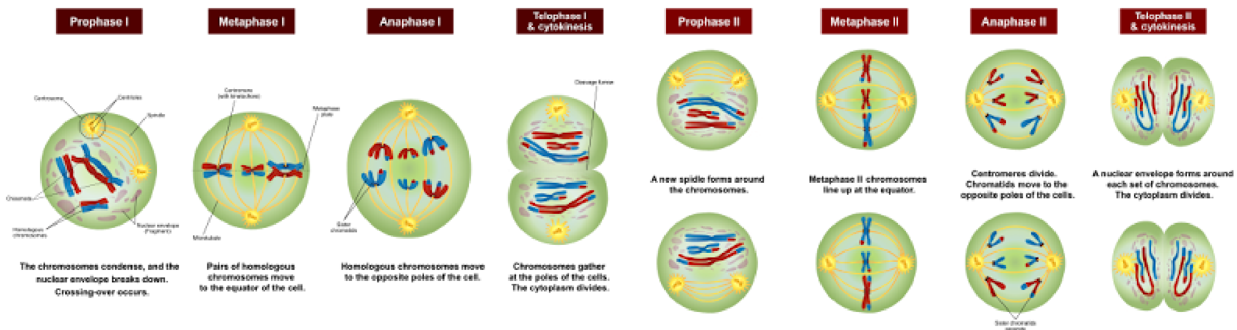
2 daughter cells

Nucleus contains haploid number of chromosomes, but each chromosome is a duplicated chromosome consisting of 2 chromatids

Meiosis II

Purpose is just to separate sister chromatids

Prophase II is the same
Metaphase II: chromosomes move toward metaphase plate lining up in a single file, not in pairs
Anaphase II:chromatids split at the centromere and each chromatid is pulled to opposite ends of cell
TElophase II: nuclear membrane forms around each set of chromosomes and a total of 4 haploid cells are produced
MEiosis I separates homologous chromosomes; Meiosis II separates sister chromatids



Gametogenesis

Spermatogenesis if sperm cells are produced

Oogenesis if egg cell/ovum is produced

Produces one ovum instead of 4

Other 3 cells, called **polar bodies** get only a tiny amount of cytoplasm and eventually degenerate

Allows female to conserve as much cytoplasm as possible for the surviving **ovum**

MITOSIS	MEIOSIS
Occurs in somatic cells	Occurs in germ cells
Produces identical cells	Produces genetically diverse gametes
Diploid cell➝Diploid cell	Diploid cell➝Haploid cell
1 cell becomes 2 cells	1 cell becomes 4 cells
Number of divisions: 1	Number of divisions: 2

Meiotic Errors

Nondisjunction: chromosomes fail to separate properly

Produces wrong number of chromones

Usually results in miscarriage or significant genetic defects

Ex. Down syndrome is a result of 3 copies of the 21st chromosome

Translocation

One or more segments of a chromosome break and are either lost or reattach to another chromosome

UNIT VI: HEREDITY

A. Mendelian Genetics

Genetics=study of heredity

Explains how certain characteristics are passed from parents to children

Heredity=transmission of traits from one generation to the next

Variation is demonstrated by the differences in appearance that offspring show from parents and siblings

Physical traits are not inherited; genes are inherited

Gregor Mendel=”father of genetics”

Traits

Expressed characteristics

character=feature(ex. Eye color); trait =specific version of that feature (ex. blue eyes)

Influenced by one or more genes

Gene=chunk of DNA that codes for a particular “recipe”

DNA is passed from generation to generation, and genes/traits go along with it

Chromosome contains many genes, each controlling the inheritance of a particular trait

Locus=position of a gene on a chromosome

Children do not inherit physical traits; they inherit genes, which influence physical traits

Genes passed along by gametes (sperm/egg)

clone=group of genetically identical individuals from same parent

common in asexual reproduction

Sexual reproduction creates genetic diversity

Diploid organisms typically have 2 copies of a gene, one on each **homologous chromosome**

Copies of chromosome may be different from each other, containing different alleles

Homozygous=organism has 2 identical alleles for a given trait

heterozygous=organisms has 2 *different* alleles for a given trait

Phenotype=physical appearance

Genotype=genetic makeup

Dominant vs. recessive allele

Dominant allele is determined by which allele is the phenotype of a heterozygous organism

Dominant allele showed by capital letter; recessive allele showed by lowercase of same letter

NAME	GENOTYPE	PHENOTYPE
Homozygous dominant	TT	Tall
Homozygous recessive	tt	Short

Heterozygous	Tt	Tall

Crosses

- 1st generation in an experiment is always called the **parent/P1 generation**
- Offspring of P1 are called the **filial/F1 generation**
- Offspring of F1 are called **F2 generation**, etc.

true-breeder=genetically pure; consistently produces same traits

Law of Dominance

- One dominant trait masks the effect of the other trait

Law of Segregation

- Monohybrid Cross
  - 2 heterozygous individuals are crossed
  - Ratios for cross of two heterozygotes
    - Phenotype ratio= 3 dom.:1 rec.
    - Genotype ratio= 1 homo dom: 2 het: 1 homo rec
- Gametes only get one of the 2 copies of a gene

Law of Independent Assortment

- Each allele of the two traits will get segregated into two gametes independently and randomly along Metaphase plate of meiosis I
- Each pair of chromosomes sorts maternal/paternal homologues independently of the other pairs
- For humans, (*n*=23), there are more than 8 million (2^{23} possible combinations of chromosomes, not including crossing over, mutations, etc.
- **Dihybrid cross**
  - 2 heterozygotes for two genes are crossed
  - 9:3:3:1 ratio
  - Easier to use probability rather than a punnett square

Random Fertilization also creates genetic variability

- Any sperm can fuse with any ovum
- 70 trillion diploid combinations

Rules of Probability

- Probability of 2 independent traits occurring together= probability of trait A*probability of trait B

Test Cross

- How to tell if an organism displaying dominant phenotype is homo-dom or het: USE TESTCROSS
- Breed mystery organism with a homo-rec
  - If all offspring display dom phenotype, the organism is homo-dom
  - If any offspring display rec phenotype, the organism is het

Linked Genes: group of genes on same chromosome tend to stay together/inherited together

- Cannot segregate independently since they are on the same chromosome, violating the law of independent assortment
- Can only be separated by crossing-over

recombinant=offspring formed from recombination events

Percentage of recombination= $\frac{\Sigma(recombinants)}{total\ offspring}$

Can be used as a measure of how far apart genes are/order

Distance on a chromosome is measured in **map units** aka centimorgans on a linkage map

One map unit=1% recombination frequency

Farther apart 2 linked alleles are on a chromosome the more often the chromosome will cross over between them

Genes on different chromosomes have 50% recombination frequency

Karyotype: ordered display of the pairs of chromosomes in a cell

2 chromosomes in a pair=homologous chromosomes

PEdigrees: show family history of allele(S)

Describes interrelationships of parents and children across generations

Inheritance patterns of particular traits can be traced back and described using pedigrees

Alterations of Chromosome Number/Structure

Nondisjunction

Pairs of homologous chromosomes don't separate properly during meiosis

One gamete receives 2 of the same type of chromosome (trisome) while the other receives none (monosome)

Results in Aneuploidy

Deletion

Removes a chromosomal segment

CDE→CE

Duplication

Repeats a segment

CDE→CDCDE

Inversion

Reverses orientation of segment within a chromosome

CDE→EDC

Translocation

Moves a segment from one chromosome to another

Genome imprinting

Phenotype depends on which parent passed along alleles for trait

Involves silencing of certain genes that are "stamped" with an imprint during gamete production

Extranuclear genes are inherited maternally because the zygote's cytoplasm comes from the egg

B. Sex-Linked Traits

autosomes=non sex chromosomes

Sex chromosomes determines sex of individual

female=XX
male=XY
Some traits carried on sex chromosomes
Ex. color blindness/hemophilia
Most only found on X-chromosome ("X-linked traits")
Since males have one X and one Y chromosome, he'll express the trait even if it is recessive since there is no second allele that would cover it up
Female will only express sex-linked trait if trait is dominant or individual is homo rec
carrier=female that carries trait but does not exhibit it
Barr Bodies
X chromosome that is condensed and visible
Females only have one X chromosome activated; other X deactivated during embryonic development
Deactivated chromosome chosen randomly by each cell
Incomplete dominance
Aka blending inheritance
Traits blend
Alleles equally expressed
Ex. red white=pink offspring
Non dominant trait
Codominance
Equal expression of multiple alleles
2 alleles affect phenotype differently
Ex. blood type options: I^A, I^B, i
Polygenic inheritance
Trait results from the interaction of many genes
Non-nuclear inheritance
Affected by genetic material in mitochondria
Mitochondria always provided by egg during sexual reproduction
Most genes have pleiotropy (have multiple phenotypic effects)
Responsible for the multiple symptoms of hereditary diseases
Epistasis: a gene at one locus alters the phenotypic expression of a gene at another locus
Norm of Reaction: phenotypic range of a genotype influenced by environmental factors
Multifactorial characters

UNIT VII: EVOLUTIONARY BIOLOGY

A. NAtural Selection

Charles Darwin
British naturalist who sailed the world
Developed theory of evolution based on natural selection after studying animals on Galapagos Islands
Observed that there were similar animals on isolated animals, but they each had slight variations (ex. Beak shape, neck length, etc.)

