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The Ultimate AP Biology Exam Study Guide for the 2019-2020 Administration

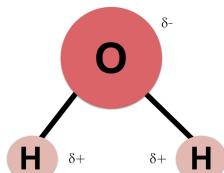
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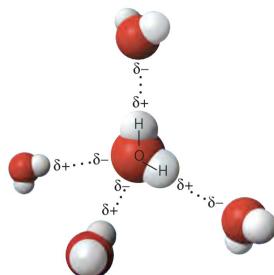
Unit 1: Chemistry of Life

1.1 Structure of Water and Hydrogen Bonding

- Formula of water: H₂O (One oxygen atom bound to two hydrogen atoms)



- Water is polar so its electrons are shared unequally
 - This causes hydrogen bonding, which are constantly breaking and reforming. When the H₂O molecules bond the attraction forms between the oxygen and hydrogen.
 - Slightly negative oxygen and slightly positive hydrogen are attracted
 - Attraction forms a weak bond between the two atoms
 - Gives water some extra structure and order



- Several properties of water are useful in sustaining life
 - Cohesion: hydrogen bonding keeps water close together
 - Applications of cohesion: in plants, water is pulled up from the roots to the leaves because as water molecules evaporate, hydrogen bonds cause other water molecules to be pulled along through the veins of the plant
 - Surface tension: measure of difficulty to stretch/break the surface of a liquid
 - Water has a greater surface tension than most other liquids since hydrogen bonding orders water molecules more than other liquids
 - Adhesion: water's polarity allows it to cling to other substances through hydrogen bonding
 - eg. in plants, hydrogen bonding binds water to cell walls, moving water up the plant against gravity
 - Capillary Action: Combination of adhesion and cohesion that allows water to travel up through a tube.

- High Specific heat Capacity: the amount of heat/cold that must be added to change the temperature of a liquid. Water takes a lot of heat/cold to change the temperature making it ideal for organisms to live in. helps sustain marine life
- High Heat of Vaporization: Water takes a lot of heat to turn into water vapor which reduces water loss due to transpiration, evaporative cooling (as liquid evaporates, surface of liquid cools down)
- Water as a solvent ("universal" solvent → solvent of life)
 - Water dissolves all other polar molecules
 - Hydrophilic (polar): any substance with an affinity of water
 - Hydrophobic (nonpolar): any substance that seems to repel water
- Hydrogen Bonding: Ice floats on water (it's less dense than water): hydrogen bonds in the crystal lattice solid keeps water molecules far apart, making the substance less dense (the bonds stabilize)
 - Application: ponds, lakes, and oceans don't freeze solid in winter
 - Floating ice insulates water below which protects aquatic life
- Acids and Bases
 - Acids are molecules that release hydrogen ions and lower pH (anything lower than 7 is acidic)
 - Bases are molecules that release hydroxide ions (OH^-) and raise the pH (anything greater than 7)
 - Water is neutral on pH scale ($\text{pH}=7$)
 - Buffer: substance that minimizes changes in concentrations of H^+ and OH^-
 - Important because slight changes in pH could damage cells and living organisms from performing properly

1.2 Elements of Life

- Organisms MUST exchange matter with the environment to grow, reproduce, and maintain organization
- Carbon: used to build bio macromolecules like carbohydrates, proteins, lipids, and nucleic acids. If something is organic, it contains carbon.
 - Used in storage compounds and cell formation in all organisms
 - All living organisms are based on carbon (backbone of life)
 - Carbon is especially useful because it can form 4 single covalent bonds to many other atoms
- Hydrogen and Oxygen: These, like carbon are in all carbs, lipids, proteins, and nucleic acids
- Hydrocarbons: molecules that consist of carbon and hydrogen. Many organic molecules have regions of hydrocarbons.
- Nitrogen: used to build proteins and nucleic acids
- Phosphorus: used to build nucleic acids and some lipids (phospholipids)
- Sulfur: Used in proteins to form S-S bonds or disulfide bridges during the tertiary structure. These are extremely strong covalent bonds
- Isomers: molecules that have similar structures but different properties
 - Types of Isomers:
 - Structural Isomers: same molecular formulas have different bonding patterns
 - *Cis-Trans* Isomers: same formula but functional groups rotated into different orientation in 3D space
 - Enantiomers: pair of molecules that are mirror image of each other

1.3 Introduction to Biological Macromolecules

- The structure and function of polymers are derived from the way that the monomers are assembled

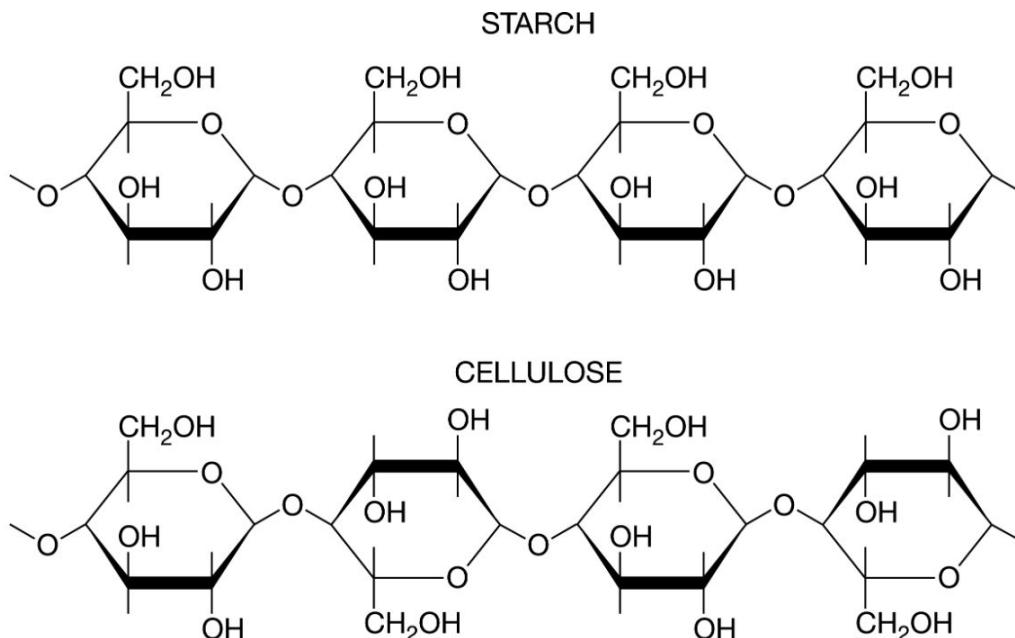


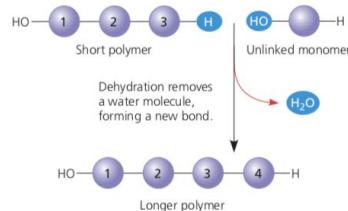
Figure 1. Comparison of segments of starch and cellulose

- Starch and cellulose are made of the same monomers but these monomers are assembled differently making some stronger (like cellulose).
- Functional groups: chemical groups that are known to affect molecular function in chemical reactions
 - Many are found in macromolecules that help modify their traits/function

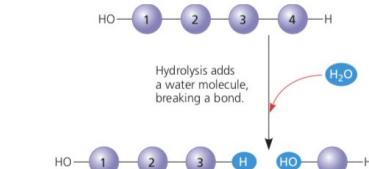
Amino	Sulphydryl	Phosphate	Methyl	Carboxyl
Amines	Thiols	Organic Phosphates	Methylated Compounds	Carboxylic acids or organic acids
Makes up one of the ends of an amino acid	In tertiary structure of proteins, disulfide	* Contributes a negative charge in DNA	* Common nonpolar functional	* Makes up one of the ends of an

(N terminus)	bridges between amino acids with these groups are formed	* Breaking off a phosphate can release a lot of energy (ie. ATP) group * Good identifier of nonpolar amino acids	group * Good identifier of nonpolar amino acids	amino acid (C terminus)
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- Polymer: long molecule consisting of many similar or identical building blocks linked by covalent bonds
- Monomers: the repeating units that are the building blocks of a polymer,. These can also have functions of their own outside of polymerization
- Polymers are created through a dehydration reaction
 - A water molecule is lost (one monomer contributes a hydrogen, the other contributes a hydroxyl group), which allows for two monomers to be covalently bonded



- Facilitated by enzymes
- Polymers are disassembled through a hydrolysis reaction:
 - Reverse of dehydration: water molecule is added which splits the bond and adds a hydroxyl group to one end and a hydrogen to the other end



- Facilitated by (hydrolytic) enzymes

1.4 Basic Properties of Biological Macromolecules

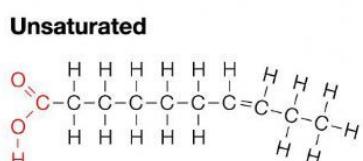
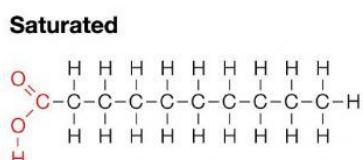
- In nucleic acids, biological information is encoded in sequences of nucleotide monomers.
 - Each nucleotide has structural components: a five-carbon sugar (deoxyribose or ribose), a phosphate, and a nitrogen base (adenine, thymine, guanine, cytosine, or uracil).
 - DNA and RNA differ in structure and function.
- In proteins, the specific order of amino acids in a polypeptide (primary structure) determines the overall shape of the protein.
 - Amino acids have directionality, with an amino (NH_2) terminus and a carboxyl (COOH) terminus.
 - The R group of an amino acid can be categorized by chemical properties (hydrophobic, hydrophilic, or ionic), and the interactions of these R groups determine structure and function of that region of the protein.
- Complex carbohydrates comprise sugar monomers whose structures determine the properties and functions of the molecules.
 - Short term energy storage
- Lipids are nonpolar macromolecules
 - Differences in saturation determine the structure and function of lipids.
 - Phospholipids contain polar regions that interact with other polar molecules, such as water, and with nonpolar regions that are often hydrophobic.

1.5 Structure and Function of Biological Macromolecules

- Carbohydrates
 - Carbohydrates are used to store energy (generally short-term).
 - Carbohydrates are made of multiple monosaccharides (which are called simple sugar or monomers ("building blocks") connected by covalent bonds.
 - Carbohydrates are made up of Carbon, Hydrogen, and Oxygen.
 - A polysaccharide is a complex carbohydrate made up of multiple monosaccharides bonded together. These can be linear or branched
 - Illustrative examples of Carbohydrates are:
 - Starch: Used by plants to store energy.
 - Cellulose: Used by plants to create rigid walls.
 - Chitin: Used by some animals to create external skeletons.
 - Glycogen: Used by animals to store energy.

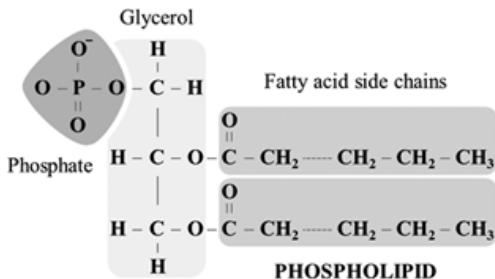
- Lipids

- Lipids are made up of multiple units called fatty acids and glycerols, which are made up of carbon, oxygen, and hydrogen atoms.
 - There are two main types of fatty acids: saturated and unsaturated fatty acids.
 - Saturated fatty acids : A straight chain where carbon atoms bond to as many hydrogen atoms as possible. Single bond between Carbon atoms. Solid at room temperature.
 - Unsaturated fatty acids: A bent chain where carbon atoms are not bonded to as many hydrogen atoms as possible. Double bond between Carbon Atoms. Liquid at room temperature.

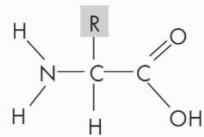


- Triglycerides :
 - Triglycerides are made up of a glycerol molecule and three fatty acid chains (Tri) attached to it.
 - Dehydration synthesis allows the hydroxyl group (OH) from the Glycerol and the carboxyl group (COOH) to bond and form an ester linkage.

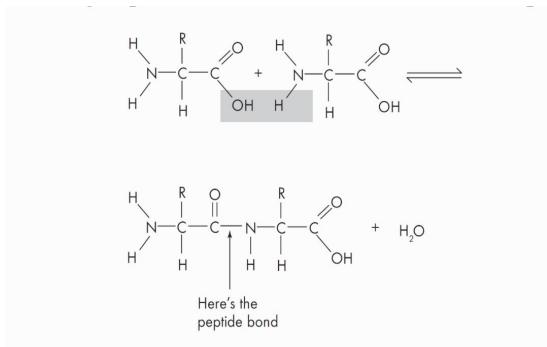
- Phospholipids
 - Phospholipids contain two fatty acid tails and a negatively charged phosphate head



- The shape of phospholipids is EXTREMELY important. The fatty acid tails are nonpolar which means they are hydrophobic (water is polar). The phosphate head is negatively charged polar which means they are hydrophilic.
- They ensure that the plasma membrane is semipermeable only letting some molecules through.
- Cholesterol
 - A four-ringed molecule found in the cell membrane. It helps stabilize the plasma membrane and make it more fluid
- Proteins
 - Proteins perform most of the work in our cell and are crucial for structure, function, and regulation of tissues and organs.
 - Amino acids are the building blocks of proteins.
 - There are roughly around 20 Amino acids
 - There are four important parts of an amino acid around a central carbon: amino group (NH₂), carboxyl group (COOH) , hydrogen, and an R-Group.



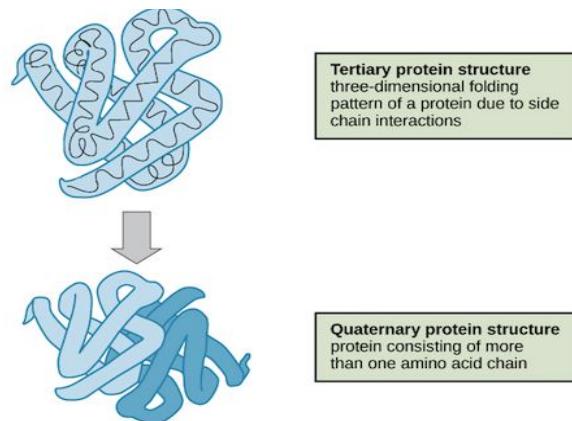
- Amino acids ONLY differ in their R-Group (side chain) and are thus classified based on the R-group properties (hydrophobic (nonpolar), hydrophilic (polar), ionic)
- Polypeptides
 - Polypeptides are strings of amino acids. Amino acids bond together with dehydration synthesis in a peptide bond. The carboxyl group (COOH) of one amino acid and the amino group (NH₂) of another amino acid combine when they combine

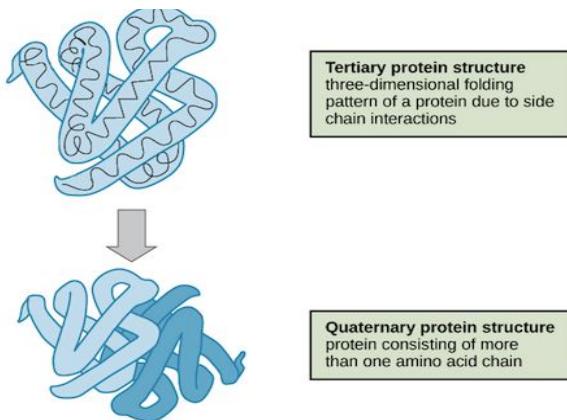


A water molecule is removed.

- Protein Structure Phases

- Polypeptides fold, bond, and glob into different structures to form a protein. The four elements of protein structure determine the function of a protein.
- There are four structures that polypeptides have to undergo.
 - Primary Structure: Linear sequence of amino acids connected with covalent bonds. Determined by amino acid sequence
 - Secondary Structure: Polypeptide begins to twist, which forms either a coil (Alpha Helix) or Zigzagging pattern (Beta-pleated sheets)
 - Polypeptides twist because of hydrogen bonding.
 - Tertiary Structure: The 3D structure caused by interactions between R-Groups. Hydrophobic amino acids are inside the protein, hydrophilic are outside. Charges go together. This structure minimizes free energy and uses hydrogen and covalent bonding (covalent through disulfide bridges from cysteine r group on some amino acids)
 - Quaternary Structure: Multiple tertiary structures bonded together. Not all polypeptides reach this structure.



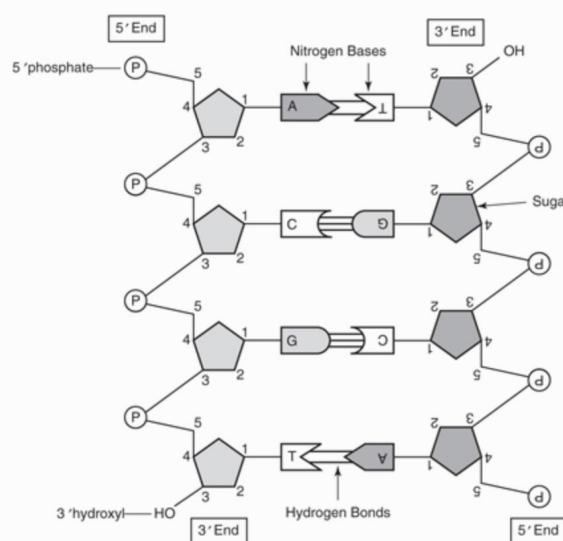
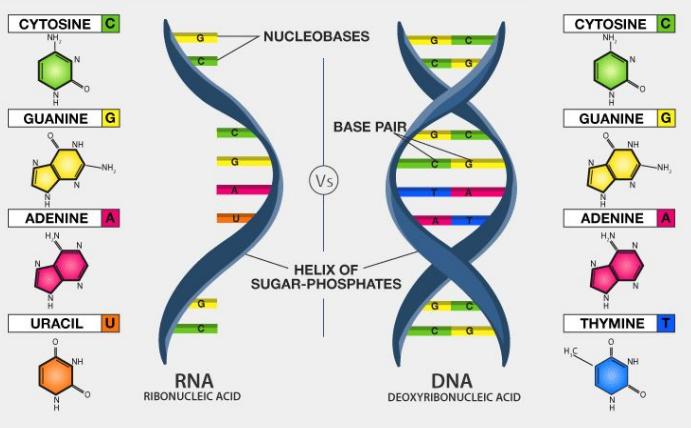


Macromolecule	Monomer	Polymer	Function(s)	Elements
Carbohydrate	Monosaccharide (eg. Glucose)	Polysaccharide (eg. Starch, Glycogen, Cellulose)	Provide energy	C, H, O
Lipids	Glycerol & Fatty acid tails.	Triglycerides, Cholesterol, phospholipid.	Store energy for the cell. Make the cell membrane	C, H, O, sometimes P
Proteins	Amino acids.	Polypeptide.	Growth, catalyse, messengers, structure, regulation, balance, transport, and storage	C, H, O, N, S.