- There must have originally been a variety of beak lengths, but only the longest ones could survive. Since those with the longest beaks could reproduce better, they were more likely to contribute offspring with the same traits to the next generation

<u>The Origin of Species</u>

- Variation exists in the population and some of this variation is heritable
- Populations tend to make lots of offspring
- Resources are limited, thus a struggle ensues
- Those with better traits (phenotypes) will do a better job getting those resources and reproduce more
- The genes that code for "better" traits in the current environment start increasing in the population
    - The earth is always changing what what may be good now may not be in the future; evolution will always be occurring

"Survival of the fittest"

Jean-Baptiste Lamarck

- Widely accepted theory of evolution in Darwin's
- Acquired traits inherited and passed onto offspring
    - "Law of use and disuse"
    - According to Lamarck, giraffes have long necks because they constantly *use* them
- WRONG
    - Changes in somatic cells do not change gametes and thus cannot be passed onto offspring

Evidence for Evolution

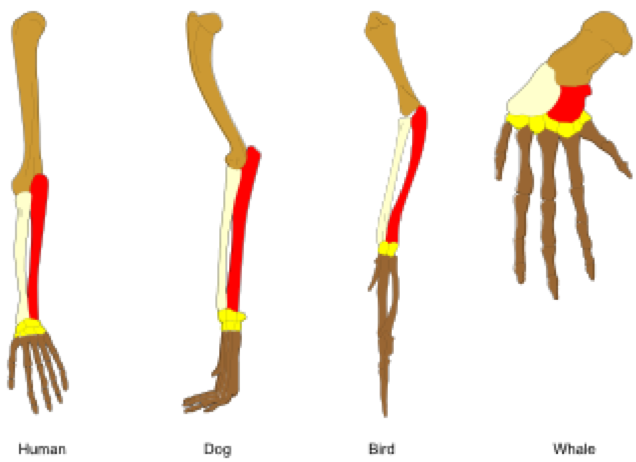
- **Paleontology**
    - Study of fossils
    - Revealed great variety of organisms and the major lines of evolution
    - Tend to form in sedimentary rock
- **Biogeography**
    - Study of the distribution of flora and fauna in the environment
    - Related species found in widely separated regions of the world
    - Suggests a common ancestor between species
    - Ex: pangea
- **Embryology**
    - Study of the development of an organism
    - Early stages of vertebrate development all look alike
        - All vertebrates show fishlike "gill slits"
- **Comparative anatomy**
    - Study of anatomy of various animals
    - Vestigial Strucutres
        - Structures with little-no function
        - Remannts of structures that served important functions in the organism's ancestors

Homologous structures

Similar structures that serve different functions

Analogous structures

Same function different structure



Molecular biology

Most compelling proof of evolution

Examining nucleotide/amino acid sequences of different organisms

Common genes and proteins

Ex: Hox Genes (body paint controller genes)

Shared structures help us to understand not only how structures develop but also supports shared shared ancestry

Artificial Selection

Humans selecting which organisms reproduce and survive so the future generations have traits that humans have selected

Ex. dog breeds

<u>B. Common Ancestry</u>

Phylogenetic trees

Aka cladogram

Study the relationships between organisms

Begin with common ancestor and then branch out

Anytime there is a fork in the road, it is called a common ancestor node

Common ancestors likely do not exist anymore, but they are the point at which evolution went in two directions

Outgroup

Related to ingroup but diverged before others

Serves as reference group

Always stems from foot of tree

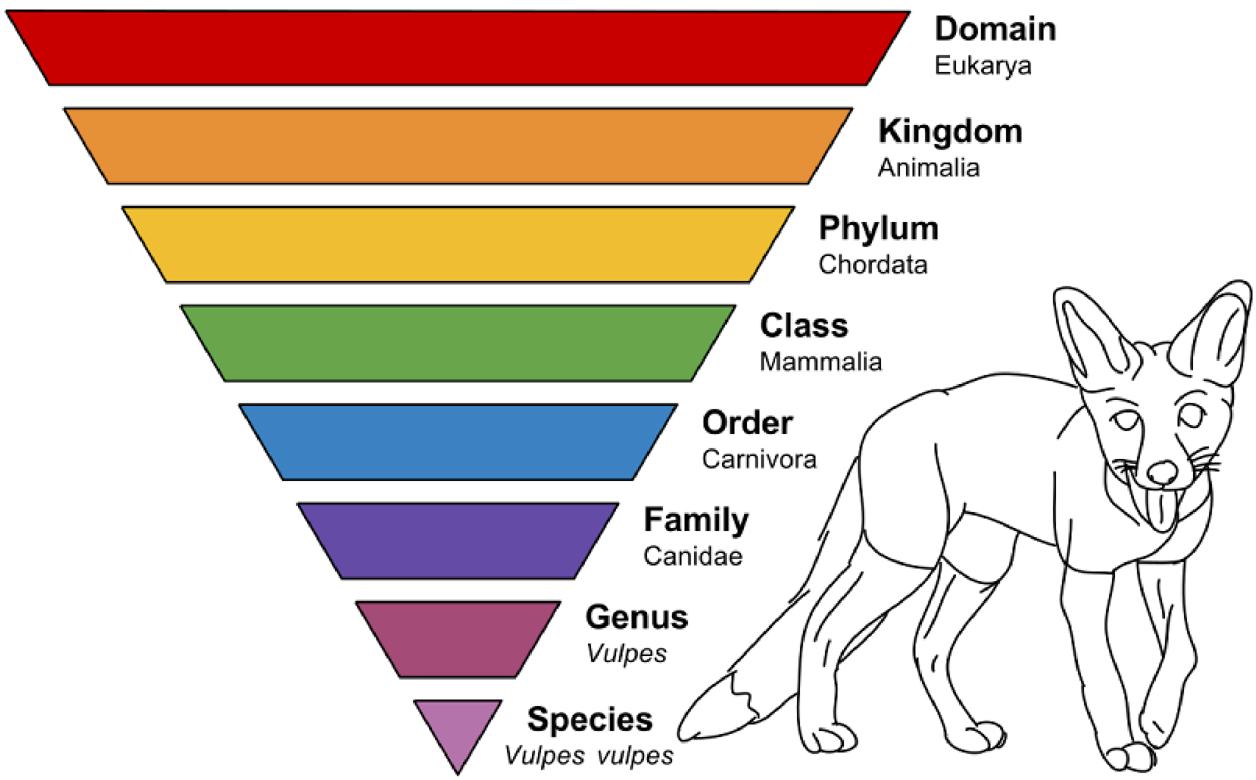
Monophyletic=ancestral species+all descendants

PAraphyletic=ancestral species+some descendants

Polyphyletic=ancestral species+descendants+distantly related organism

Taxonomic categories

DOMAIN
KINGDOM
CHORDATA
PHYLUM
CLASS
ORDER
FAMILY
GENUS
SPECIES



Red fox (*Vulpes vulpes*)

C. Genetic Variability

- **Genetic variability**: differences in each person/individual
- Only identical twins have exactly identical sets of alleles
- Survival of a species is dependent on genetic variation, allowing a species to survive in a changing environment
    - NAtural selection only occurs if some individuals have more evolutionary fitness and can be selected
- Cause of genetic variability
    - Random mutations
    - DNA polymerase errors
    - Changes to DNA by transposons, etc.
    - Meiosis
        - Crossing-over
        - Independent assortment

Bacteria

Conjugation

Transduction

Viruses pass around chunks of the bacterial genome during infection

D. Causes of Evolution

Natural selection works internally through random mutations and externally through environmental pressures

As long as a mutation does not kill an organisms before it reproduces, it may be passed on to the next generation

Advantages brought about by a mutation will only be apparent until environmental pressure occurs

Adaptation: variation favored by natural selection

Any trati that causes an individual to reproduce better gives that individual **evolutionary fitness**

Sexual selection can also spur evolution

Speciation occurs once 2 populations can no longer reproduce together

Biological Species Theory

Species is a group of populations whose members have the potential to interbreed in nature and produce fertile, viable offspring

They do not breed successfully with other populations

Catastrophic events speed up natural selection

Genetic drift

Something that causes a change in a population besides natural selection

Caused by random events that drastically reduce the number of individuals in a population

Bottleneck effect

Sudden change in environment reduces size of population

New gene pool is not reflective of original population

Founder effect

Few individuals become so isolated from larger population and establish a new popluation that may not be representative of original population

Gene Flow

Tends to make a population more similar

When a poppulation gains/loses alles by genetic additions/subtractions from population

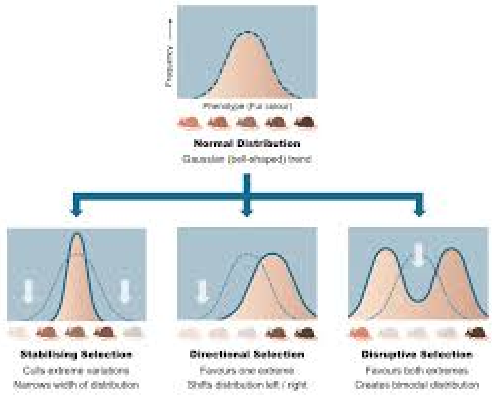
Only a few individuals are left to mate and regrow a population, so their traits become overemphasized without necessarily having any reproductive advantage