1.6 Nucleic Acids

- The main nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)
 - DNA and RNA contain hereditary information.
- Nucleic acids are polymers that are made of nucleotides.
 - Nucleotides consist of a phosphate (P), 5-carbon sugar deoxyribose or ribose, and nitrogen bases that match with each other.
 - Nitrogenous bases: adenine (A), cytosine (C) , guanine (G), thymine (T), uracil (U). (A+G are purines, U+T+C are pyrimidines)
 - DNA: Adenine, cytosine, guanine, and thymine
 - Adenine \leftrightarrow Thymine with double h-bonds
 - Cytosine \leftrightarrow Guanine with triple h-bonds
 - RNA: Adenine, cytosine, guanine, and uracil
 - Adenine \rightarrow Uracil
 - Cytosine \leftrightarrow Guanine
- DNA consists of two strands in a double helix structure. One strand runs from 5' to 3' and one runs from 3' to 5'. 3' is hydroxyl and 5' is phosphate. These strands are called antiparallel
- There are covalent bonds that connect the nucleotides together in RNA and DNA and there are hydrogen bonds that connect the nitrogenous bases together allowing for DNA replication
- The basic structural differences between DNA and RNA include the following:
 - DNA contains deoxyribose and RNA contains ribose.
 - RNA contains uracil and DNA contains thymine.
 - DNA is usually double stranded; RNA is usually single stranded.
 - The two DNA strands in double-stranded DNA are antiparallel in directionality.

DIFFERENCE BETWEEN DNA AND RNA



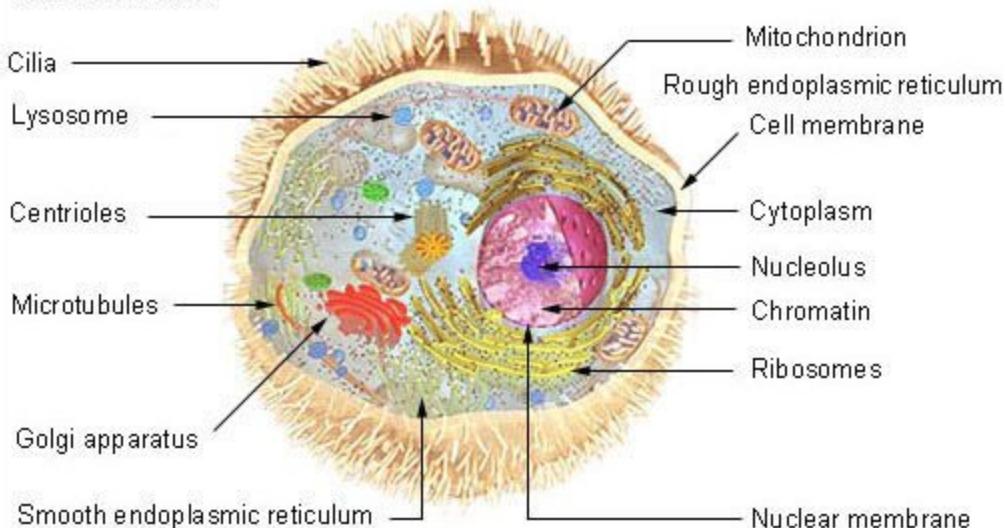
(Image Above: This is an example of the nucleotide DNA).

(Notice how T is absent in RNA and U is absent in DNA)

Unit 2: Cell Structure and Function

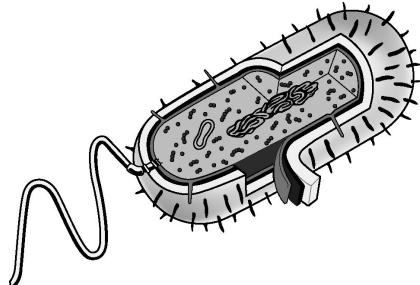
2.1 Cell Structure: Subcellular Components

Cell Structure



- *Prokaryotic Cells (Prokaryotes)*

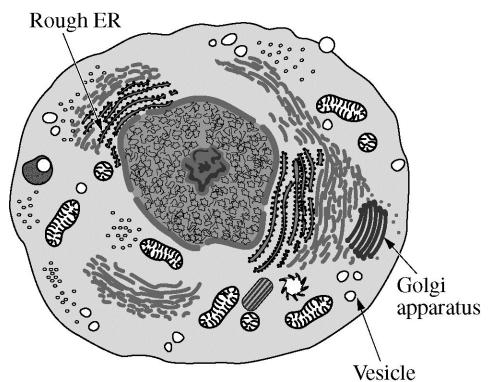
- No internal membranes: no nuclear membrane, ER, mitochondria, vacuoles, or other organelles
- Circular, naked DNA
- Ribosomes are very small
- Metabolism is anaerobic or aerobic
- Cytoskeleton absent
- Mainly unicellular
- Cells are very small ($1\text{-}10\mu\text{m}$)



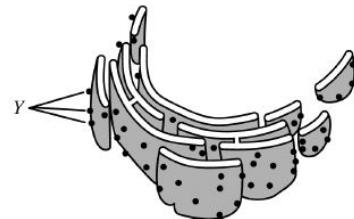
- *Eukaryotic Cells (Eukaryotes)*

- Contains distinct membrane-bound organelles
- DNA wrapped with histone proteins into chromosomes
- Ribosomes are larger
- Metabolism is aerobic
- Cytoskeleton present
- Mainly multicellular with differentiation of cell types
- Cells are larger ($10\text{-}100\mu\text{m}$)

- Organelles

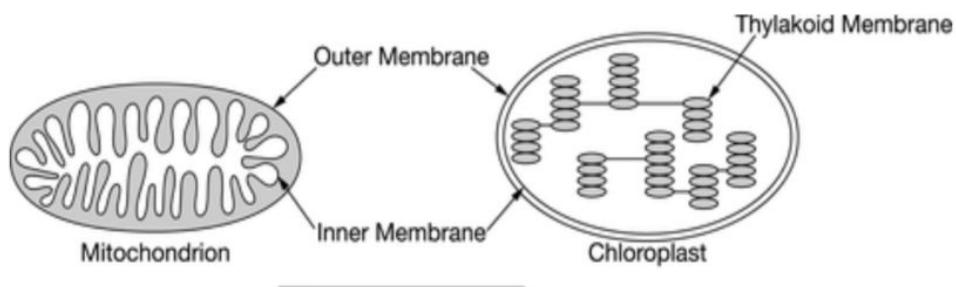


- Ribosomes
 - Made of rRNA and proteins
 - Synthesizes proteins
 - Found in all forms of life (Common Ancestor)
- Rough ER
 - Studded with ribosomes (represented by Y) and produces proteins
 - Compartmentalizes the cell
- Smooth ER
 - Helps in the synthesis of steroid hormones, like sex hormones, and other lipids
 - Stores Ca^{++} ions in muscle cells to facilitate normal muscle contractions
 - Detoxifies drugs and poisons from the body
- Golgi Body
 - Process and package substances produced in the rough ER and secretes the substances to other parts of the cell or to the cell surface for export.
 - Set of highly folded flattened membranes specialized for protein modification, packaging, and transport
- Mitochondria
 - Site of "cellular respiration"
 - Has a inner series of membranes called "cristae"
 - Double membrane - outer membrane is smooth & inner membrane convoluted (folded)
- Lysosomes
 - Membrane-enclosed sacs that contain (hydrolytic) enzymes used for digestion.
- Vacuoles
 - Membrane-bound structures used for storage
 - Plants - single large central vacuole
 - Animal- Used for exocytosis and endocytosis
- Chloroplasts (plants only)
 - Specialized organelles that are found in photosynthetic algae and plants.
 - Double outer membrane
 - Contains inner membranes called thylakoids
- Nucleolus (Prokaryotes)
 - Site of ribosomal RNA (rRNA) synthesis



2.2 Cell Structure and Function

- Organelles
 - Ribosomes
 - Endoplasmic Reticulum (ER)
 - Provides mechanical support
 - Carries out protein synthesis on membrane-bound organelles (Rough ER)
 - Helps in transport of proteins
 - Golgi Body
 - Mitochondria
 - ATP Production in aerobic condition
 - Double membrane provides compartments for the different metabolic reactions
 - The Krebs Cycle (citric acid cycle) occurs in the matrix of the mitochondria.
 - Electron Transport occur in the inner mitochondrial membrane
 - Lysosomes
 - Helps in apoptosis (programmed cell death)
 - Hydrolytic enzymes helps in digestion
 - Helps with the recycling of cells organic molecules
 - Vacuoles
 - Helps in storage and release of macromolecules and cellular waste products.
 - In plants, vacuoles helps in maintaining turgor pressure
 - Chloroplasts
 - Thylakoids - organized into stacks called "grana"
 - Light-dependent reaction (of photosynthesis) occurs in the grana
 - Stroma - fluid within the inner chloroplast membrane and outside of the thylakoid
 - Carbon Fixation Cycle (Calvin-Benson cycle) occurs in the stroma

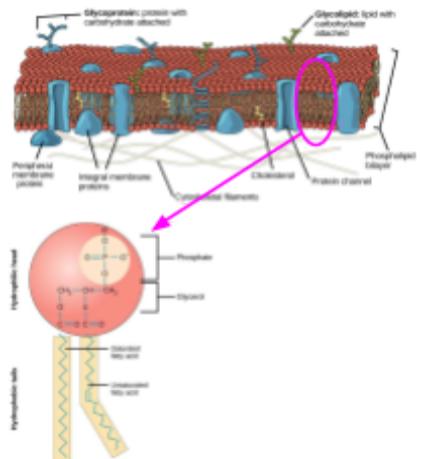


2.3 Cell Size

- As Volume increases, Surface Area decreases.
 - Surface area-to-volume ratios affect the ability of a biological system to obtain resources, remove waste products, acquire or dissipate heat (thermal energy), and exchange energy (and chemicals) with the environment.
 - Equations (Volume):
 - Volume of Sphere = $\frac{4}{3}\pi r^3$
 - Volume of Cube = s^3
 - Volume of Rectangular Solid = $l \times w \times h$
 - Volume of Cylinder = $\pi r^2 h$
 - Equations (Surface Area):
 - Surface Area of Sphere = $4\pi r^2$
 - Surface Area of Cube = $6s^2$
 - Surface Area of Rectangular Solid = $2lh + 2lw + 2wh$
 - Surface Area of Cylinder = $2\pi rh + 2\pi r^2$
 - Key:
 - r = radius
 - l = length
 - h = height
 - w = width
 - s = length of one side of a cube
1. The surface area of the plasma membrane must be large enough for it to exchange materials properly-
 - a. These limitations can restrict cell size and shape. Smaller cells typically have a higher surface area-to-volume ratio and more efficient exchange of materials with the environment
 - b. As cells increase in volume, the relative surface area decreases and the need for internal resources increases.
 - c. More complex cellular structures (e.g., membrane folds) are necessary to properly exchange materials with the environment.
 - d. As organisms increase in size, their surface area-to-volume ratio decreases, affecting properties like rate of heat exchange with the environment.

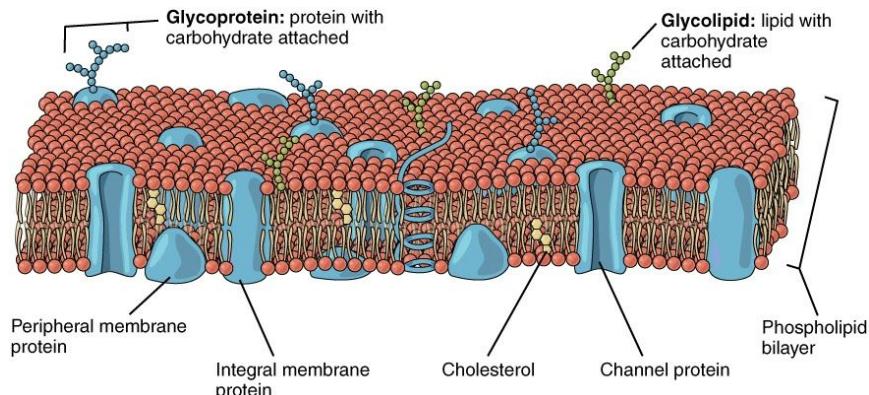
2.4 Plasma Membrane

- Plasma Membrane - a selectively permeable membrane that regulates the material that is allowed for things to pass through.
 - Phospholipid Bilayer -



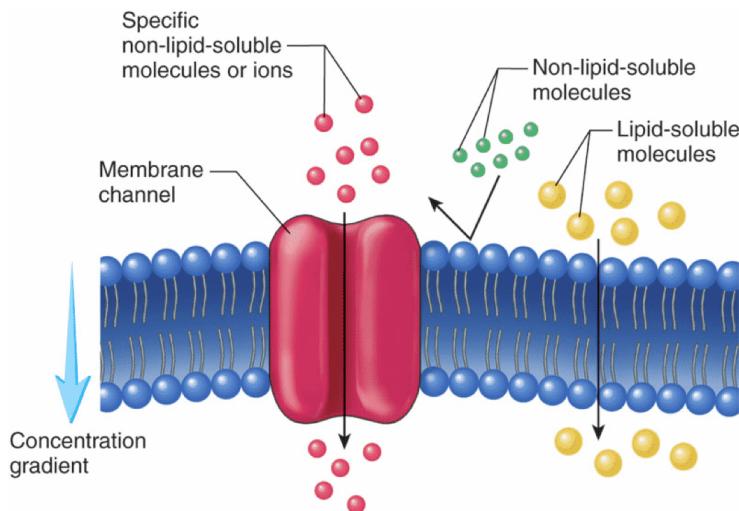
- Hydrophilic region (Phosphate heads) - likes aqueous environments
- Hydrophobic region (Fatty acid tails) - dislikes aqueous environments
- Integral Proteins -(have nonpolar regions that) span the hydrophobic interior of the membrane
- Peripheral proteins - loosely bound to membrane
- Cholesterol Molecules - embedded inside of the bilayer for stabilization
 - Low temp.: prevents from getting too rigid
 - Hot temp.: decrease membrane fluidity
- Cell membrane's structural framework has proteins, steroids, glycoproteins, and glycolipids that flow around the surface

- Each molecule has different functions that relate to how a cell behaves.



2.5 Membrane Permeability

- The structure of cell membranes allows them to be selectively permeable
 - Selective Permeability: the ability of certain molecules to be able to pass the phospholipid bilayer.
 - Factors that influence cell membrane fluidity
 - Temperature:
 - cold → rigid and may break without cholesterol
 - hot → won't hold shape
 - Cholesterol:
 - cold → fill in gaps → increase fluidity
 - hot → pulls phospholipids together, decrease fluidity
 - Saturated/ Unsaturated fatty acid tails
 - Saturated: no double bonds, straight tails → maximize interactions → decreases fluidity
 - Unsaturated: double bonds, crooked, kinked tails → increase fluidity
 - Examples of things that can pass through a cell membrane:



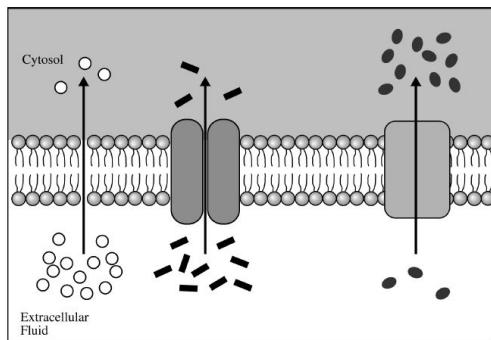
Characteristic of Molecule	Example, and how they cross
Small, nonpolar	O_2 , CO_2 , N_2 Pass through between lipids, diffusion
Large polar molecules or ions	Glucose, sodium ions (Na^+), Pass through channel proteins (imbedded proteins and transport proteins)
Polar, uncharged	H_2O , Through aquaporins; others pass between lipids
Large, nonpolar	Pass slowly between lipids

- Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments
 - Cell walls of plants, prokaryotes, and fungi are composed of complex carbohydrates (mainly cellulose)
 - Cellulose → fibers called microfibrils

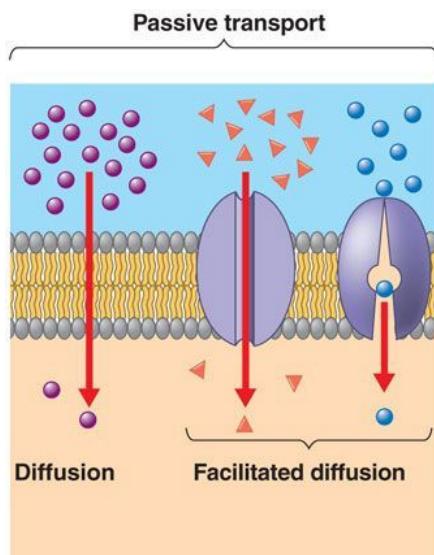
2.6 Membrane Transport

Passive Transport: net movement of molecules from high concentration to low concentration without the direct input of metabolic energy

- Plays a primary role in the import of materials and the export of waste.
- Example of passive transport: diffusion/ facilitated diffusion

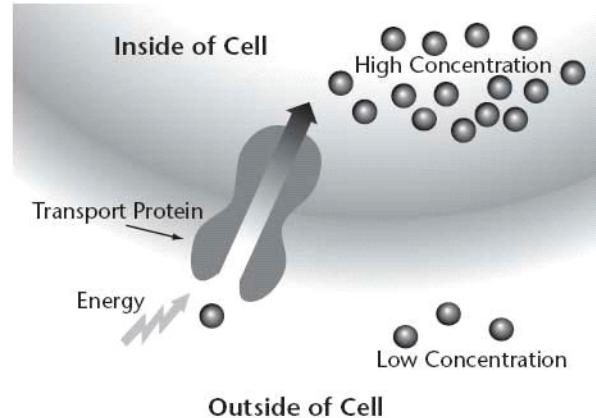


- Diffusion: substance moves from an area of higher concentration to an area of lower concentration without the help of any transmembrane integral protein.
 - The selective permeability of the cell membrane (ie permeability due to polar head and non-polar hydrophobic tail) allows for diffusion across the membrane
 - Because the cell is semipermeable, only small, uncharged substances like CO_2 and O_2 can easily diffuse across it.
- Facilitated Diffusion: Charged ions or large molecules require assistance to move across the membrane.



Active Transport: Requires the direct input of energy to move molecules from regions of low concentration to high concentration.

- Requires assistance from carrier proteins (not channel proteins) which change conformation when ATP hydrolysis occurs.
- Example of active transportation: selective permeability of membranes like the sodium-potassium pump, which moves sodium ions to the outside of the cell and potassium ions to the inside of the cell.
 - Allows formation of concentration gradients of solutes across the membrane

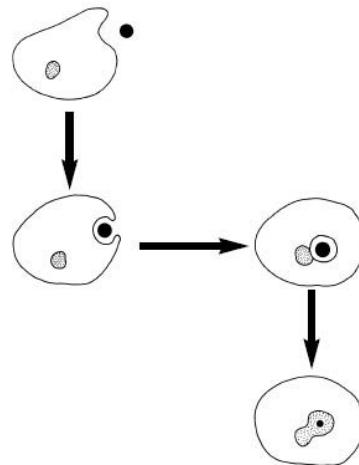


Channel Proteins are not used in active transport because substances can only move them along the concentration gradient.

Endocytosis - Cell takes in macromolecules and particulate matter by forming new vesicles derived from the plasma membrane

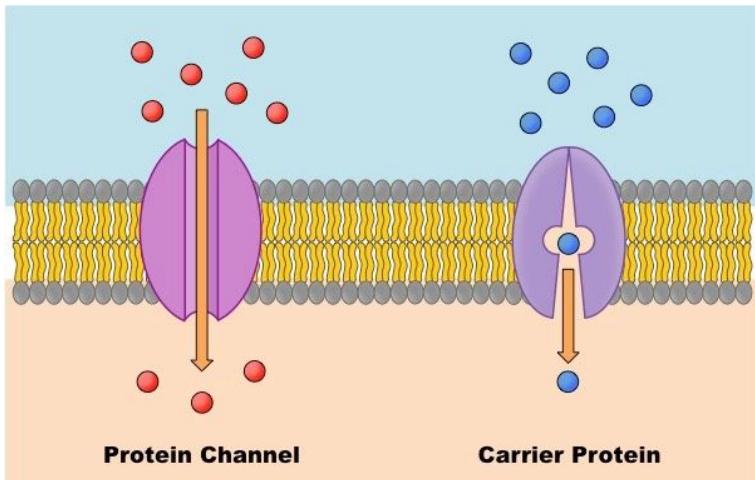
Exocytosis - internal vesicles fuse with the plasma membrane and secrete large macromolecules out the cell

- Both of these need energy and therefore are forms of active transport.



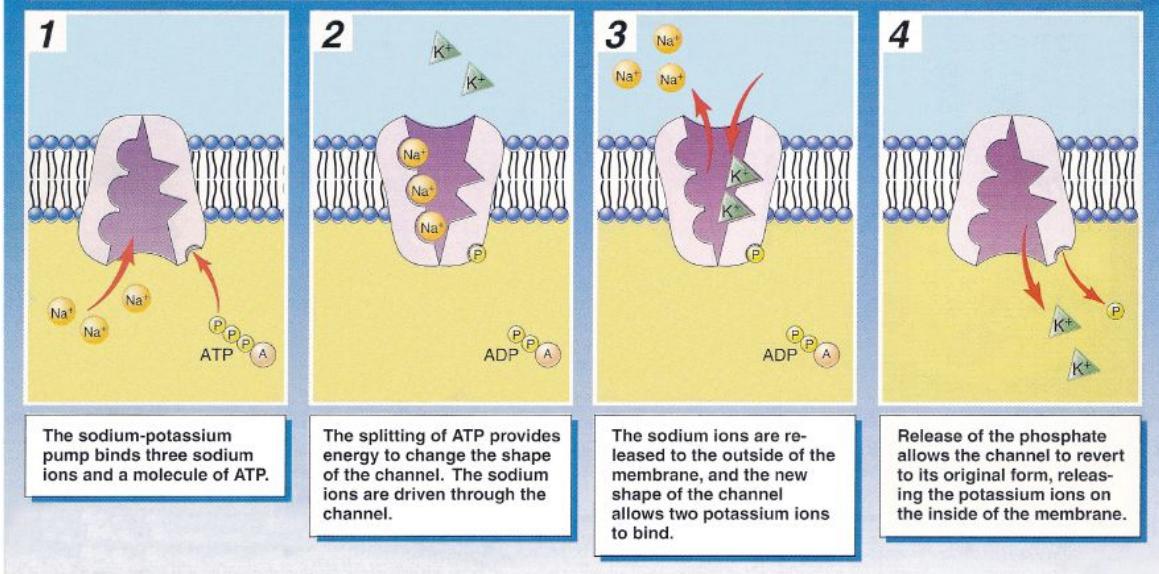
2.7 Facilitated Diffusion

- Passive - Movement down a concentration gradient (NO ENERGY)
 - Simple Diffusion
 - Net movement from areas of higher concentration to lower concentration
 - Osmosis
 - The diffusion of *water molecules* across a selectively permeable membrane
 - Dialysis
 - The diffusion of *solute molecules* across a selectively permeable membrane
 - Countercurrent Exchange
 - The diffusion of substances between two regions in which substances are moving by bulk flow in opposite directions.
 - Ex: Direction of water flow through the gills of a fish is opposite to the flow of blood in the blood vessels in order to maintain the concentration gradient
- Active - Movement AGAINST a concentration gradient, requires ENERGY
 - Uses energy(usually ATP)
 - Transport proteins in the plasma membrane transfer solutes such as small ions (Na^+ , K^+ , Cl^- , H^+), amino acids, and monosaccharides across the membrane
- The diffusion of solutes through *transport proteins* in the plasma membrane.
 - STILL PASSIVE TRANSPORT
 - The solutes still travel down the concentration gradient and no energy is needed
- Used by molecules that are unable to freely cross the phospholipid bilayer (e.g. large, polar molecules and ions)
- This process is mediated by two distinct types of transport proteins – channel proteins and carrier proteins
- Channel Proteins
 - Specific to certain ions (ie, selective)
 - Channel proteins only move molecules along a concentration gradient (i.e. are not used in active transport)
 - Channel proteins have a much faster rate of transport than carrier proteins
 - *Aquaporins* - channel proteins specifically for water transport
- Carrier Proteins
 - Carrier proteins will only bind a specific molecule via an attachment similar to an enzyme-substrate interaction
 - Carrier proteins may move molecules against concentration gradients in the presence of ATP (i.e. are used in active transport)
 - Carrier proteins have a much slower rate of transport than channel proteins



- Membrane Potential - Na^+/K^+ ATPase to maintain voltage across the membrane

SODIUM-POTASSIUM PUMP



2.8 Tonicity and Osmoregulation

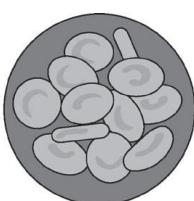
- Tonicity - The ability of an extracellular solution to make water move into or out of a cell by osmosis
- Osmolarity - total concentration of all solutes in the solution
 - Hypertonic
 - The extracellular fluid has a higher osmolarity than the cell, then it is hypertonic and water will move out of the cell to the region of higher solute concentration
 - Hypotonic
 - If the extracellular fluid has lower osmolarity than the fluid inside the cell, it's said to be hypotonic and the net flow of water will be into the cell
 - Isotonic
 - In an isotonic solution, the extracellular fluid has the same osmolarity as the cell, and there will be no net movement of water into or out of the cell
- Water Potential - Measure of the potential energy in water (typically used for comparison not for an individual source of water)
- $\Psi = \Psi_s + \Psi_p$ (in mPa)
 - Ψ = water potential
 - Ψ_p = pressure potential (typically 0 at atmospheric pressure)
 - Ψ_s = solute potential
 - Ψ_s decreases with increasing solute concentration. The more solute you add to a solution, the lower solute potential is and the lower the total water potential is
- WATER MOVES FROM HIGH TO LOW WATER POTENTIAL, AND FROM LOW TO HIGH SOLUTE CONCENTRATION
- Applications in living organisms:
 - Blood cells want to maintain isotonic solutions, otherwise, they shrivel or burst due to the influx or reflux of water.
 - Plant cells want to maintain hypotonic solutions, to maintain turgidity and keep their stiff structure



Shows Shrunken RBCs



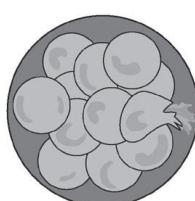
View 1



Shows Normal RBCs



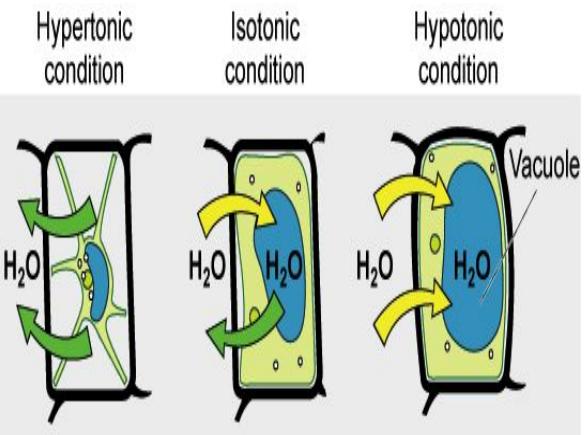
View 2



Shows Swollen and Bursting RBCs



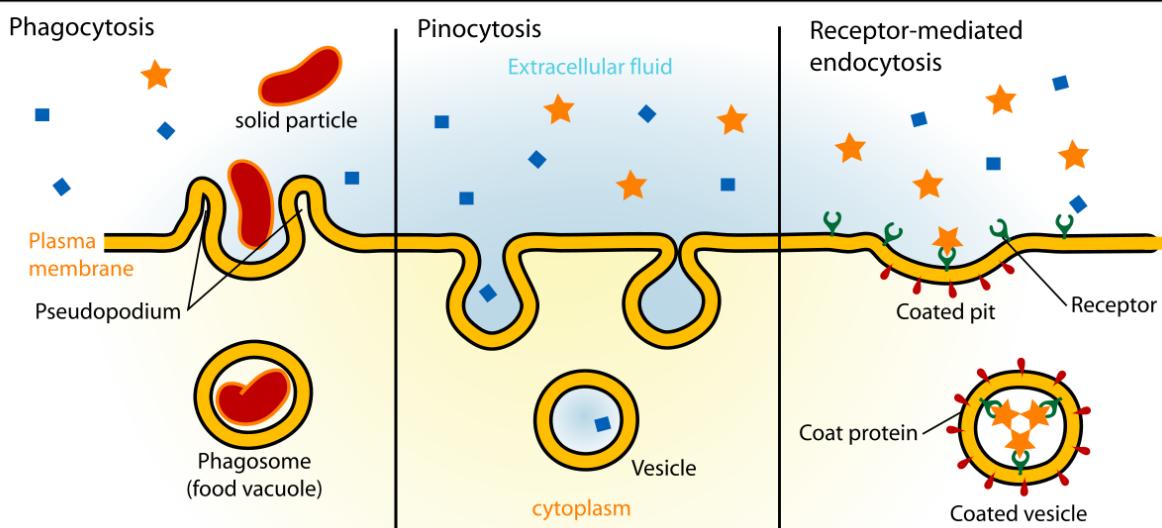
View 3



2.9 Mechanisms of Transport

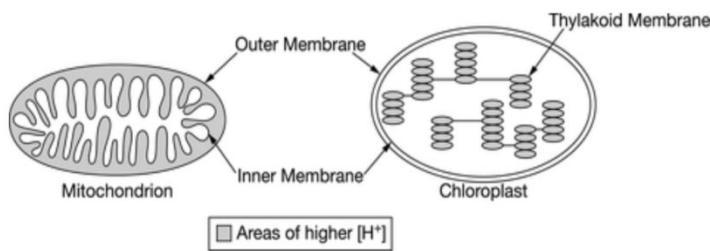
- Vesicular - Use vesicles to transport across the membrane
 - Exocytosis - Vesicle merges with the plasma membrane and releases content to the outside of the cell
 - Endocytosis - Vesicle forms within the cell to take in materials from extracellular space
 - Phagocytosis: "eat" ingest or engulf other cells
 - Pinocytosis: "drink" ingest liquid into the cell via small vesicles from the cell membrane
 - Receptor-mediated: specific molecules enter the cell after binding to cell surface receptors.

Endocytosis



2.10 Cell Compartmentalization

- Main Idea: Eukaryotic cells have several different *organelles* which are tiny "organs" that compartmentalize certain functions necessary to the survival of the cell. They are able to isolate reactions allowing for multiple reactions to occur simultaneously and increasing metabolic efficiency.
- Mitochondria
 - The powerhouse of the cell (i had to)
 - Their job is to make a steady supply of adenosine triphosphate (ATP), the cell's main energy-carrying molecule through cellular respiration
 - One adaptation that they have to undergo these reactions are cristae
 - Cristae are folded areas of the membrane, which increase surface area allowing for a greater amount of ATP production to occur
 - The multi-compartment structure of the mitochondria allows reactions to be kept separate and different concentrations of molecules to be maintained in different "rooms."
- Chloroplasts
 - Found only in plants and photosynthetic algae, and carry out the reactions necessary for photosynthesis
 - Also, have compartments akin to the mitochondria
 - They have outer and inner membranes with an intermembrane space between them
 - In the centre membrane, discs known as thylakoids, are arranged in interconnected stacks called grana (singular, granum).
 - Again, compartmentalizing allows for different reactions to occur and efficiency of reactions to increase



- (a) Describe the importance of the inner membranes separating different regions of the mitochondrion and the chloroplast.

Separating regions allows for multiple reactions to occur and the folds between them increase efficiency through increased surface area allowing more reaction to occur.

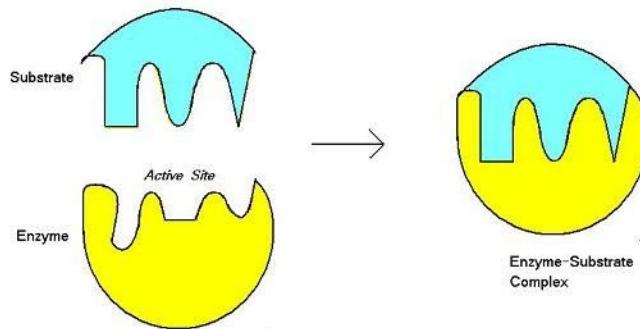
2.11 Origins of Cell Compartmentalization

- Both mitochondria and chloroplasts contain their own DNA and ribosomes, which brings up the question as to why they need their own DNA when there is already DNA present in the nucleus and chromosomes?
- Endosymbiotic Theory
 - A process called endosymbiosis probably led to mitochondria and plastids(the general term for chloroplasts and related organelles).
 - The endosymbiont theory suggests that mitochondria and plastids were small prokaryotes that began living within larger cells.
 - The prokaryotic ancestors of mitochondria and plastids probably gained entry to the host cell as undigested prey or internal parasites.
 - The symbiosis became mutually beneficial
 - A heterotrophic host could use nutrients released from photosynthetic endosymbionts
 - An anaerobic host benefited from an aerobic endosymbiont.
 - As they became increasingly interdependent, the host and endosymbionts became a single organism.
 - A great deal of evidence supports an endosymbiotic origin of plastids and mitochondria
 - The inner membranes of both organelles have enzymes and transport systems that are homologous to those in the plasma membranes of modern prokaryotes
 - Both mitochondria and plastids replicate by a splitting process similar to prokaryotic binary fission
 - These organelles have their own proprietary DNA
 - These organelles contain tRNAs, ribosomes, and other molecules needed to transcribe and translate their DNA into protein.
 - Ribosomes of mitochondria and plastids are more similar to prokaryotic ribosomes than to the cytoplasmic ribosomes of eukaryotic cells

Unit 3: Cellular Energetics

3.1 Enzyme Structure

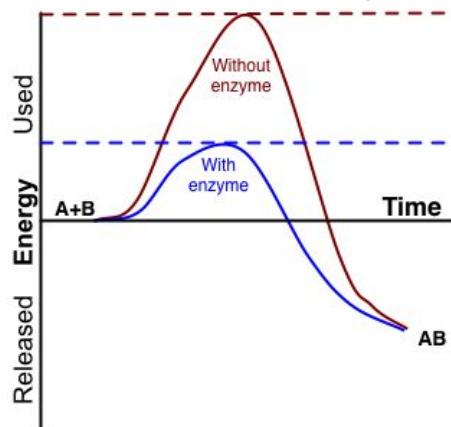
- Enzymes are proteins that speed up chemical reactions
 - Active site that needs to be the right shape and charge to bind to the substrate (substances enzyme binds to)
 - If they have the wrong shape or charge, they cannot bind to the substrate.
 - Metabolic pathway: specific; controlled by enzymes
 - Catabolic pathway: degradation of complex molecules into smaller ones; releases energy
 - Anabolic pathway: synthesize simpler ones to more complex one; require energy
 - Induced fit: substrate enters active site → induce enzyme to change shape slightly so substrate fits better
 - Can be reused; catalyze reaction in both direction
 - Assistance from cofactors (inorganic) or coenzymes (vitamins)



Induced-fit Model. - The enzyme active site forms a complementary shape to the substrate after binding.