Types of SElection

Directional selection favors one extreme of the normal distribution

Stabilizing selection: extreme traits are selected against

Disruptive selection favors both extremes,common traits selected against



<u>E. Species</u>

Divergent evolution

In order for a population to split into different species, they must be **reproductively isolated**

Allows the two groups to undergo natural selection and evolve differently

a population evolves into 2 separate species due to different variation/environmental pressures until the 2 groups can no longer mate together

Prezygotic barriers prevent fertilization

- Habitat isolation
  - 2 species don’t encounter each other
  - Same geographic area, but different habitats
- Temporal Isolation
  - Species breed during different times of da/season/etc.
- Behavioral Isolation
  - Different courting rituals
  - Species do not respond to mating signals
- MEchanical isolation
  - Unsuccessful mating attempt
  - Species are anatomically incompatible
- Gametic isolation
  - Sperm unable to fertilize eggs
  - Gametes are unable to fuse to forma zygote

Post-zygotic barriers are related to the inability of the hybrid to survive/reproduce

- Reduced hybrid viability
  - Genes impair hybrid development
- Reduced hybrid fertility
  - sTerile hybrids
- Hybrid breakdown
  - Weaker hybrids over generations
  - Offspring of htbrids are weak/sterile

Convergent evolution

Process by which two unrelated and dissimilar species come to have analogous traits
Often due to exposure to similar selective pressures
2 types of speciation
Allopatric
Population becomes separated from the rest of the species by a geographic barrier so the 2 population can interbreed
Sympatric
New species form without any geographic barrier
Common in plants
Through polyploidy, sexual selection, habitat differentiation, etc.
Polyploidy
Presence of extra sets of chromosomes due to accidents during cell division
Common in plants
Autopolyploidy
Individual with more than two chromosome sets
derived from same species
Allopolyploid
Species with multiple sets of chromosomes derived from different species (interbreeding)

F. Population Genetics

Hardy-Weinberg Equilibrium
Law states that even with all the shuffling of genes that goes on, the relative frequencies of genotypes in a population still prevail over time, creating a stable gene pool
5 Conditions
Large population
No mutations
No immigration/emigration
Random mating
Natural selection
All populations violate one of these five--populations are always evolving
$p + q = 1$
$p^2 + 2pq + q^2 = 1$

UNIT VIII: ANIMAL STRUCTURE AND FUNCTION

Homeostasis
Set of conditions that living things can live successfully in
Body is constantly trying to maintain this state by taking measurements and adjusting accordingly
Controlled by feedback pathways
Negative Feedback
Aka feedback inhibition
End product turns pathway off

Conserves energy

Positive feedback

End product stimulates the pathway

Less common

Ex. fruit ripening

A. Development

Embryonic development

morphogenesis=cell changing shape many times by going through a succession of stages

When an egg is fertilized by a sperm, the result is a diploid **zygote**

Fertilization triggers zygote to go through a series of divisions, and embryo becomes increasingly differentiated

Organizer cells release signals that let cells knowhow they should develop

Once a change has been made, it can't go back

Certain genes turned on/off in differentiation

Homeotic genes

Genes that turn cells into other types of cells

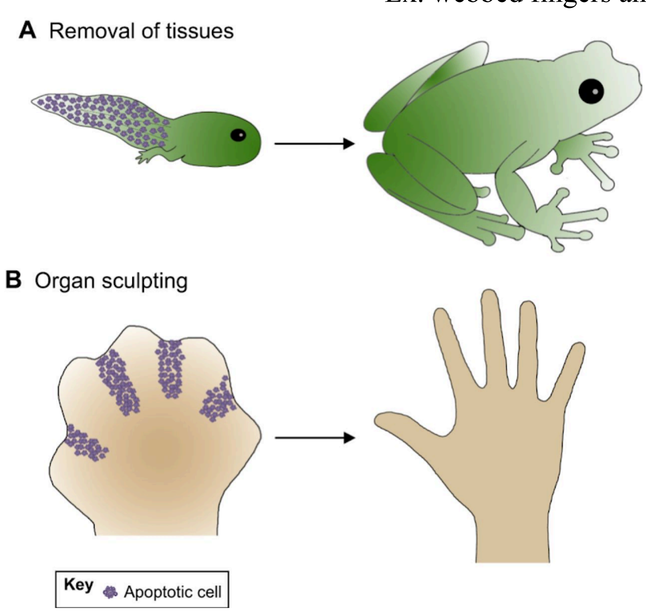
Timing essential for activation of genes

Severely damaged embryos will stop development

Apoptosis also used in embryonic development

Some parts used as "scaffolding" in development and then those cells undergo apoptosis

Ex. webbed fingers and toes that become digits



B. Body Systems

tissue=group of cells that all perform the same function

organ=several tissues come together to form specialized structures

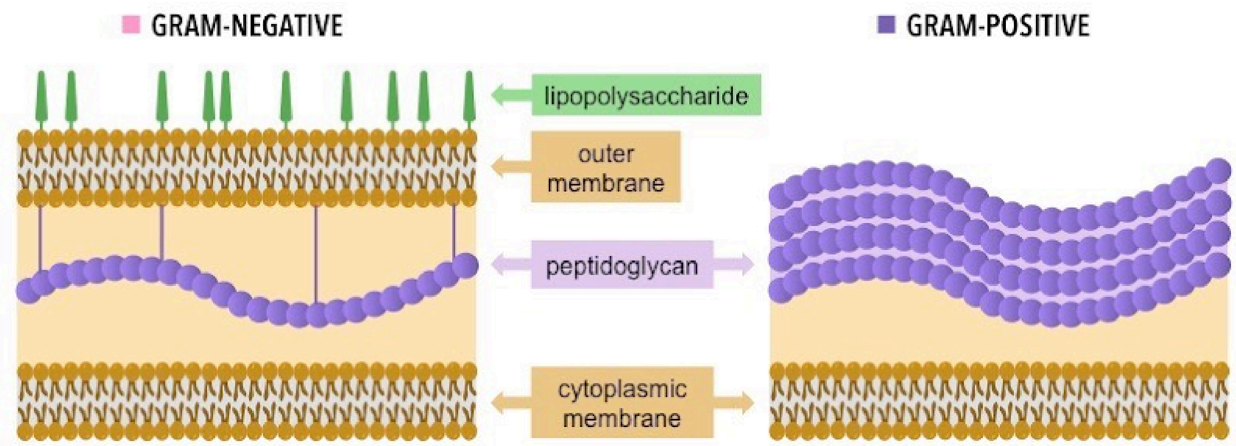
Body system=several united organs

Immune system
Nervous system
Endocrine system
Circulatory
Blood vessels carry blood around body to transport chemical signals and to bring supplies to cells and carry waste way
The blood flow is controlled by the heart, which pumps blood through the blood vessels
Respiratory
Lungs are responsible for gas exchange (O_2 and CO_2)
Help maintain pH levels in blood
Digestive
Esophagus, stomach, small intestine, large intestine, pancreas, liver, and gallbladder work together to break down food and absorb nutrients
stomach=mixing/breakdown
Small intestine=absorption
pancreatic=enzyme secretion/secretion
Excretory
Kidneys filter blood and reabsorb things the body wants to keep and gets rid of the rest in urine
Reproductive
Male and female systems largely controlled by hormones and allow the production of gametes and the ability to reproduce
Muscular and Skeletal
Skeletal and smooth muscles contract via an action potential signal from nervous system
Skeletal system provides:
Structure
Protection
Calcium storage

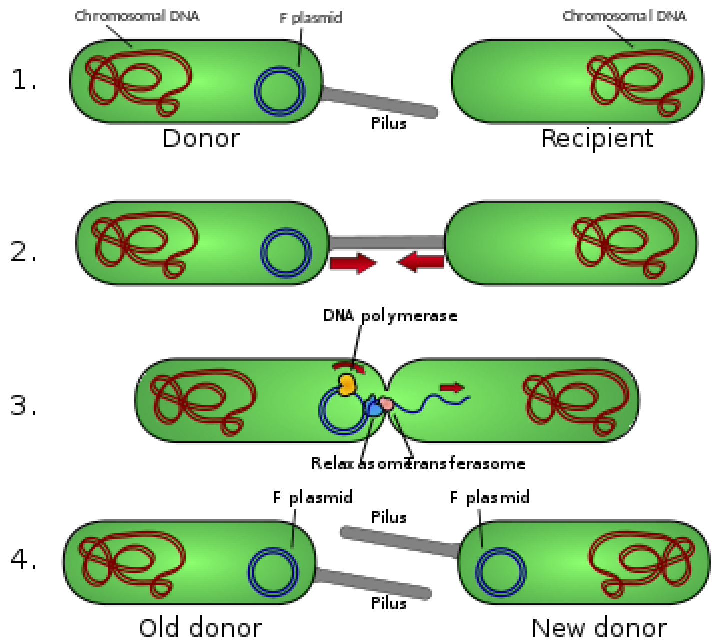
C. Immune System

Body's defense system
pathogens=disease-causing biological agents that can generally be divided into:
Bacteria
Prokaryotes of many shapes and sizes
Shapes
Cocci (sphere)
Bachi (rod)
spiral
Infect many things
Have cell wall
Maintain cell shape
Protect cell