3.2 Enzyme Catalysis

- Enzymes catalyse chemical reactions by lowering the energy needed to initiate the reaction, or the activation energy.
 - Activation Energy: energy needed to drive/initiate a chemical reaction
- 2nd Law of Thermodynamics (Law of entropy): Every energy transfer or transformation increases the entropy, or disorder, of the universe.
 - Exergonic reactions: Spontaneous reaction where energy is released
 - Endergonic reactions: Nonspontaneous reaction where energy is gained



3.3 Environmental Impacts on Enzyme Function

- Enzymes can be changed or *denatured* because of environmental impacts.
 - Denaturation: protein structure disrupted → cannot catalyze reactions; may be reversible
- pH: Some enzymes only work at certain pH values.
 - Examples:
 - Tripsin: works best at 8, located in pancreas, digestive
 - Pepsin: 1.5
 - Lipase: 8 in pancreas but 4-5 in stomach
- Temperature
 - At high temperatures, some enzymes can denature
- Enzyme concentration
 - Increasing enzyme concentration will speed up the reaction, as long as there is substrate available to bind to. Once all of the substrate is bound, the reaction will no longer speed up, since there will be nothing for additional enzymes to bind to
- Substrate concentration
 - Increasing substrate concentration also increases the rate of reaction to a certain point. Once all of the enzymes have bound, any substrate increase will have no effect on the rate of reaction, as the available enzymes will be saturated and working at their maximum rate
- Competitive Inhibition: compounds resemble substrate molecules → competes for the same active site → Reduce the amount of product produced
 - Solution: increase concentration of substrate
- Noncompetitive Inhibition/ Allosteric regulators: bind to allosteric (not-active) site → enzyme changes site → substrate cannot bind to active site. It indirectly changes the shape of the active site so enzymes can not bind to the substrate.
 - Feedback inhibition: allosteric inhibition is the end product of metabolic pathway
- Cooperativity: binding of one substrate to one active site → change in entire molecule → amplifies the response

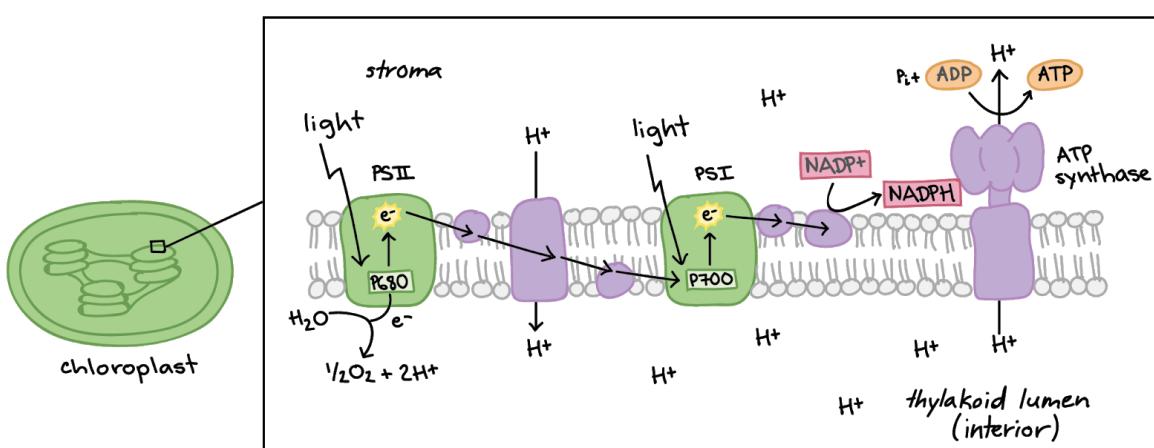
3.4 Cellular Energy

- Life requires a highly ordered system that cannot violate the second law of thermodynamics
 - Energy input must exceed energy loss to maintain order and to power cellular processes
 - **MUST ALWAYS BE CONSTANT**
 - Cellular processes that release energy may be coupled with cellular processes that require energy
 - Glycolysis produces NADH (releases energy) and is used later in Oxidative Phosphorylation (Electron Transport Chain) which requires energy (NADH)
 - Loss of order or energy flow results in death

3.5 Photosynthesis

Photosynthesis (abbrev. photo) captures energy from the sun and produces sugars

- Photosynthesis first appeared in prokaryotes
- Prokaryotic (cyanobacteria) photosynthesis is responsible for production of a oxygenated atmosphere (remember from Unit 7 that the early atmosphere didn't have oxygen only carbon dioxide, light, and methane, and a few other gases, the reactants for photosynthesis)
- Prokaryotic photo pathways are the foundation of eukaryotic photo pathways
- Light Dependent Reactions is the part of photosynthesis that starts with photons
 - You don't need to know the steps for the ap exam (since they usually give a diagram with the steps)
 - However, you do need to know that:
 - The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture energy present in light to yield ATP and NADPH, which power the production of organic molecules.
 - Basically saying they produce ATP and NADPH which makes organic molecules by capturing the energy stored in light or photons
- During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II
- Photosystems I and II are embedded in the internal membranes of chloroplasts and are connected by the transfer of higher energy electrons through an electron transport chain (ETC)



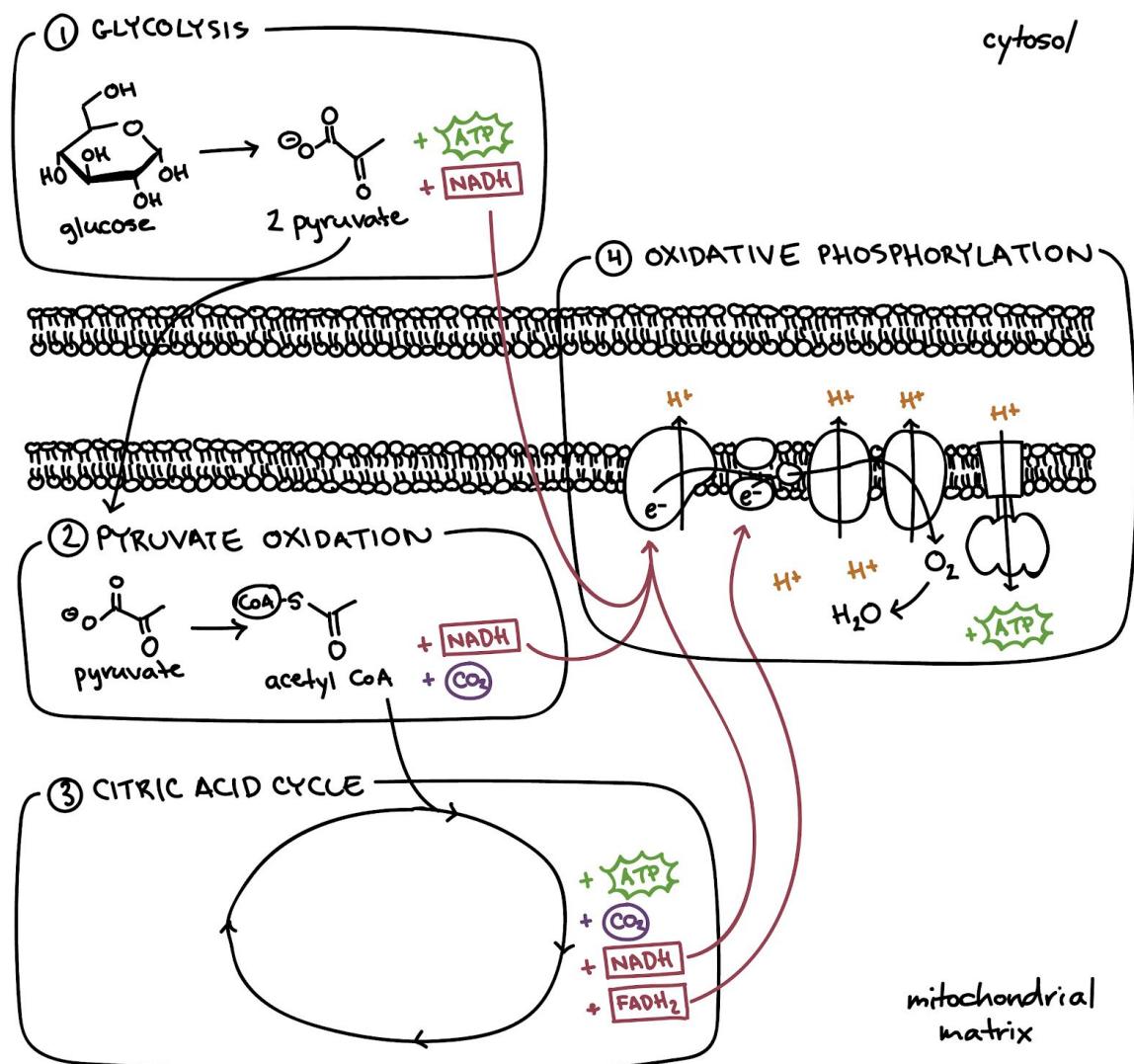
- The photosystems are marked by PS2 and PS1 and they are connected by the electrons (e-) (notice the arrow connecting them)

- When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) is established across the internal membrane
 - This proton gradient will be used in a process called chemiosmosis
- The proton gradient creates a osmotic pressure on the membrane and the ATP synthase protein which spins to turn ADP into ATP with the energy from this pressure and an inorganic phosphate (Pi)
 - This process is called photophosphorylation
- The energy captured in the light reactions and transferred to ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, which occurs in the stroma of the chloroplast

3.6 Cellular Respiration

- Fermentation and cellular respiration use energy from biological macromolecules to produce ATP. Respiration and fermentation are characteristic of all forms of life
- Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that capture energy from biological macromolecules
- The electron transport chain transfers energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes
 - Electron transport chain reactions occur in chloroplasts, mitochondria, and prokaryotic plasma membranes.
 - In cellular respiration, electrons delivered by NADH and FADH₂ are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is NADP+. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules.
 - The transfer of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the internal membrane of chloroplasts, with the membrane(s) separating a region of high proton concentration from a region of low proton concentration. In prokaryotes, the passage of electrons is accompanied by the movement of protons across the plasma membrane
 - The flow of protons back through membrane-bound ATP synthase by chemiosmosis drives the formation of ATP from ADP and inorganic phosphate. This is known as oxidative phosphorylation in cellular respiration, and photophosphorylation in photosynthesis.
 - In cellular respiration, decoupling oxidative phosphorylation from electron transport generates heat. This heat can be used by endothermic organisms to regulate body temperature
- Glycolysis is a biochemical pathway that releases energy in glucose to form ATP from ADP and inorganic phosphate, NADH from NAD+, and pyruvate (knowing these products are important)
 - Glycolysis happens in the cytosol, the rest of cell resp. happens in the mitochondria
 - Pyruvate is transported from the cytosol to the mitochondrion, where further oxidation occurs
 - In the Krebs cycle, carbon dioxide is released from organic intermediates, ATP is synthesized from ADP and inorganic phosphate, and electrons are transferred to the coenzymes NADH and FADH₂
 - Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and FADH₂ to the electron transport chain in the inner mitochondrial membrane
 - Know the electron transporters

- When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) across the inner mitochondrial membrane is established
- Fermentation allows glycolysis to proceed in the absence of oxygen and produces organic molecules, including alcohol and lactic acid, as waste products
- Glycolysis is the only anaerobically-capable process in cellular respiration
- The conversion of ATP to ADP releases energy, which is used to power many metabolic processes (Phosphate is removed which breaks the bond which releases energy)



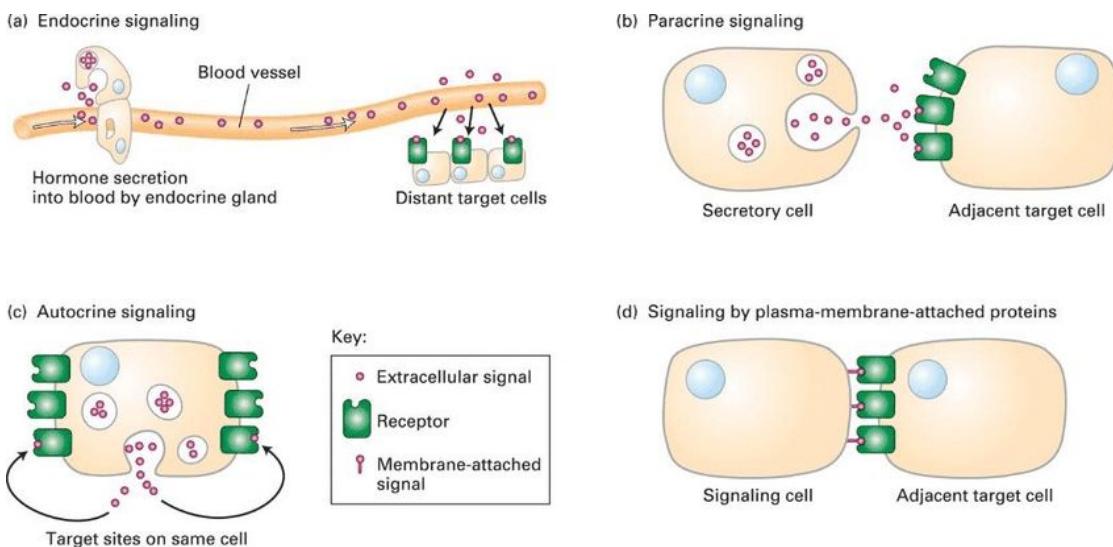
3.7 Fitness

- Variation at the molecular level provides organisms with the ability to respond to a variety of environmental stimuli
- Variation in the number and types of molecules within cells provides organisms a greater ability to survive and/or reproduce in different environments
- Examples:
 - Different types of phospholipids in cell membranes allow the organism flexibility to adapt to different environmental temperatures
 - Different types of hemoglobin maximize oxygen absorption in organisms at different developmental stages
 - Different chlorophylls give the plant greater flexibility to exploit/absorb incoming wavelengths of light for photosynthesis
 - Chlorophyll α and Chlorophyll β

Unit 4: Cell Communication and Cell Cycle

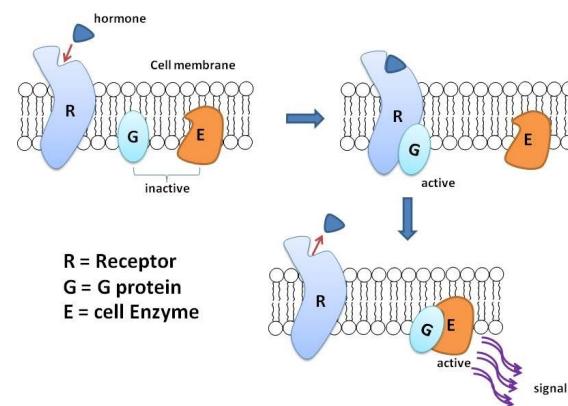
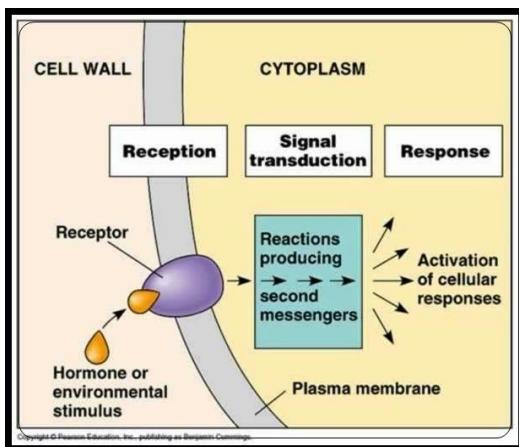
4.1 Cell Communication

- Cells communicate in two ways. Through direct cell to cell contact or by distance using chemical signals (ex. hormones)
- Cells can communicate signals to cells in the vicinity using local regulators which target cells nearby
 - Signals can travel long distances to reach target cells
 - The process by which this signal initiates a response is known as **Signal Transduction**
 - Common long distance is endocrine



4.2 Introduction to Signal Transduction

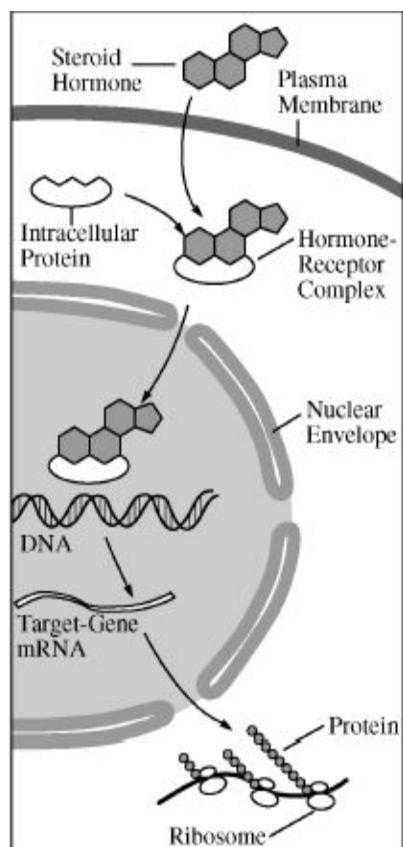
- Signal transduction pathways are responsible for taking signals and causing a cellular response.
 - There are three main components
 - Reception: A ligand binds to a receptor protein initiating a response
 - Transduction: A cascade of reactions involving the activation of other proteins through phosphorylation occur
 - Response: there is a final response that often results in transcription to make a certain protein in response to the signal.



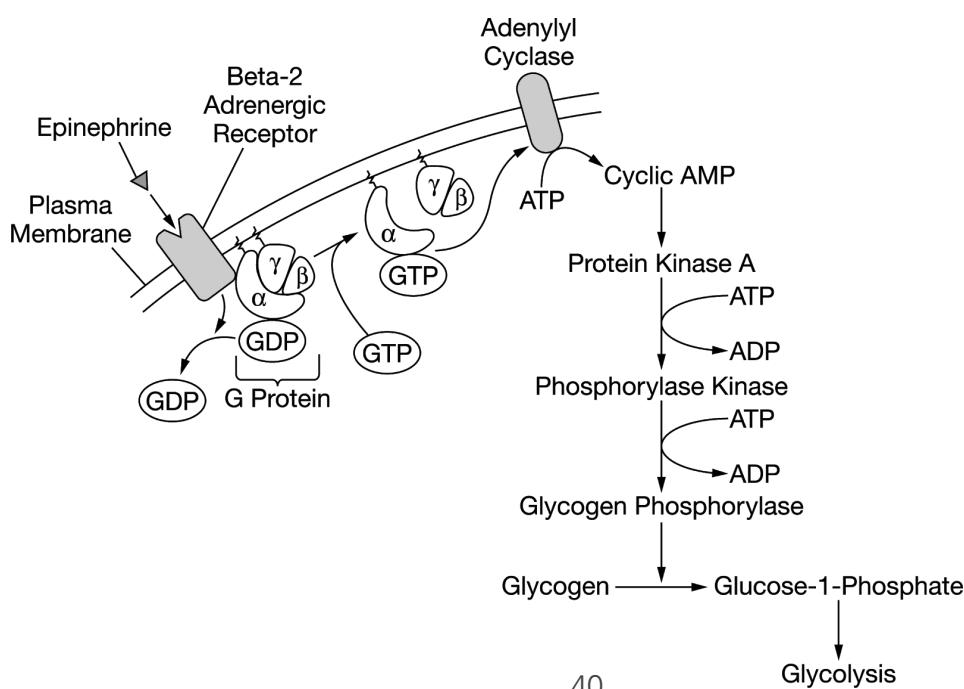
- Many signal transduction pathways include protein modifications and phosphorylation cascades.
- Signaling begins with the recognition of a chemical messenger—a ligand—by a receptor protein in a target cell
 - The ligand-binding domain of a receptor recognizes a specific chemical messenger, which can be a peptide, a small chemical, or protein, in a specific one-to-one relationship.
 - G protein-coupled receptors are an example of a receptor protein in eukaryotic cells.
- Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, resulting in the appropriate responses by the cell, which could include cell growth, secretion of molecules, or gene expression—
 - After the ligand binds, the intracellular domain of a receptor protein changes shape initiating transduction of the signal.
 - Secondary messengers (such as cyclic AMP in epinephrine pathways) amplify the intracellular signal.
 - Binding of ligand-to-ligand-gated channels can cause the channel to open or close.

4.3 Signal Transduction

- Signal transductions often result in changes in gene expression which can often change cell function and alter an organism's phenotype. It can also cause apoptosis to prevent cells from entering mitosis.

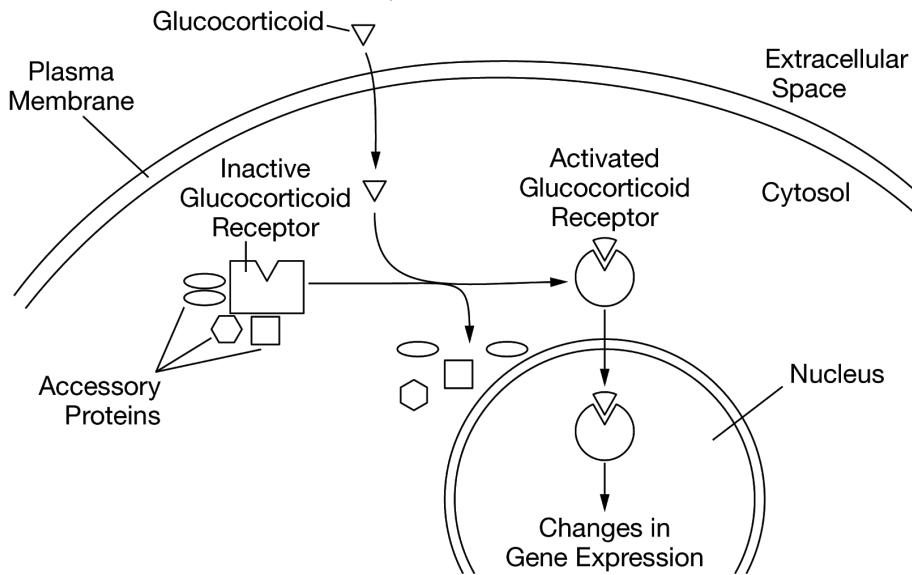


- Examples: (these have all showed up on past exams and are on ap topic questions)
 - Cytokines regulate gene expression to allow for cell replication and division.
 - Mating pheromones in yeast trigger mating gene expression.
 - Expression of the SRY gene triggers the male sexual development pathway in animals.
 - Ethylene levels cause changes in the production of different enzymes allowing fruits to ripen.
 - HOX genes and their role in development.
 - Epinephrine signaling pathway which stimulates glycogen breakdown.
 - Also, it plays a role in regulating population density like with quorum sensing
 - Bacteria population detections autoinducers in the environment to sense population density → change behavior when density reaches certain threshold
 - Autoinducers: Small and hydrophobic, can diffuse freely across membranes



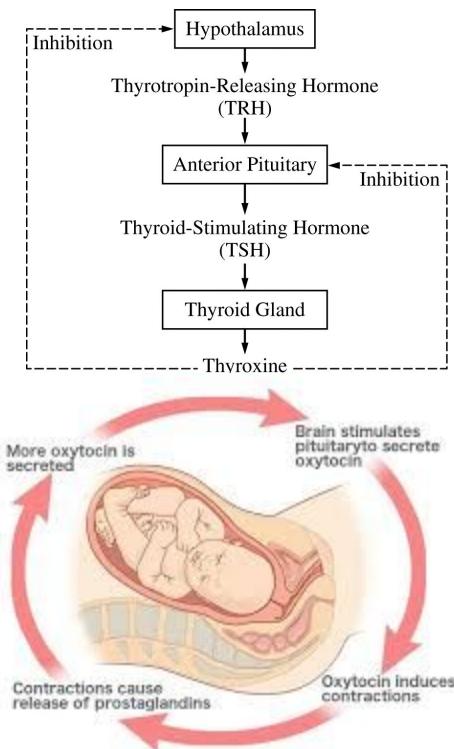
4.4 Changes in Signal Transduction Pathways

- Changes in one part of a transduction pathway can greatly affect the outcome of the behavior of a cell
 - Any changes/mutations to the intracellular domain/structure of the receptor protein can alter the transduction events late on.
 - Chemicals can also interfere with a part of the pathway which can cause activation or inhibition of the pathway



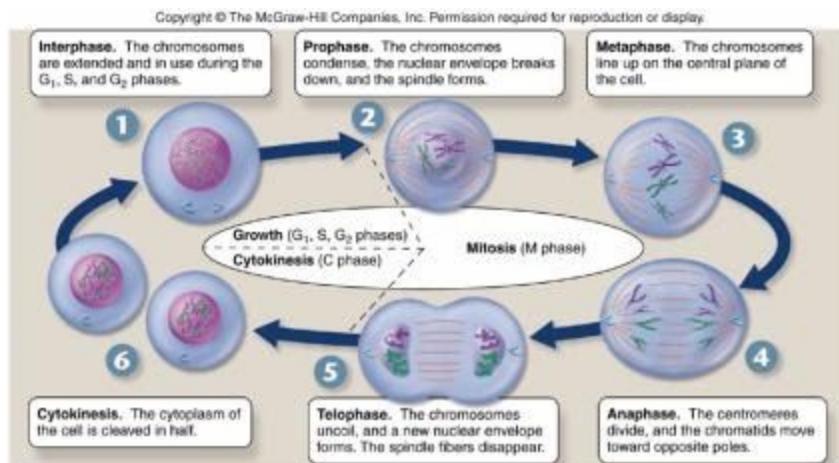
4.5 Feedback

- Organisms use feedback mechanisms to maintain their internal environments and respond to internal and external environmental changes. (homeostasis)
- During negative feedback, a system's mechanisms return the system back to its target set point
 - Ex. when it is too hot, a thermostat will induce a heater to turn off, resulting in a decreased temperature.
- During positive feedback, a system's mechanisms amplify processes. Once the stimulus is further activated, additional response is induced.
 - Ex. When a break/tear appears in a blood vessel, clotting occurs as platelets adhere to the site and release chemicals. These released chemicals attract more proteins and clotting continues until the break is sealed by a newly formed clot.



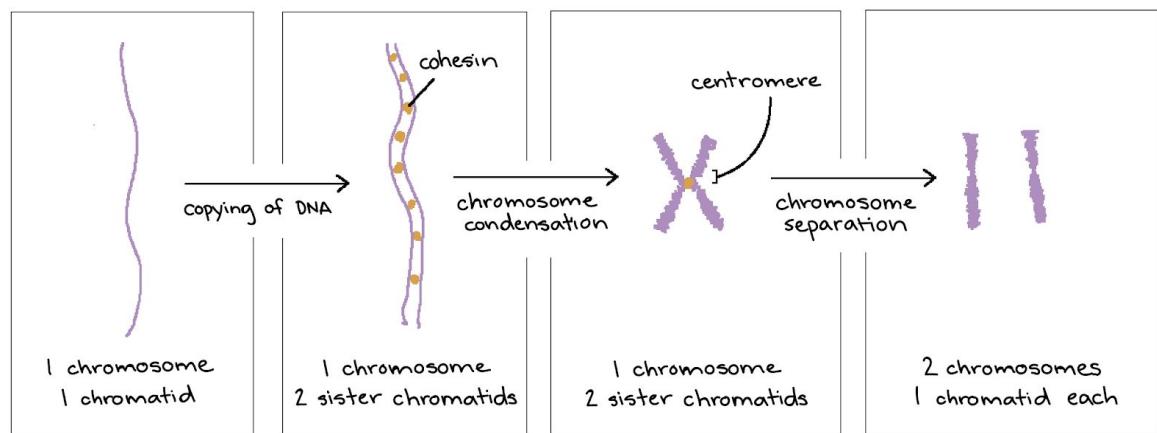
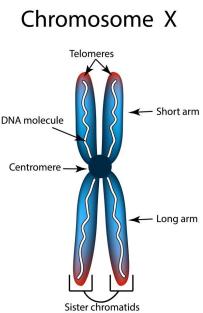
4.6 Cell Cycle

- The cell cycle is a highly regulated series of events for the growth and reproduction of cells.



- Interphase is the when the cell grows and makes a copy of its DNA, this includes most of the cell's life and is the stage between 1 mitotic phase and another
- G1. Grows larger, copies organelles, forms molecular building blocks
- S. synthesizes a copy of DNA in nucleus,
- G2. More growth, makes proteins and organelles,
- G0. Not actively preparing to divide, performing cellular duties.
- Mitosis, a process that ensures the transfer of a complete genome from a parent cell to two genetically identical daughter cells. It plays a role in growth, tissue repair, and asexual reproduction.
 - Early Prophase. Chromosomes condense and mitotic spindle fibers (made of microtubules) form between centrosomes as they part. Nucleolus disappears.
 - Late Prophase. Spindles capture and organize chromosomes. The nuclear envelope breaks down, releasing chromosomes, spindle grows and tubules begin to capture chromosomes. The tubules bind at kinetochores on the chromatid (now "asters").
 - Prometaphase: The nuclear envelope breaks down giving access for the microtubules to attach to the coiled chromosomes.
 - Metaphase. Chromosomes line up at metaphase plate, Spindle Fiber checkpoint helps w/ even splitting of chromatids.
 - Anaphase. Sister chromatides separate, each now are their own chromosomes.

- Telophase. Cytokinesis (div. Of cellular contents). Mitotic spindle breaks down, 2 nuclei form, nuclear membranes and nucleoli form, chromosomes condense.
- Structure of chromosomes
 - Replicated chromosome= two sister (same copies) no chromaids
 - Centromere: region that holds two chromatids together
 - Kinetochore: disc-shaped protein on the centromere; attaches the chromatids to the mitotic spindle during cell division
 - *When sister chromatids are connected at the centromere, still one chromosome



4.7 Regulation of Cell Cycle

Internal Regulation

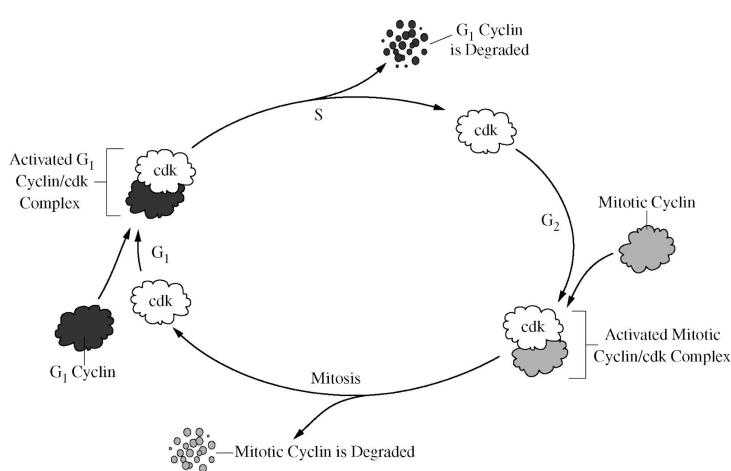
Three checkpoints: G1, G2, Metaphase (Look at figure below)

G1: Nutrients, growth factors, and DNA damages

Past G1 Checkpoint there is no more going back until 2 daughter cells created

If G1 Checkpoint fails cell can enter G0 phase or resting state

G2: Checks for Cell Size & DNA replication errors after Synthesis phase, preparing for division



Metaphase Checkpoint: Checks for chromosome spindle attachment before pulling apart for Anaphase

Most checkpoints involve interactions between cyclin and cyclin-dependent kinase (CDK enzyme)

CYCLIN is a regulatory protein that controls when and how often a cell divides

CDK activity is based on phosphorylation

CDKs regulate cell growth, division, and transcription

External Regulation

Ligands eg. growth factors binding to cell receptor molecules sending signal transduction pathway to arrest cell cycle, pause cell cycle, or start cell cycle

Effects/Disruptions to Cell Cycle

Cancer/Apoptosis:

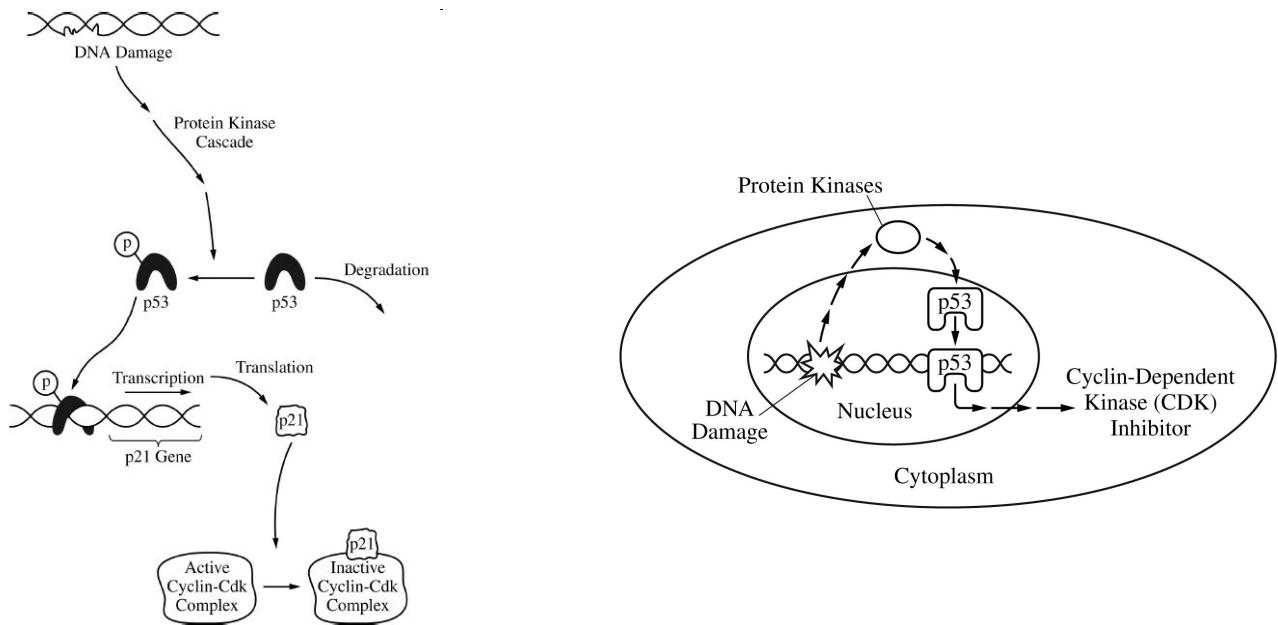
Cause: Cells do not respond to checkpoints

Why: Gene mutations & environmental factors

Eg. gene p53 in G1/S restriction point. Normally p53 gene halts cell division when damaged DNA is detected. It stimulates repair enzymes to fix DNA & signals apoptosis.

p53 Gene mutation -> uncontrolled cell division & cancer

p53 stimulates expression of the CDK inhibitor, preventing progression of the cell cycle. (The CDK inhibitor blocks the interaction between the CDK and cyclins.)