Prevent bursting in hypotonic environment
Made of peptidoglycan
    Archaea contain polysaccharides and proteins
Gram-positive bacteria have simpler walls with a large amount of peptidoglycan
Gram-negative bacteria have less peptidoglycan and an outer membrane than can be toxic
    More likely to be antibiotic resistant

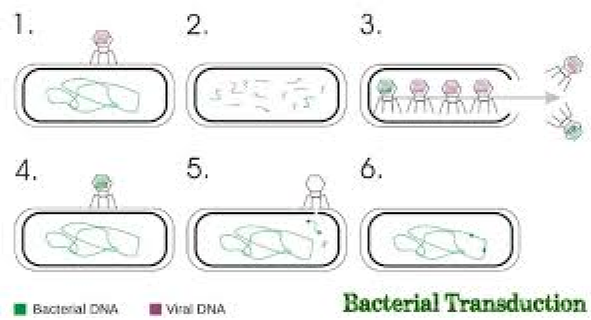


CApsule: polysaccharide/protein layer covering many prokaryotes
Some bacteria develop resistant cells called **endospores** when that lack an essential nutrient
    thick -coated resistant cell produced by some bacteria cells when exposed to harsh conditions
Fimbriae help stick to substrate
Contain circular DNA and Plasmids
Reproduce by binary fission; short generation times (1-3 hours)
May or may not cause harm
Divide By fission--does not increase genetic diversity
Can perform **conjugation** with other bacterial cells and swap some DNA
    F-factor=piece of DNA required for production of oil
    Cells containing F Plasmid (F^+) serve as donors; F^- cells are receivers
    F-factor transferrable during conjugation



Bacterial Transformation

Transduction



Genetic variety among bacteria is leading to increased antibiotic resistance

Horizontal gene transfer: movement from one organism to another

Viruses

- Non Living agents capable of infecting cells
- Nonliving bc require a host cell's machinery to replicate (hijack DNA Polymerase); can't reproduce on their own
- envelope:glycoproteins which the cells of animals receive to allow entrance into the virus
  - Determines attachment to cell
- Host range=types of cells virus can infect
- 2 main components
  - Protein capsid
    - Protein shell enclosing viral genome
    - Many shapes: rod, polyhedral, etc.

        - Genetic material made up of DNA or RNA, depending upon specific virus
- Very specific to which cells they infect
- **host**=victim cell of viral infection
- GOal=replicate and spread
    - To do so, virus must make more genome and capsid and then these components will self-assemble
        - Viral genome carries genes for building capsid and anything else the virus needs that the host cell cannot provide
        - Sometimes, two viruses will infect a cell and their genomes wil mix
- **Bacteriophage**
    - 3 cellular defenses against phages
        - Natural selection
        - Restriction enzymes
        - lysogeny
    - Virus that infects bacteria
    - 2 types of replication cycles
        - **Lytic**
            - Virulent phages
            - Virus immediately starts using host cell's machinery to replicate genetic material and create more protein capsids
            - Spontaneously assemble into new viruses and cause cell the lyse, releasing new viruses into the environment
        - **Lysogenic**
            - Temperate phages
            - Prophage: viral DNA integrated into bacterial chromosome via lysogenic cycle
            - Virus incorporates itself into host genome and remains dormant until it is triggered to switch into the lytic cycle by an environmental signal
            - During the dormant phase, acell may replicate many times, replicating the viral genome along with it
- **Transduction**
    - When a virus exercises (becomes unintegrated) from host genome, it sometimes accidentally takes some host NA with it
    - New DNA is replicated and packaged into new viral particles, becoming part of other cells
    - DNA may have carried a trait such as antibiotic resistance
- **Enveloped viruses**

- In animal cells, viruses don't have to lyse the cell; they can just just exit via exocytosis
- Virus becomes enveloped by a hunk of cell membrane that it takes with it
- Thus these viruses have a lipid envelope

Retroviruses
- Eex. HIV
- RNA viruses that use reverse transcriptase to convert their RNA genomes into DNA so they can be inserted into a host genome
- Extremely high rates of mutation
  - Lack proofreading mechanisms upon replication
  - Difficult to treat

Two immune responses
- Foreign molecules that can trigger an immune response=antigens
- **Innate response**
  - More general anti-invader response
  - 1st line of defense=skin, mucous lining of respiratory/digestive tract, etc.
  - Other nonspecific defenses
    - **Phagocytes/macrophages**
      - Engulf antigens
    - **Complement proteins**
      - Lyse cell wall of antigen
    - **Interferons**
      - inhibit viral replication
      - Activate surrounding cells that have antiviral actions
    - **Inflammatory responses**
      - Series of events in response to antigen invasion/physical injury
    - Requires immune cells to recognize foreign substance when it successfully binds to the immune cell's receptor and activate intracellular signalling pathways
  - Destroys foreign things
- **Adaptive/Specific Immune Response**
  - Carefully catalogs each antigen in a particular way
  - Memory component to help fight repeat attack efficiently
  - **Lymphocytes**
    - Primary cells of immune system
    - Found in blood and lymph nodes
    - Type of white blood cell (aka leukocyte)
    - 2 types
      - B-cell
        - In bone marrow
        - Involved in **humoral response**

        - Defends body against pathogens in extracellular fluids
    - Each B-cell has special receptor on surface than can bind only to foreign antigens
    - If pathogen arrive that fits the receptor, B-cell becomes activated with help of T-cell
    - B-cell will begin to replicate and seek out more of that pathogen
    - Some becomes **memory B-cells**
        - Remain in circulation
        - Allows body to mount a quicker response if a second exposure should occur
    - Can also become **plasma cell**
        - Produce **antibodies**
            - Specific proteins that bind to same antigen originally activated B-cell
        - Antibody produced by plasma cell identical to the surface receptor that originally caught the antigen
    - Each B-cell has a unique receptor/antibody that it makes
- T-cell
    - Mature in thymus
    - Involved in **cell-mediated immunity**
        - Responsible for monitoring "self" cells to make sure they are still healthy
        - Plasma membrane has **major histocompatibility complex (MTOC) markers** that allow T-cells to get a glimpse of what is happening inside each cell
    - Have special antigen-recognizing receptors like B-cells
    - MHC I on all nucleated cells
        - Take peptides that have been found inside cell and hold them up to surface to let **cytotoxic T-cells** see
        - Cytotoxic T-cell will trigger apoptosis in cell if they decide it is infected
    - MHC II on special immune cells that identify and engulf antigens
        - Aka antigen-presenting cells

Hold up antigen immune cell has picked up to let **helper T-cell** see
If T-cell agrees that it is foreign, it helps activate immune cell

Antibodies
- All have same basic monomer structure that is shaped like letter Y
- Stem of Y always the same; can interact with other cells in immune response
- Arms of Y always unique; where antibody binds to antigen
- On each antibody, both arms bind the the same shape so that it can hold 2 antigens at once
- Can combat antigen on its own just by binding to it
  - Antigen can no longer bind to anything else, so it cannot enter any cells

Lymph node
- Mass of tissue found along lymph vessel
- Contains large number of lymphocytes
- Multiply rapidly upon contact with antigen
- Swell when fighting infection

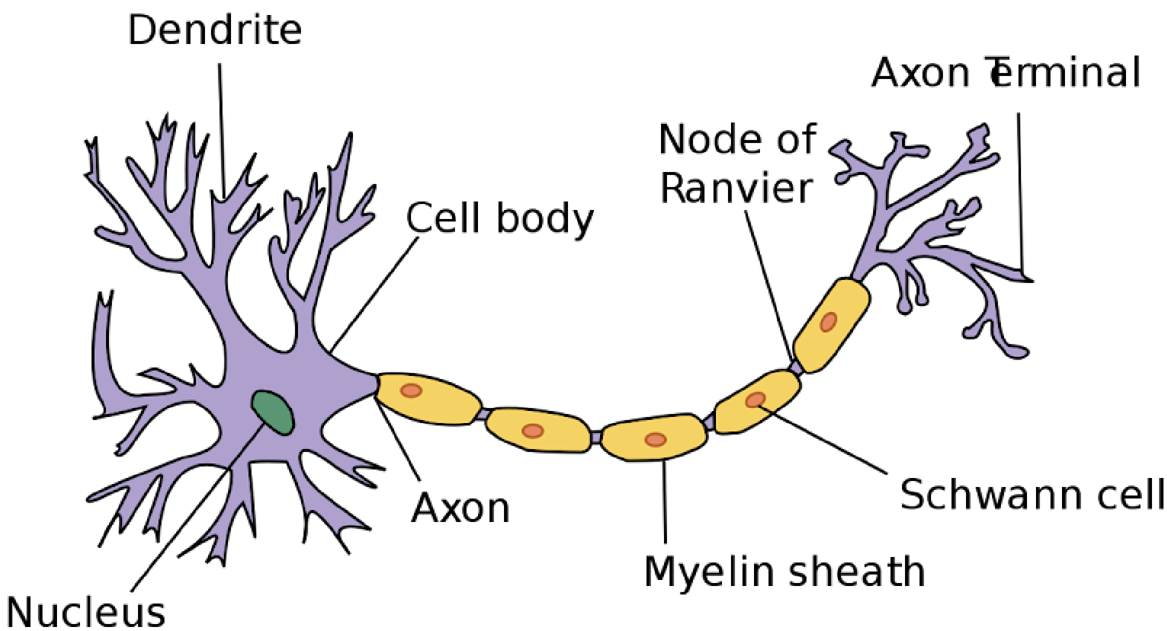
Red blood cells play no part in immune system; only transport oxygen and contain hemoglobin