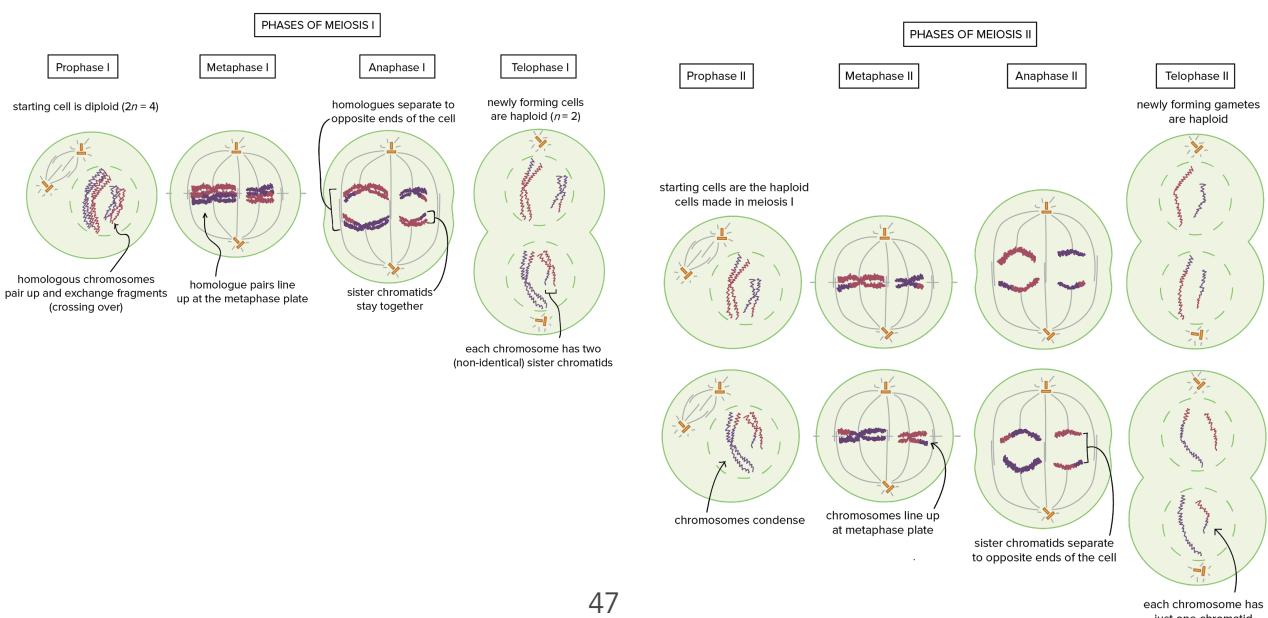


Unit 5: Heredity

5.1 Meiosis

- Formation of haploid (n) gamete cells in sexually reproducing diploid ($2n$) organisms → gametes (sex cells; sperm and egg)
 - Results in 4 haploid daughter cells with half the number of chromosomes of the parent cell; genetically identical to parent
 - i.e. Humans: 46 → 23 chromosomes
 - Meiosis I
 - Same interphase as mitosis
 - Enter: Diploid Cell ($2n=4$)
 - Homologous pairs separate
 - Result: 2 haploid(n) daughter cells
 - Meiosis II
 - Enter: 2 haploid(n) daughter cells
 - Sister Chromatids separate
 - Results: 4 haploid (n) daughter cells
 - Mitosis vs. Meiosis

Mitosis	Similar	Meiosis
1 round Somatic Cells Chromosome no unchanged 2 diploid daughter cells Genetic Variation unchanged	Produces New Cells Start with single parent cell Interphase	2 rounds Germ cells Chromosome no. halved 4 haploid daughter cells Genetic Variation Increased

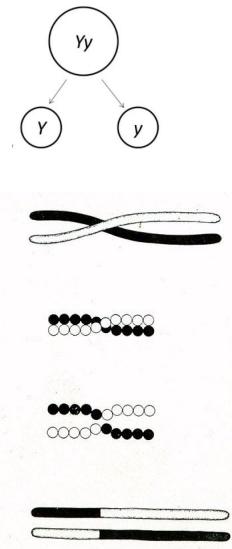


5.2 Meiosis and Genetic Diversity

- Independent Assortment of Chromosomes
 - Alleles of two or more different genes are sorted into gametes independently of one another, aka the allele a gamete receives doesn't influence the allele received for another gene
 - Homologous pairs of chromosomes separate randomly (Prophase I) and line up randomly during (Metaphase I) -> $\frac{1}{2}$ chance a gamete will receive the maternal chromosome/ $\frac{1}{2}$ for paternal chromosome
 - i.e. Humans have 23 pairs of chromosome-> possible combination about 8 million
- Law of Segregation
 - During the formation of gametes, two traits carried by each parent separate-> randomly unite at fertilization
- Crossover
 - Produces recombinant chromosomes: genes inherited from both parents
 - i.e. human: ~2 or 3 crossover events occur in each chromosome pair
 - Metaphase 2: recombinant chromosomes line up randomly-> more variation
- Random Fertilization
 - Probability of any set of genes has an equal likelihood of combining to form offspring
 - (Ovum: one in 8 mil possible chromosome combination) x (Sperm: one in 8 mil possible combination)

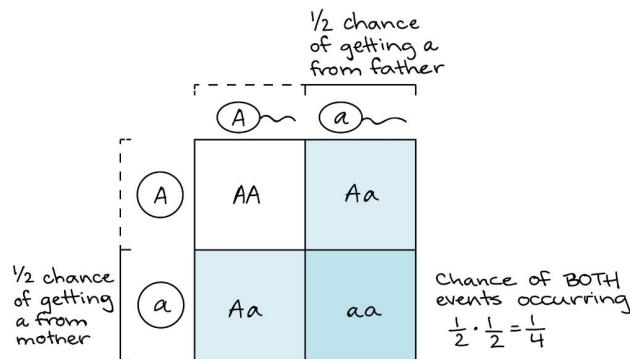
Biological significance of meiosis:

- Provides phenotypic diversity within a population-> more likely some individuals possess alleles that are more suited for the changing environment
- Maintains the correct diploid number of chromosomes when gametes join

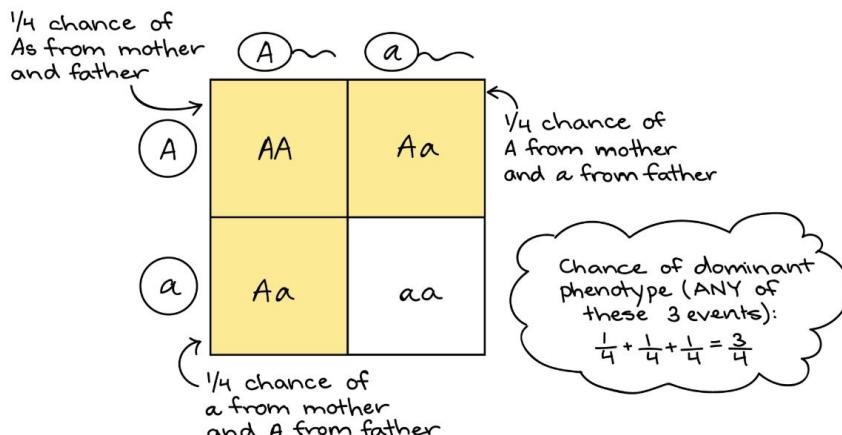


5.3 Mendelian Genetics

- Mendel's Laws:
 - ◆ The Law of Dominance: When two alleles of an inherited pair are heterozygous, then, the allele that is expressed is dominant whereas the allele that is not expressed is recessive.
 - ◆ The Law of Segregation: allele pairs separate or segregate during gamete formation and randomly unite at fertilization
 - ◆ The Law of Independent Assortment: the alleles of two (or more) different genes get sorted into gametes independently of one another
- Certain traits/parts of cells are conserved among generations: This means that they are for the most part similar in different species and do not change as often over time.
 - ◆ Ribosomes are found and mainly similar in all forms of life
 - ◆ Core metabolic pathways such as glycolysis is similarly found in all organisms
 - ◆ Major features of the genetic code are conserved like the fact that is organized into triplet codons which code for the same amino acids and different organisms
- Fertilization involves the fusion of two haploid gametes, restoring the diploid number of chromosomes and increasing genetic variation in populations by creating new combinations of alleles in the zygote
 - ◆ Law of segregation: two alleles for a heritable character separate and segregate during gamete production and end up in different gametes.
 - ◆ Punnett square predicts the results of a genetic cross between individuals of known genotypes.
 - ◆ Law of independent assortment: two pairs of alleles segregate independently of each other
 - The presence of a specific allele for one trait in a gamete has no impact on the presence of a specific allele for the second.
- Heritable variables like eye color are traits transmitted from parents to offspring. These patterns of development are governed by the laws of probability.
 - ◆ Product rule: states that the probability of two (or more) independent events occurring together can be calculated by multiplying the individual probabilities of the events.
 - We can use the product rule to predict frequencies of fertilization event
 - For instance, consider a cross between two heterozygous (Aa) individuals. What are the odds of getting an "aa" individual in the next generation? Each parent has a 1/2 chance of making a gamete. Thus, the chance of an aa offspring is: (probability of mother contributing a) x (probability of father contributing a) = (1/2) times (1/2)=1/4

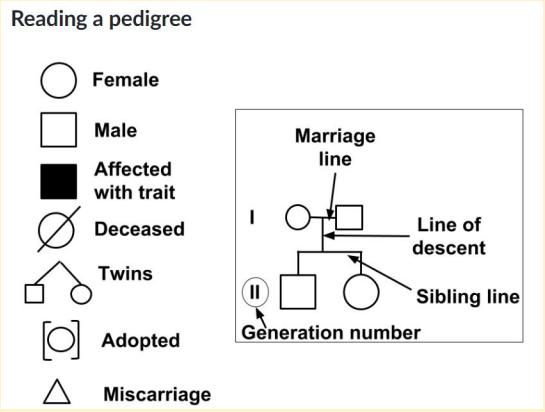


- ◆ Sum rule: the probability that any of several mutually exclusive events will occur is equal to the sum of the events' individual probabilities.
 - As an example, let's use the sum rule to predict the fraction of offspring from an Aa x Aa cross that will have the dominant phenotype (AA or Aa genotype).



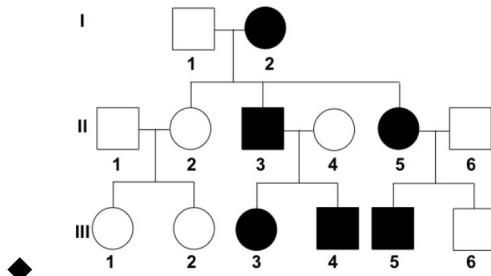
- ◆ Pedigree analysis reveals Mendelian patterns in human inheritance:
 - Dominant pedigree or Recessive pedigree
 - Sex-linked pedigree or Autosomal pedigree

→ How to interpret a pedigree..

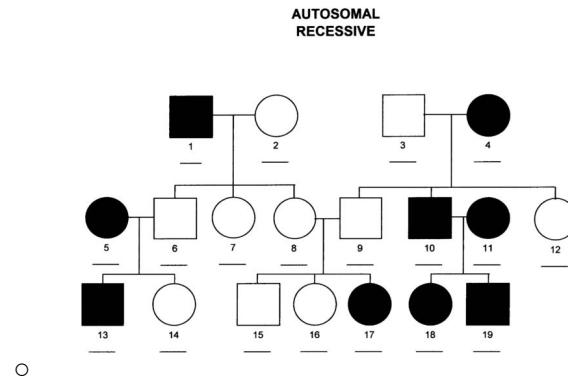


Pedigrees are used to analyze the pattern of inheritance of a particular trait throughout a family. Pedigrees show the presence or absence of a trait as it relates to the relationship among parents, offspring, and siblings.

- ◆ There are four common identifications for a pedigree: Autosomal dominant, autosomal recessive, x-linked dominant, and x-linked recessive (there can also be y-linked and mitochondrial which will be shown later)
- ◆ Autosomal dominant:



- ◆
 - If both parents are affected and an offspring is unaffected, the trait must be dominant (parents are both heterozygous)
 - All affected individuals must have at least one affected parent
 - If both parents are unaffected, all offspring must be unaffected (homozygous recessive)
- ◆ Autosomal recessive

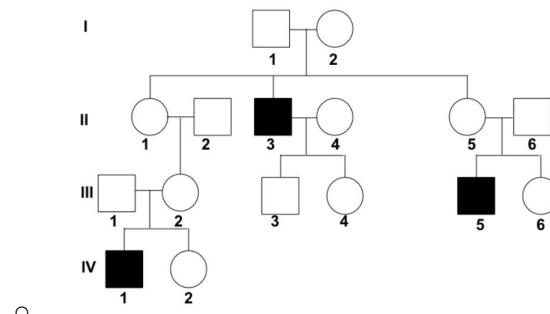


- Both parents in the second generation are unaffected and one of their offspring is affected, the trait must be recessive (parents are heterozygous carriers)
- If both parents show a trait, all offspring must also exhibit the trait (homozygous recessive)

◆ X-linked dominant (Technically Non-Mendelian)

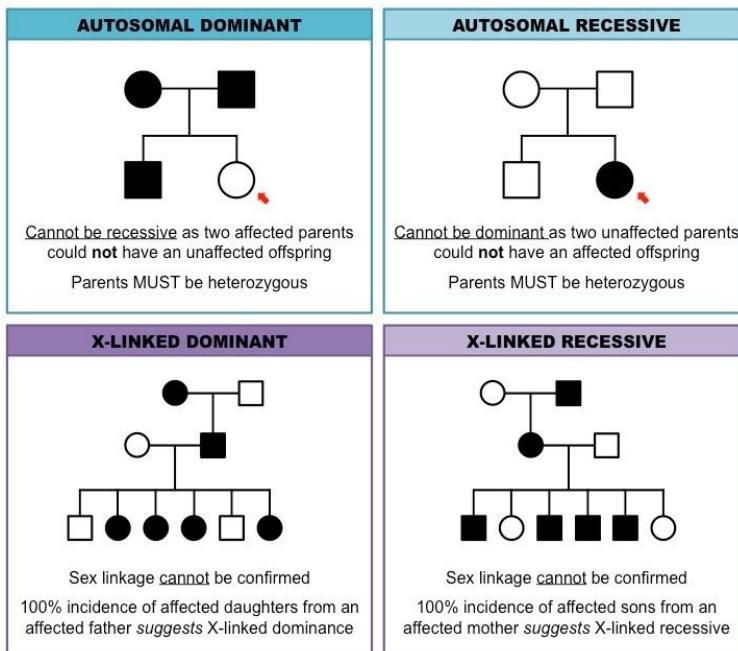
- If a male shows a trait, so too must all daughters as well as his mother
- An unaffected mother cannot have affected sons (or an affected father)
- X-linked dominant traits tend to be more common in females (this is not sufficient evidence though)

◆ X-linked recessive (Technically Non-Mendelian)



- This is a Recessive because the parents in generation 1 are not affected but one son is. The parents are not affected because the affected allele is recessive. Recessive genes allow parents to not be affected but carry a gene for their children to be if both parents are not expressing the affected trait and the children do express the trait.
- This pedigree is not autosomal because only the sons are affected.
- More rules to spot an x-linked recessive:
- If a female shows a trait, so too must all sons as well as her father

- An unaffected mother can have affected sons if she is a carrier (heterozygous)
- X-linked recessive traits tend to be more common in males (this is not sufficient evidence though)
- Review:

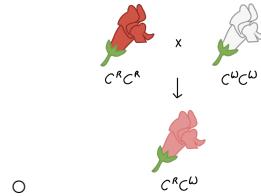


5.4 Non-Mendelian Genetics

→ Inheritance patterns are often more complex than predicted by simple Mendelian genetics

◆ Incomplete dominance: two dominant genes coexist in an organism

- (e.g) P generation (red) cross-pollinate P generation (white)
 - Offspring: 100% pink



- Blood genes are incomplete dominance
- Because each individual carries two alleles, there are six possible genotypes and four possible blood types (written as IAIA)

◆ Codominance: two alleles may be simultaneously expressed with both are present.