Vaccines
- After an immune response, memory T-/B-cells are kept around
- "Remember" how to fight previous infection, allowing secondary immune response to be much quicker
- Vaccines are tiny doses of an antigen that have been modified so they're not dangerous, so memory cells are created without having to go through a real infection

AIDS
- Acquired immunodeficiency syndrome
- Caused by specific infection of helper T-cells by HIV
  - Helper T-cells wiped out, so that there is no immune system
  - Death is not caused by AIDS itself, but rather by an inability to fight off infections

<u>D, The Nervous System</u>

Neurons
- Functional unit of nervous system
- Receive and send neural impulses that trigger organisms' responses to their environment



Dendrites receive stimuli
Axon transmits signal
Nerve impulse begins at top of dendrites, passes through cell body, and moves down the axon

How Neurons Communicate

Within a neuron, the signal is called an **action potential**
- Wave of positive charge that sweeps down the axon
- In order for the signal to be clear, the cell must have a “normal”, non-positive state
- **Resting membrane potential**
  - Natural charge of a cell
  - Represents difference in charge from inside to outside
  - Nearly all cells in body have a negative resting state
- NEgative Resting potential result from 2 activities:
  - **Na^+K^+-ATPase pump**
    - Pushes 2 potassium ions into cell for every 3 sodium ions pushed out
    - Results in a net loss of positive charge in cell
  - **Leaky K^+ Channels**
    - Some potassium ion channels in membrane are “leaky”, allowing for a slow diffusion of K^+ out of cell
- Membrane potential is always negative in cell, and the neuronal membrane is said to be polarized

Action Potential

All-or-none response

If the stimulus has enough intensity to excite a neuron, the cell reaches its **threshold**

threshold=minimum amount of stimulus a neuron needs to respond

When threshold is reached, the cell fires its action potential

1. Reaching threshold

    An outside stimulus causes a slight influx of positive charge in the neuron

    When this influx causes the cell body to reach -50mV, threshold is reached

2.Sodium Channels open (**depolarization**)

    -50mV voltage causes the opening of many voltage-gated sodium channels near where the axon meets the cell body

    Sodium potassium pump has created a higher concentration of sodium outside cell

    When channels open, sodium ions flow in, increasing the charge

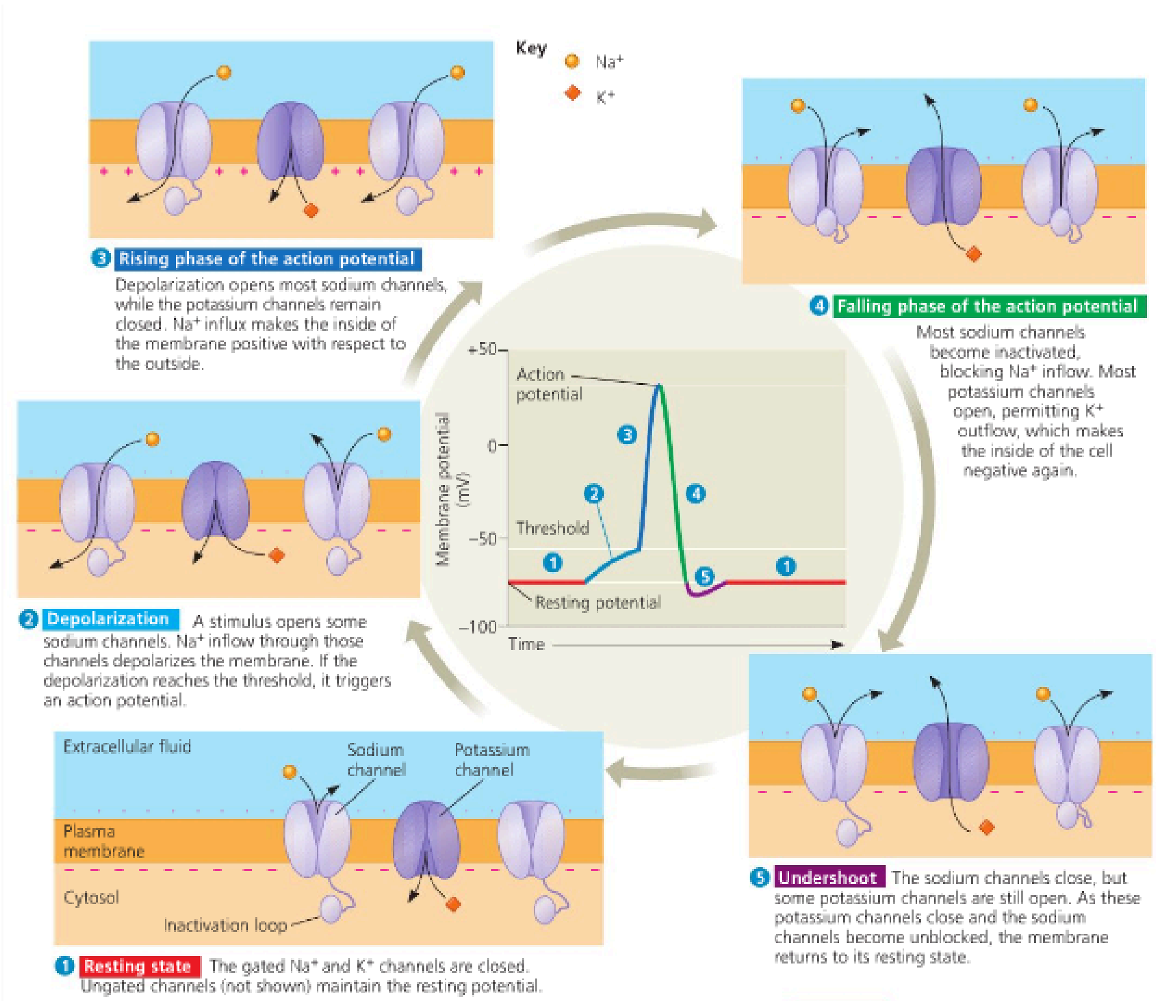
    Once the membrane reaches +35mV, sodium ion channels close again

3. Potassium Channels Open (**Repolarization**)

    As the sodium channels close, potassium channels open

    Potassium flows out of cell, decreasing membrane voltage

    Potassium channels close at -90mV, and cell returns to resting membrane potential



Ligand attaches to Na^+ gate, causing it to enter, increasing the charge near that area. The increase in voltage causes a chain reaction down the membrane of opening Na^+ gates until the charge is positive enough to allow the K^+ gates to open, decreasing the charge until it has returned to just below its resting state

Refractory Period

2 different refractory periods

1. Caused by sodium channels unable to open again right away
2. Cell dips below resting membrane potential

A greater stimulus is needed to reach threshold, so it is more difficult to initiate another action potential right away

Passing along the Signal

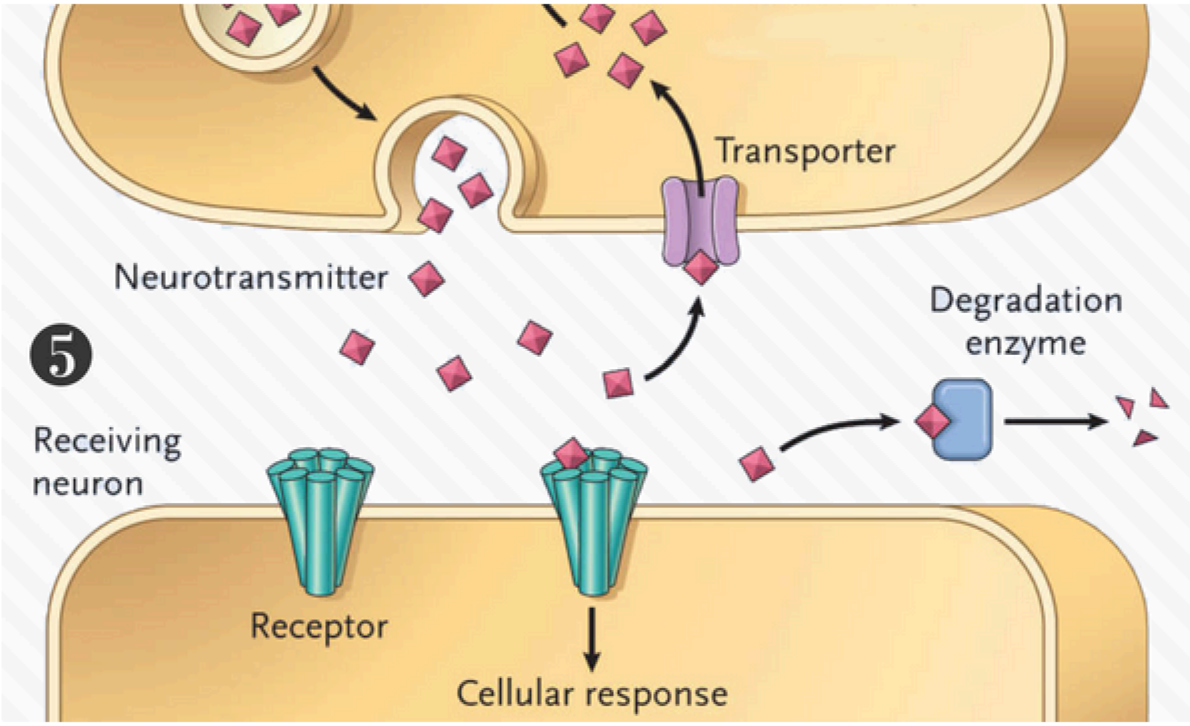
Impulse is transmitted down the axonal membrane until it reaches the **axon bulb**

When an impulse reaches the end of a axon, the axon releases chemicals called **neurotransmitters** into the **synapse** (space between the two membranes)

Cell before synapse=”presynaptic cell”

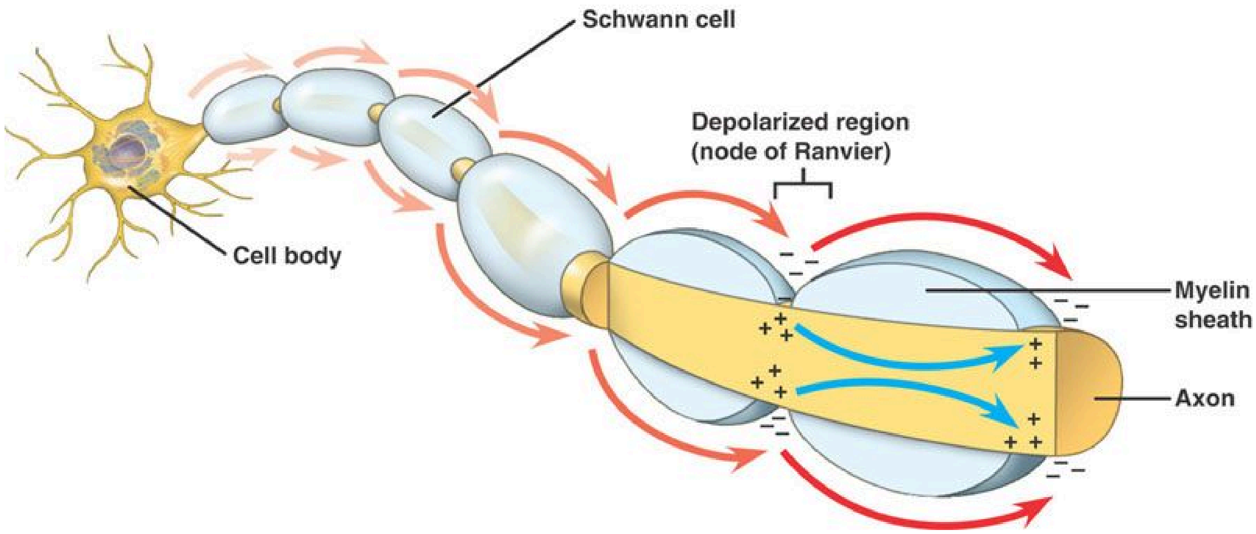
Cell after synapse=”postsynaptic cell”

Neurotransmitter diffuses across the synaptic cleft and binds to receptors on the dendrites of the next neuron, triggering an action potential in the cell



Speed of an Impulse

- **Schwann cells**
  - Supporting cells that wrap around axon
  - Produce the **myelin sheath**
    - Spaces between myelin sheaths=**nodes of Ranvier**
    - Speed of propagation of an impulse
      - Impulses jump from node to node instead of across membrane
      - Called **saltatory conduction**



Parts of the Nervous System

Central Nervous System=All neurons within brain and spinal cord

Peripheral nervous System=neurons outside brain/spinal cord

Stimulus-Decision-Response PAthway

Sensory neurons

Aka effector neurons

Receive impulses from the environment and bring them to body

Interneurons

Make decisions about what to with stimuli from sensory neurons

Motor neurons

Aka effector neurons

Transmit the decision from brain to muscles/glands to produce a response

E. The Endocrine System

Maintains homeostasis

Coordinates responses to stimuli

Hormones produced by **endocrine glands**

Hormones are chemical messengers with many functions

Ex.

Growth

Behavior

Development

Reproduction

Hormones flow in blood but only affect **target cells**

Operate by a negative feedback system

How Hormones Work

If a hormone is a steroid (lipid soluble), it can diffuse across the membrane of the target cell

Then binds to receptor protein in nucleus, regulating DNA transcription and protein production

If a hormone is a protein/peptide/amine, it must bind to a receptor on plasma membrane

- Causes signal cascade without hormone ever entering cell

F. Plant Structure and Function

- Plants take up water and mineral from below ground
- Plants take up CO_2 and light from above ground
- Tissues:
  - Dermal
  - Vascular
  - Ground tissues
- Root System
  - Rely upon sugar produced in photosynthesis
  - Root
    - Organ with important functions:
      - Anchoring the plant
      - Absorbing minerals and water
      - Storing carbohydrates
  - Most eudicots and gymnosperms have a taproot system, which consists of:
    - A tap root, the main vertical root
    - Lateral root, or branch roots, that arise from the taproot
  - Most monocots have a fibrous root system, which consists of:
    - Adventitious roots that arise from stems or leaves
    - Lateral roots that arise from the adventitious roots
  - In most plants, absorption of water and minerals occur near the root hairs, where vast numbers of tiny root hairs increase the surface area
- Shoot system
  - Rely on water and minerals absorbed by root system
  - Stems
    - stem=organ consisting of:
      - Alternating system of nodes, the points at which leaves are attached
      - Internodes, the stem segments between nodes
    - An axillary bud is a structure that has the potential to form a lateral shoot, or branch
    - An apical bud, or terminal bud, is located near the shoot tip and causes elongation of a young shoot
      - Apical dominance: apical buds maintain dormancy in axillary buds
  - Leaves
    - The leaf is the main photosynthetic organ of most vascular plants
    - Leaves generally consist of a flattened blade and a stalk called the petiole, which join the leaf to a node of the stem

Monocots and eudicots differ in the arrangements of veins, the vascular tissue of leaves