- (e.g) P generation (red) cross-pollinate P generation (white)
- Offspring are 100% part white and part red, not pink like indominence.

◆ Polygenic inheritance and environmental effects

- Many characteristics such as height, skin color, eye color, and risk of disease are controlled by many factors. These factors may be genetic, environmental, or both.
- Polygenic inheritance: some characteristics are polygenic, meaning they're controlled by a number of different genes.

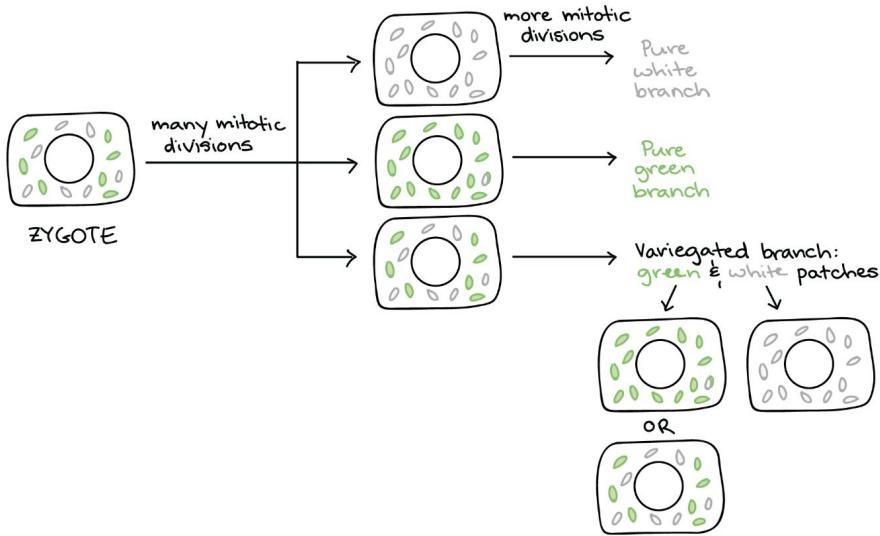
Relationship among alleles of a single gene	Description	Example
Complete dominance of one allele <i>Mendelian Pattern</i>	Heterozygous phenotype same as that of homozygous dominant	PP Pp
Incomplete dominance of either allele	Heterozygous phenotype intermediate between the two homozygous phenotypes	 C^RC^R C^RC^W C^WC^W
Codominance	Both phenotypes expressed in heterozygotes	$I^A I^B$
Multiple alleles	In the whole population, some genes have more than two alleles	ABO blood group alleles I^A , I^B , i
Pleiotropy	One gene is able to affect multiple phenotypic characters	Sickle-cell disease

Relationship among two or more genes	Description	Example																
Epistasis	The phenotypic expression of one gene affects the expression of another gene	$BbEe$ \times $BbEe$ <table border="1"> <tr> <td>BE</td> <td>bE</td> <td>Be</td> <td>be</td> </tr> </table> $9 \text{ black} : 3 \text{ brown} : 4 \text{ tan}$	BE															
BE	bE	Be	be															
BE	bE	Be	be															
BE	bE	Be	be															
BE	bE	Be	be															
Polygenic Inheritance	A single phenotypic character is affected by two or more genes	$AaBbCc$ \times $AaBbCc$ 																

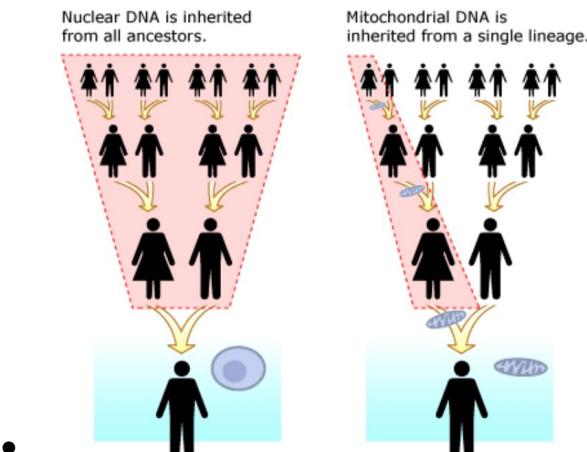
→ Mitochondrial and chloroplast genes

- ◆ Mitochondrial and chloroplast DNA differ from the DNA found in the nucleus because they inherited from the maternal parent only. The genes are considered extranuclear (for being outside of the nucleus).
- ◆ Chloroplast:
 - Chloroplast in the cytoplasm carries heredity factors (genes.)
 - This picture below is an example of a zygote with a mixture of chloroplast inherited from an egg cell. Some chloroplasts are green or white. We see in the picture that some of the zygotes undergo

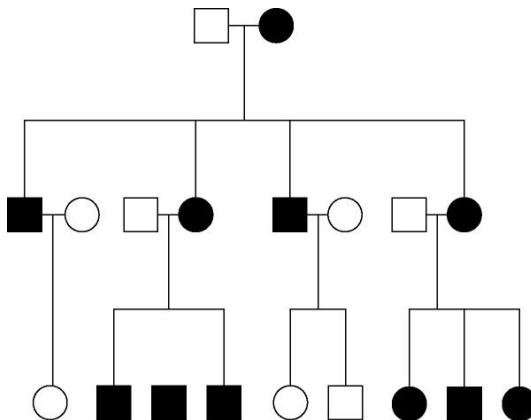
many rounds of mitosis and the chloroplasts are divided and are distributed randomly to daughter cells at each division.



- ◆
 - The color of the egg cell-containing branch from the mother determined the color of the offspring.
 - Female parent branches that were pure green or pure white produced only pure green or pure white offspring, respectively.
 - Female parent branches that were variegated could produce all three types of offspring, but not in any predictable ratios.
- ◆ Mitochondria:
 - In the case of humans, it is the mother who contributes mitochondria to the zygote, or one-celled embryo, by way of the egg's cytoplasm. Sperm do contain mitochondria, but they are not usually inherited by the zygote. There has been a reported case of paternal inheritance of mitochondria in a human, but this is extremely rare.
 - If one mother has a mitochondrial condition all the children will have it. If one father has it, none of the children will.



- Ex Pedigree: affected males do not pass down. Affected females pass down to ALL



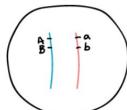
→ Unlinked Genes

- ◆ When genes are found on different chromosomes or far apart on the same chromosome, they assort independently and are said to be unlinked.
- ◆ When the percentage of the recombination frequency is 50%, then the genes are not linked

→ Linked Genes

- ◆ When genes are close together on the same chromosome, they are said to be linked. That means the alleles, or gene versions, already together on one chromosome will be inherited as a unit more frequently than not.
- ◆ When genes are very close together on the same chromosome, crossing over still occurs, but the outcome (in terms of gamete types produced) is different. Instead of assorting independently, the genes tend to "stick together" during meiosis. That is, the alleles of the genes that are already together on a chromosome will tend to be passed as a unit to gametes. In this case, the genes are linked. For example:
- ◆ When genes are linked and crossed together the majority of the phenotypes will be the same as the parent

GENES CLOSE TOGETHER ON THE SAME CHROMOSOME

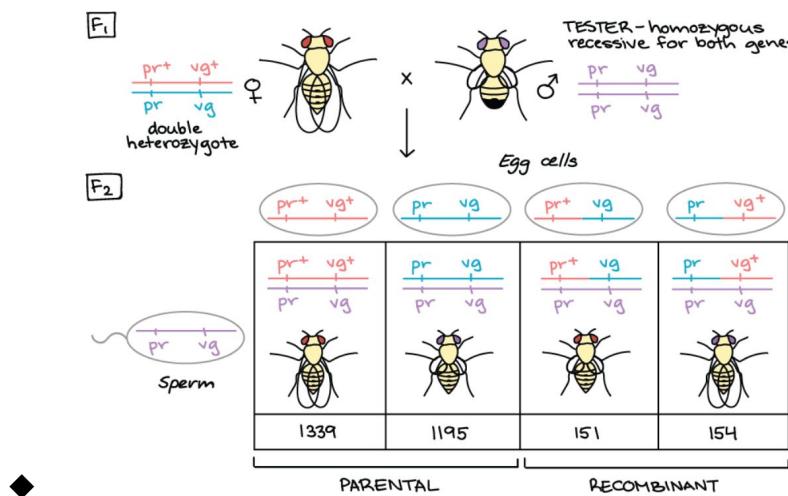


Gametes made:

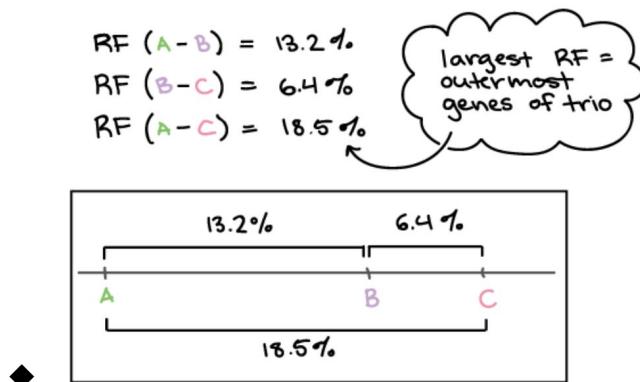
AB	Ab	aB	ab
48%	2%	2%	48%
↑ Recombinant	↑ Parental	↑	↑

- The results of these games are in unequal proportions.

- The crossovers between two genes that are close together are not very common.
- The phenotypes that are not similar to the parents in a cross involving linked genes are considered recombinants as they result from the crossovers that occur. (Don't worry if you do not understand the linkage maps below as they are beyond the scope of the exam)



- ◆ Purpose of recombinant frequency: to build linkage maps
- ◆ Recombination frequency is not a direct measure of how physically far apart genes are on chromosomes. However, it provides an estimate or approximation of physical distance.
- ◆ Importantly, recombination frequency "maxes out" at 50% (which corresponds to genes being unlinked, or assorting independently).
- ◆ Comparison of recombination frequencies can also be used to figure out the order of genes on a chromosome.



NOTE: Chi square analysis tutorial is located on supplemental doc.

5.5 Environmental Effects on Phenotype

- Environmental factors influence gene expression
- Phenotypic Plasticity occurs when organisms with similar genotype display different phenotypes in different environments.
- E.g. Seasonal Fur color in arctic fox: Dark coat in spring and summer to match brown dirt in the environment; white coats during fall and winter to match surrounding snow

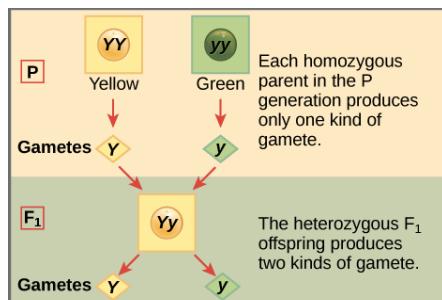


- E.g. Hydrangea flowers can be pink or blue depending on the soil pH. Blue in acidic soil and pink in alkaline soil

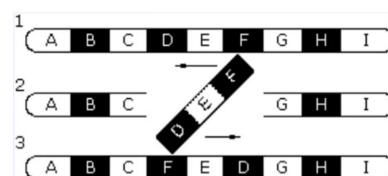
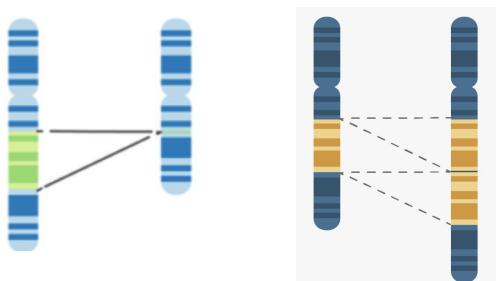


5.6 Chromosomal Inheritance

- Genetic Variation can be caused by
 - Segregation: copies of genes separate so that each gamete receive only one allele



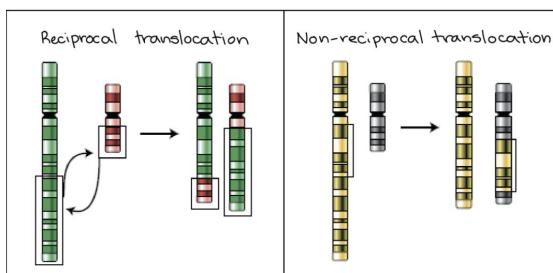
- law of Independent Assortment
 - Genes on different chromosomes
 - Traits segregate independently → randomly via how homologous pairs line up
- Fertilization: haploid gametes fuse to form diploid cell → zygote
- Chromosomal changes:
 - inherited mutated allele → genetic disorders
 - Often occur during meiosis when chromosome break and rejoin incorrectly
 - Duplication: part of a chromosome copied
 - Deletion: part of a chromosome is removed
 - Inversion: segment reversed within a chromosome ← double break, piece reattaches backwards



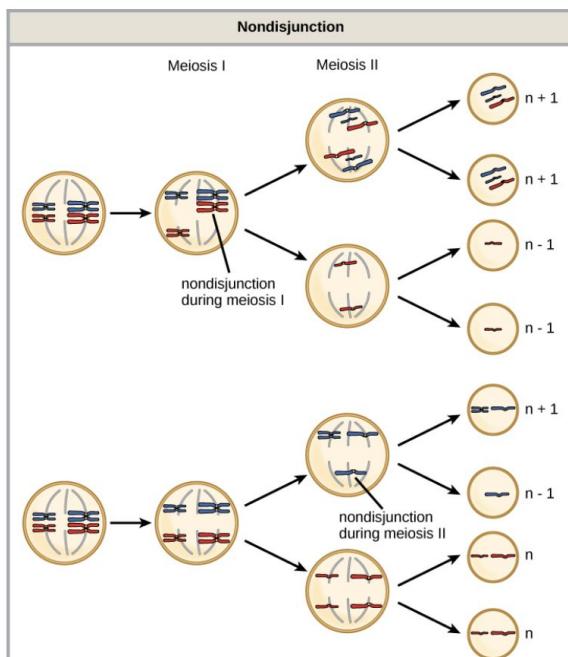
- e.g Hemophilia: inversion on the X chromosome

- - Translocation: chromosome

piece break off from one chromosome and reattaches to a different chromosome



- - Reciprocal translocation: two chromosome swaps segments
- - Non-reciprocal: a segment of chromosome moves to another segment
- - Nondisjunction: when homologous chromosomes fail to separate normally; error in meiosis
 - - during meiosis I → two gametes don't have that chromosome, remaining gametes with two copies of chromosomes
 - - during meiosis II → one gamete don't have that chromosome, two normal gametes, one gamete with two copies
- - Aneuploidy: abnormal number of chromosomes
- - E.g. Down syndrome: extra chromosome 21 (Trisomy 21)

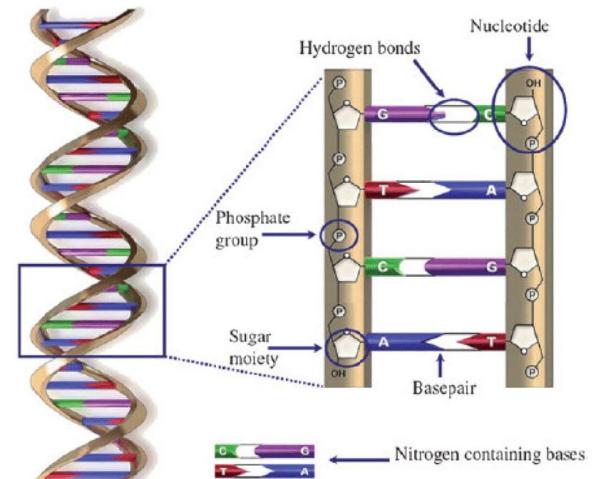


Unit 6: Gene Expression and Regulation

6.1 DNA and RNA Structure

DNA: primary source of heritable information.

- Genetic info stored and passed via DNA molecules
 - Cell division → pass on a copy of DNA to each daughter cell
 - Fertilization → zygote has genetic material from both parents
- Long string of paired nucleotides (A-T, C-G) → genes: instruction to make specific proteins
 - Nucleotide: Nitrogen base + Five-carbon sugar (deoxyribose) + a phosphate + a nitrogen base
 - Adenine with Thymine (double hydrogen bond)
 - Cytosine with Guanine (triple hydrogen bond)
 - Purines (double ring): Adenine and Guanine
 - Pyrimidine (single ring): Uracil, Thymine and Cytosine
- Double helix; two strands run from 5' to 3' and 3' to 5' (antiparallel)
- Sugar-phosphate backbone
 - Nuclear DNA
 - Mitochondrial DNA: maternal inheritance
 - Chloroplast DNA
 - Bacterial DNA: in nucleoid; not surrounded by membrane
- Prokaryotes: circular chromosome; no free ends → less stable
- Eukaryotes: linear chromosome; with terminal ends → replication of large genomes easier



RNA: single stranded, Uracil instead of Thymine

- 5-carbon sugar (ribose)
- mRNA: messenger between DNA and ribosome, carries coded instructions for building protein
- rRNA: (ribosomal) helps mRNA bind to the right spot
- tRNA: (transfer) cloverleaf shaped; brings amino acid → ribosome for protein synthesis
- Non-protein-coding RNA

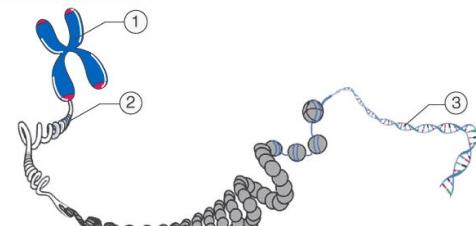
- i.e. miRNA: (micro) regulator of other genes

Chromatin: @ nucleus; DNA and histones (proteins that allow DNA to wind around it)
*kind of like a bobbin

- Packs DNA into a small volume, determines which genes are active
- Decondensed most of the time-> long thin strings
 - Easily read and copied at this state
- Condensed to prepare for division→ broken into separate linear pieces (chromosomes)
- Euchromatin: loosely packed chromatin where translation occurs; majority of genes
- Heterochromatin: firmly packed chromatin and genetically inactive

CHROMATIN

BYJU'S
The Learning App



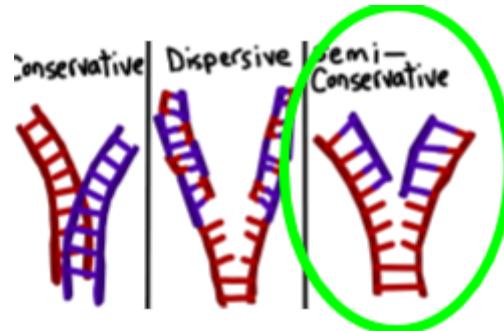
① Chromosome | ② Chromatin | ③ DNA Helix

Chromatin is a genetic material or a macromolecule comprising of DNA, RNA, and proteins which result in the formation of chromosomes within the nucleus of eukaryotic organisms is termed as chromatin.