Most monocots have parallel veins

Most dicots have branching veins

Short-Distance Transport in Plants

xylem:H_2O and mineral from the roots up

Phloem: sugar from leaves to areas of need

Bulk-Flow=long distance

Transpiration

1. Water enters roots via osmosis
2. Water moves up xylem cells through capillary action

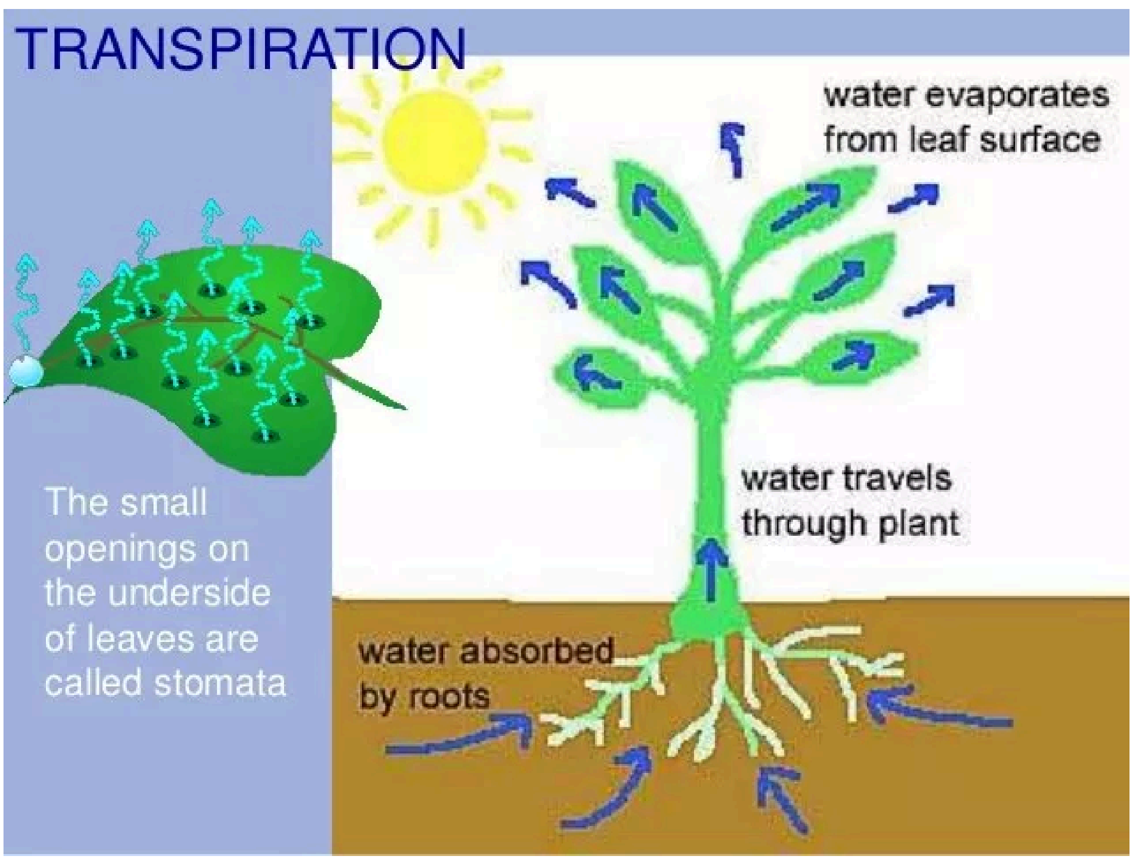
Adhesion to cell walls

Cohesion water to water

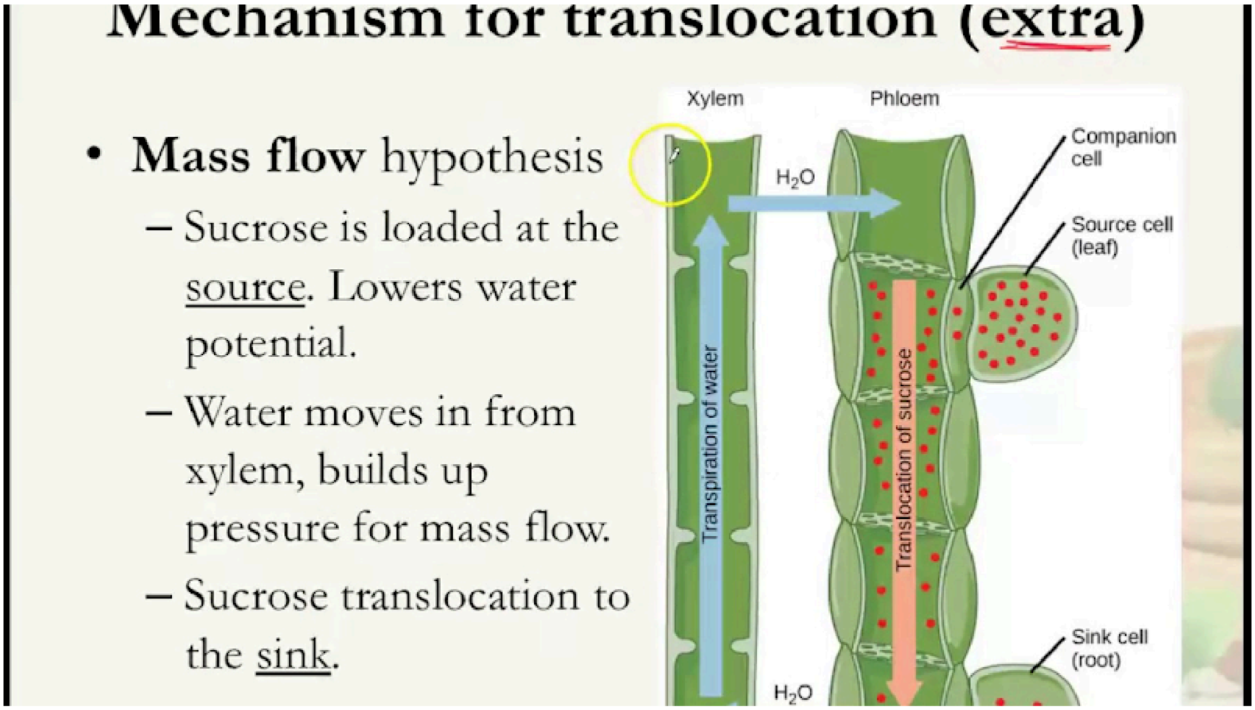
When the H_2O Molecule leaves through the stomata it pulls the next one up each H_2O molecule pulls on the one below all the way down to the leaves

3.Water is lost to the environment due to open stomata

stomata=open pores in leaves; brings in CO_2, H_2O exits



Translocation



Apoplastic=moving within cell walls
symplastic=moving directly through the plasmodesmata
Transmembrane=move straight through walls and membranes via water channels
filter/blockade
Casparian Strip
Waxy water impervious strip that prevents movement through cell walls
Forces transfer to symplastic method
Filters out toxins/other unneeded substances
Prevents leaks

UNIT IX: BEHAVIOR AND ECOLOGY

A. Behavior

Instinct
- Inborn, unlearned behavior
- Sometimes triggered by environmental signals called releasers
- Some only last part of an animal's life and are gradually replaced by a learned behavior
- **Fixed action pattern**
  - Not simple reflexes, but not conscious decisions

Learning
- Change in a behavior brought about by experience
- **Imprinting**
  - Recognize mother and follow her
    - If mother is absent, newborns will accept the first moving object as their mother
  - Used to recognize members of same species

- Occurs during critical period--window of time when the animal is sensitive to certain aspects of the environment
- **Classical Conditioning**
    - Aka **associative learning**
    - Associates a stimulus with a reward/punishment and acts accordingly
- **Operant Conditioning**
    - Aka **trial-and-error learning**
    - Animal learns to perform an act in order to receive a reward
    - Of behavior is not reinforced, conditioned response will be lost (extinction)
- **Habituation**
    - Animal learns not to respond to a stimulus
    - If an animal encounters a stimulus over and over, the response will gradually lessen and may disappear
- Circadian rhythm=daily internal clock

<u>B. How Animals Communicate</u>

- Use chemical/visual/electrical/tactile fro communication, esp. To influence mating and social behavior
- Social BEhavior
    - Agonistic
        - Aggressive behavior as a result of competition for resources
    - Dominance hierarchies
        - Often The most dominant male will become the leader of the group and will usually have best picking of food and females in the group
        - Once the hierarchy is established, competition and tension within the group is reduced
    - Territoriality
        - Common behavior when food/nesting sites in short supply
    - Altruistic Behavior
    - Unselfish behavior that benefits another organism in the group at the individual's expense
- Symbiotic Relationships
    - **Mutualism**
        - Both organisms benefit
    - **Commensalism**
        - One benefits, other is unaffected
    - **PArasitism**
        - One benefits, the other is harmed
- Plant Behavior
    - **Photoperiodism**
        - Plants flower in response to changes in the amount of daylight/darkness they recieve
    - Tropism
        - Turning in response to a stimulus

- **Phototropism**
  - Bend towards light
- **Gravitropism**
  - Stems: negative gravitropism (grow away from gravity)
  - Roots: positive gravitropism (grow into earth)
- **Thigmotropism**
  - How plants respond to touch
  - Ex. ivy grows around a post

<u>C. Ecology</u>

- ecology=study of living things in their environment
- **Biosphere**
  - Entire part of the earth where living things are
  - Divided into biomes divided into **biomes**
    - Massive areas classified by climate and plant life
- **Ecosystem**
  - Interaction of living and nonliving things
  - **Biotic vs. abiotic factors**
- **Community**
  - Group of populations interacting in the same area
  - Each organism has its own **niche**--its own position/function in a community
  - When two organisms occupy the same niche, they will compete for resources within that niche
  - **Food chain**
    - Describes The way different organisms depend on one another for food
  - 4 levels to food chain
    - **Producers**
      - Aka autotrophs
      - Make their own food via photo/chemosynthesis
      - **Primary productivity**
        - Gross productivity from photosynthesis cannot be measured because cellular respiration is occuring at the same time
        - Net productivity measures organic materials after photosynthetic organisms have taken care of their own cellular energy needs
          - Calculated by measuring oxygen production in light when both photosynthesis and cellular respiration are occuring
      - Produce all available food
      - Make up first trophic level
      - Possess highest **biomass** and greatest numbers
    - **Consumers**
      - Aka heterotrophs

Digest carbs of prey into carbon, hydrogen and oxygen in order to create energy and organic substances

Get their energy from the things they consume

Primary consumers feed directly on producers

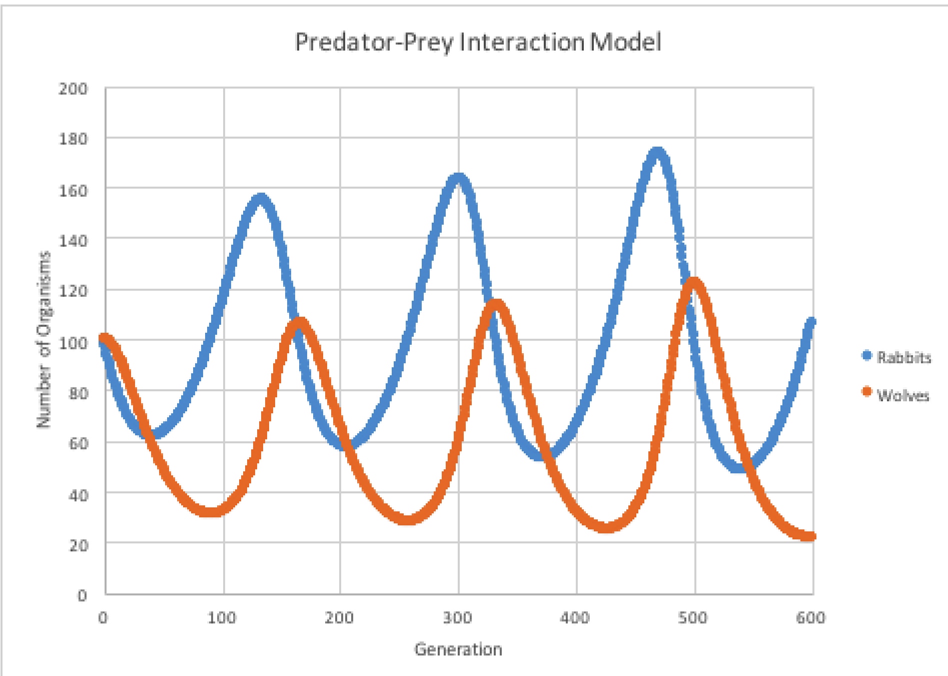
Aka herbivores

Make up second trophic level

Secondary consumers feed on primary consumers

Make up third trophic level

Tertiary consumers feed on secondary consumers; make up fourth trophic level



Decomposers

Break down organic matter into simple products

Ex. fungi/bacteria

Population

Group of individuals that belong to the same species and that are interbreeding

Keystone species

If removed from ecosystem balance will be undone very quickly

Dominant species

Most abundant/highest biomass

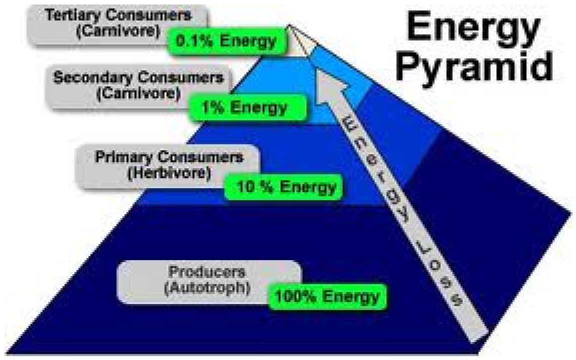
Affect the occurrence and distribution of other species

10% rule

In a food chain, only about 10% of energy is transferred from one level to the next

Other 90% used for respiration/digestion/running/etc,

Energy flow/biomass/numbers of members within an ecosystem can be represented in an ecological pyramid



Buildup of toxins

Downside of food pyramids is that when the consumers at the top eat something beneath the,. It is like they are eat the thing and thing it ate and the thing it ate, etc.

If there is a toxin in the environment, consumers are getting the most of it because it becomes more concentrated at each level

D. Population Ecology

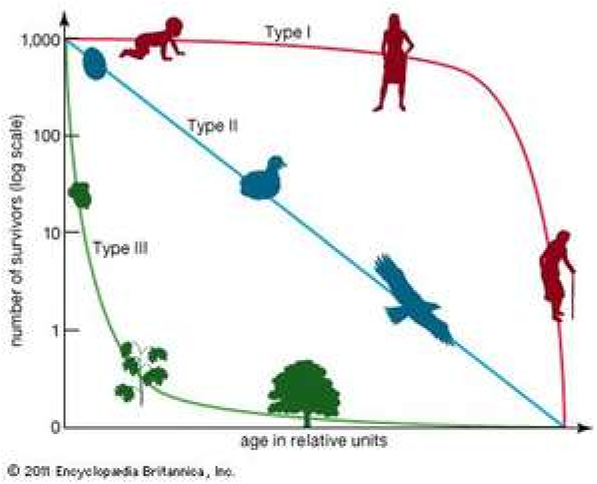
When examining a population, look at:

Size

Density

Distribution patterns

Age structure



Population growth

$$r = (births - deaths)/N$$

$$\frac{Change\ in\ population\ size}{change\ in\ time} = Birth\ Rate - death\ rate$$

Carrying capacity

Maximum number of individuals a habitat can support

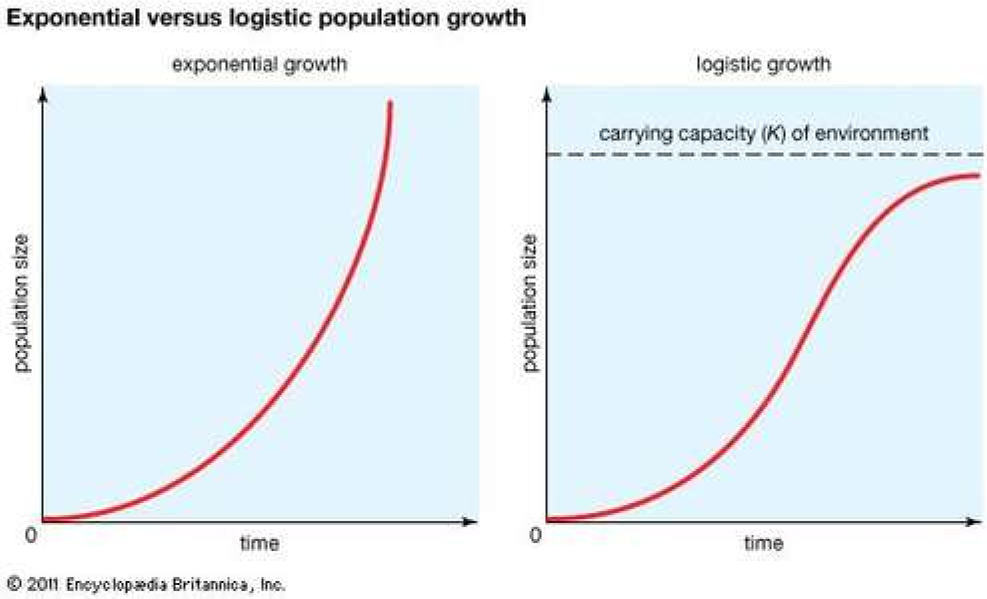
Most Populations do not reach carrying capacity due to limiting factors

Density independent vs. Density independent factors

Affect population regardless of size vs. effects depend on population density

E. Exponential Growth

Exponential growth occurs when a population is in an ideal environment
Logistic growth occurs when a population is restricted; S-shaped curve



R-strategists

tend to thrive in areas that are barren or uninhabited

Reproduce as quickly as possible

K-strategists

Organisms are best suited for survival in stable environments

Tend to be large animals

Long lifespans

Tend to produce few offspring

Don't ave contend with competition from other organisms

F. Ecological SUCCession

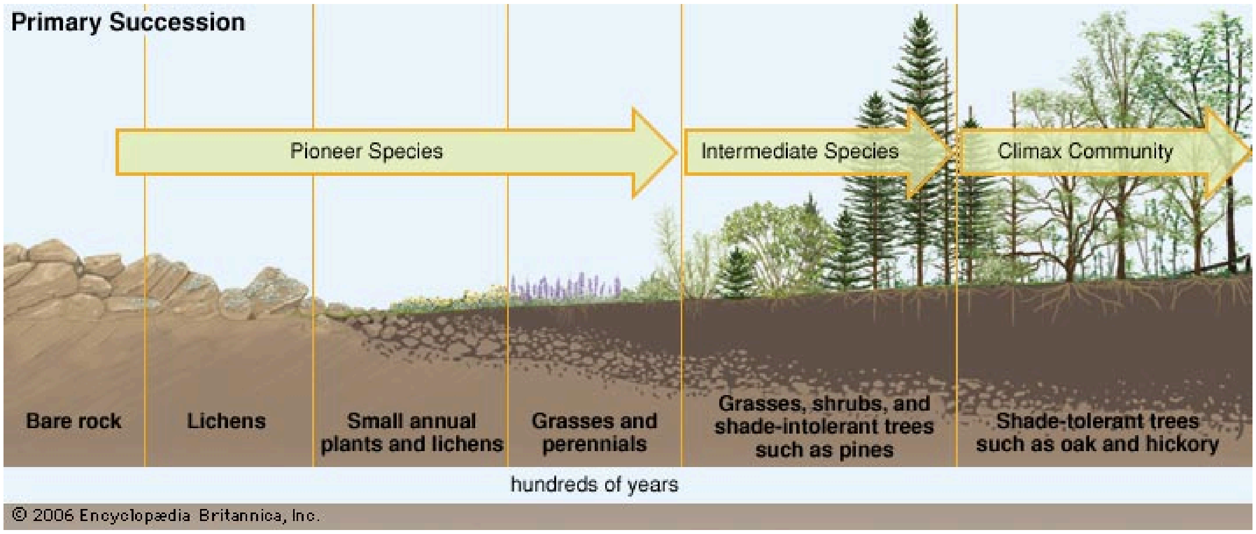
Ecological succession refers to the predictable procession of plant communities over a relatively short period of time

Primary succession

Process of ecological succession in which no previous organisms have existed

sere

1. Lichens (**pioneer organisms)**
2. mosses/ferns
3. Rough grasses
4. Evergreen trees
5. Deciduous trees



Final community=**climax community**

Secondary succession

Same as primary, but starts off with grasses instead of lichens

Occurs when habitat/community has been destroyed/disrupted

G. Human Impact on the Environment

Greenhouse effect

Atmospheric concentration of CO_2 have increased due to the burning of fossil fuels and forests, contributing to the warming of the Earth

Higher temperatures cause ice caps to melt, flooding

Can change precipitation patterns, plant/animal populations/agriculture

Ozone depletion

Caused by pollution (ex. CFCs)

Ozone (O_3) forms when UV radiation reacts with O_2

Ozone protects earth from excessive UV radiation

Loss can increase genetic defects and cancer

Acid Rain

Burning of fossil fuels produces pollutants such as SO_2 and NO_2

When these compounds interact with water in clouds, acids are created

Acidic rain causes lower pH in aquatic ecosystems, damaging water systems, plants, and soil, and kills fish

Desertification

When land is overgrazed by animals, it turns grasslands into deserts and reduces the available habitats for organisms

Deforestation

When forests are cleared (esp. By slash and burn methods), erosion, floods, and changes in weather patterns can occur

Pollution

Toxic chemicals in environment

Biomagnification

Reduction in biodiversity

As different habitats have been destroyed many plants and animals have become extinct

Some of these plants could have provided us with medicines and products that may have been beneficial