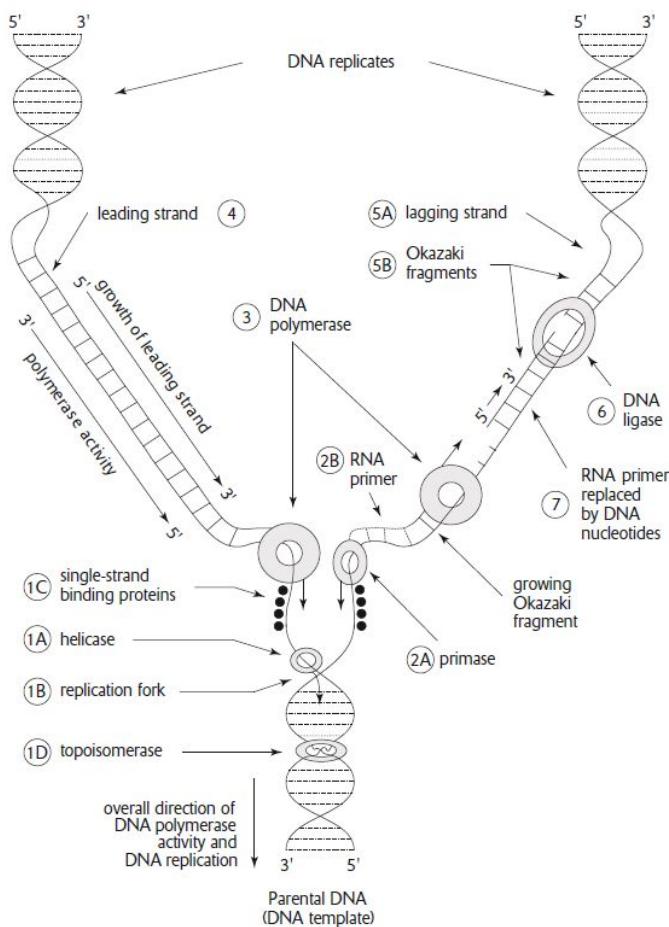
	Nucleotide Components		Function	Structure
	Sugar	Nitrogen Bases		
DNA	deoxyribose	adenine, thymine, guanine, cytosine	contains hereditary information (genes) of the cell	double helix
RNA (3 kinds)	ribose	adenine, uracil, guanine, cytosine	mRNA - provides the instructions for assembling amino acids into a polypeptide chain	linear
			tRNA - delivers amino acids to a ribosome for their addition into a growing polypeptide chain	"clover-leaf" shaped
			rRNA - combines with proteins to form ribosomes	globular

6.2 Replication

DNA replicates in a semi-conservative manner, one strand of DNA is used to make the other strand of DNA.



- DNA is made (synthesized) from the 5' to 3' direction
- DNA polymerase needs RNA primers to start DNA synthesis.
- DNA polymerase also makes new strands of DNA continuously on the leading strand and discontinuously on the lagging strand.



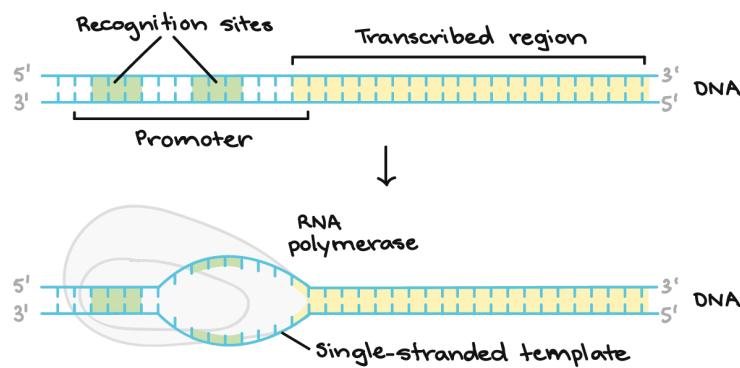
DNA Replication Enzymes	
Helicase (unzipping enzyme)	Used to unwind the DNA strand before the replication process.
Topoisomerase	Breaks, swivels, and rejoins [relaxes] the parental DNA ahead of the replication fork, relieving strain (caused from unwinding of DNA).
DNA Polymerase III	Adds nucleotides to the primer on the lagging strand to form Okazaki fragments.
DNA Polymerase I	Removes the primers on both of the strands (leading and lagging) replacing the primers with DNA nucleotides.
DNA ligase	Joins the Okazaki fragments together on the lagging strand by joining the sugar-phosphate backbones to create a continuous DNA strand.
<p>**Note: DNA polymerase enzymes also act as proofreading enzymes for replication and accuracy and mismatch pairs.</p> <p>Primers are basically anything attached to the strand that tells the DNA replication process where to start. **</p>	

6.3 Transcription and RNA Processing

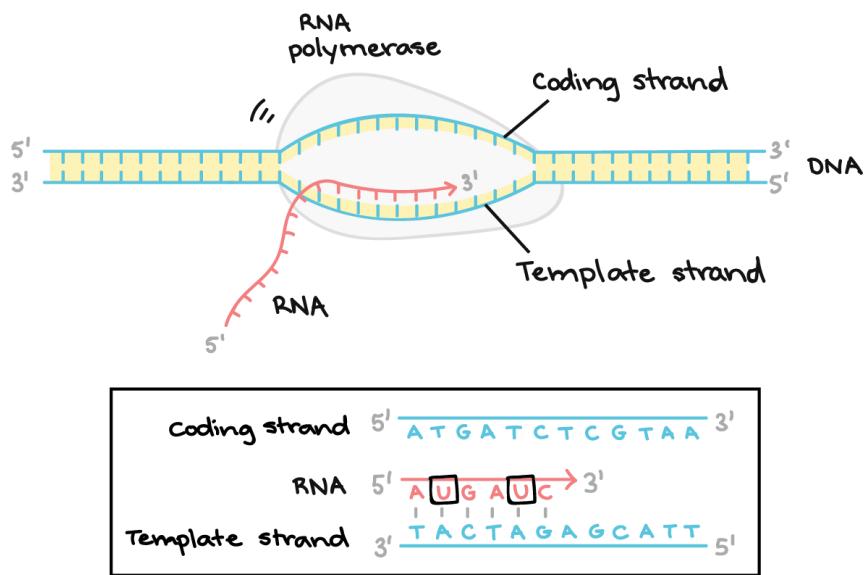
Transcription - Transcription is the process in which a gene's DNA sequence is transcribed (copied) to make mRNA. It begins when RNA Polymerase binds to the promoter region at the beginning of a gene. RNA Polymerase, then, uses a DNA strand, as a template strand, to make a new molecule, known as mRNA.

There are three main steps to this process:

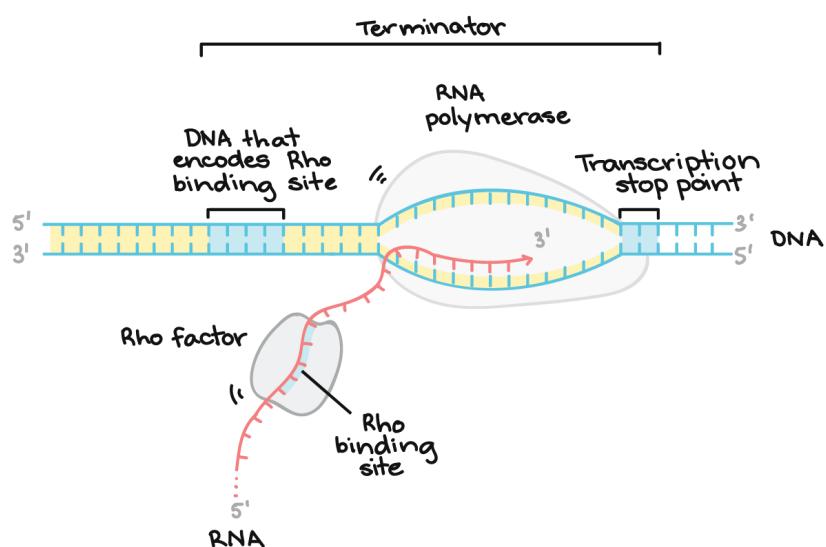
1. Initiation - To begin transcribing a gene, RNA Polymerase binds to the DNA of the gene, which is known as the promoter region. Each gene has its own promoter. Once bound to the promoter region, RNA Polymerase separates the DNA strands and uses one strand as a template to begin transcribing.



2. Elongation - Once the RNA polymerase enzyme has begun to transcribe one of the DNA template strands, the polymerase builds an RNA molecule out of nucleotides, complementary to the DNA strand, making a chain that goes from 5' to 3'. The newly formed RNA strand carries the same information and nucleotides as the non-coding DNA strand except that it has a Uracil in place for a Thymine.
The enzyme RNA polymerase synthesizes mRNA molecules in the 5' to 3' direction by reading the template DNA strand in the 3' to 5' direction.



- Termination - As the RNA polymerase continues to transcribe the DNA template strand to a new RNA strand, it eventually has to stop. In order to stop transcribing the template, sequences called terminators signal that the RNA transcript is complete. Once they are transcribed, the newly formed RNA transcript is released from RNA polymerase.



RNA Processing: mRNA is modified to protect it, provide directionality, and only make necessary proteins

- In eukaryotes, introns (non-coding) segments are removed while in the nucleus before the mRNA is translated. This does not happen in prokaryotes because their genome is organized into operons so all segments in mRNA are useful (coding).

- Addition of a poly-A tail.
- Addition of a GTP cap.
- Excision of introns and splicing and retention of exons can generate different versions of the resulting mRNA molecule; this is known as alternative splicing.

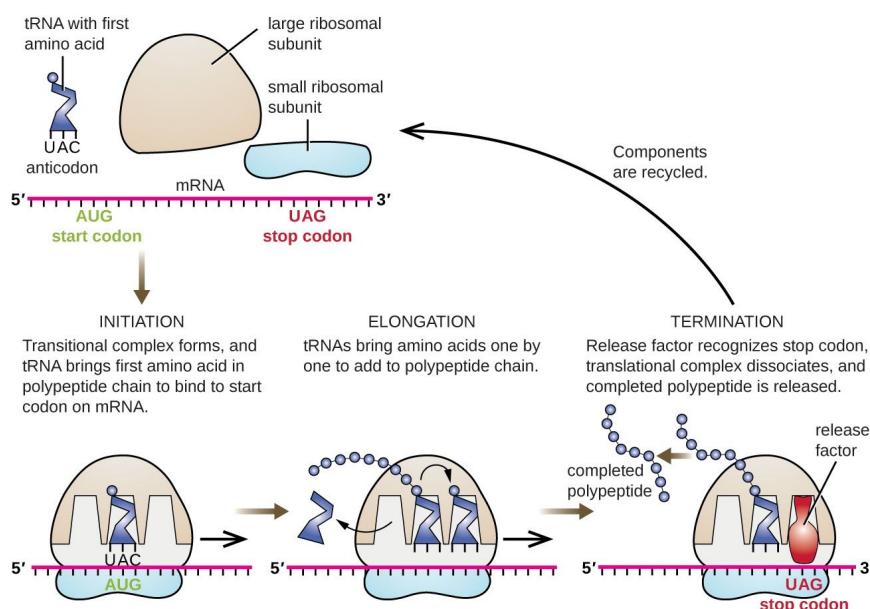
6.4 Translation

Translation: The process involving the decoding of mRNA and using its information to build a polypeptide chain of amino acids.

- Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids are encoded by more than one codon. d. Nearly all living organisms use the same genetic code, which is evidence for the common ancestry of all living organisms.

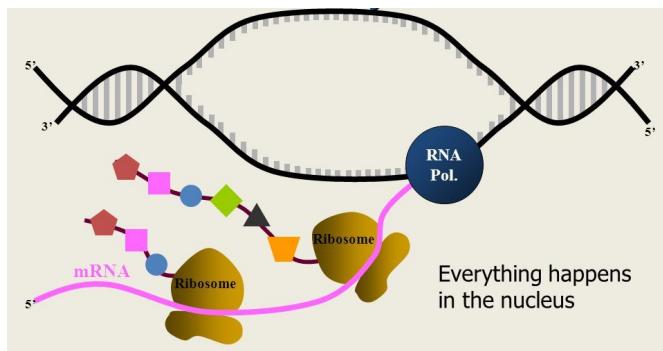
Just like transcription there are three steps in translation:

1. Initiation: In initiation, the mRNA goes to the ribosome. As it assembled there, the tRNA comes and starts the polypeptide chain with the start codon AUG which codes for methionine. (OCCURS WHEN rRNA interacts with mRNA start codon)
2. Elongation: Elongation is the stage where the amino acid chain becomes bigger and bigger. In elongation, the mRNA is read one codon at a time and matches complementary to the tRNA's anticodon. tRNA brings the correct amino acid to the correct place specified by the codon on the mRNA. The amino acid matching the mRNA codon is added to the growing polypeptide chain.
3. Termination: Termination is the stage where the finished polypeptide chain is released. It happens when the ribosome reads a stop codon, which are UAA, UAG or UGA (these do not code for an amino acid). Once the stop codon is read, the polypeptide chain is separated from the tRNA and it leaves the ribosome. (WAY TO REMEMBER STOP CODONS: YOU ARE UGLY, YOU ARE GROSS, YOU GO AWAY)



Prokaryotic differences:

- In prokaryotes the mRNA is translated as the DNA is being transcribed because there is no nucleus so both the DNA and ribosomes are free floating next to each other allowing the mRNA to go into the ribosome right after it has been transcribed.



Deviation from the Central Dogma in a RNA Virus:

- Genetic information in retroviruses is a special case and has an alternate flow of information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome into DNA. This DNA integrates into the host genome and becomes transcribed and translated for the assembly of new viral progeny.

6.5 Regulation of Gene Expression

- There's not a lot you need to know about epigenetics for the AP Exam
 - Adding methyl groups to DNA inhibits transcription
 - Adding acetyl groups to DNA promotes transcription
- Operons are what bacteria use to regulate gene expression. To understand operons, you need a bit of background knowledge: genes in bacteria are grouped by function. What this means is that if I need the enzymes A, B, and C to digest starch, they will be ordered in this order in the genome: promoter(including the operon), gene A, gene B, gene C. Now what is an operon? It's an area on the promoter that binds to repressor proteins, proteins which stop gene expression by physically blocking RNA polymerase.
- Operons work in 2 ways: inducible or repressible. The inducible operon blocks transcription until there is a substrate to act on, at which point it allows transcription(see diagram 1)
- A repressible operon allows transcription until there is no more substrate, at which point it blocks transcription(see Diagram 2)
- Usually, when the gene codes for a substrate being broken down, it is inducible, and when the substrate is built up, it is repressible.

Diagram 1

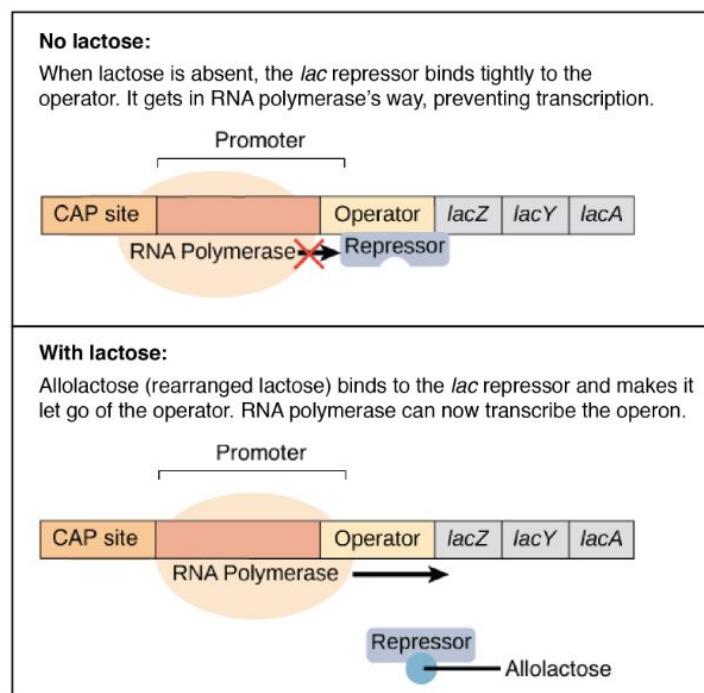
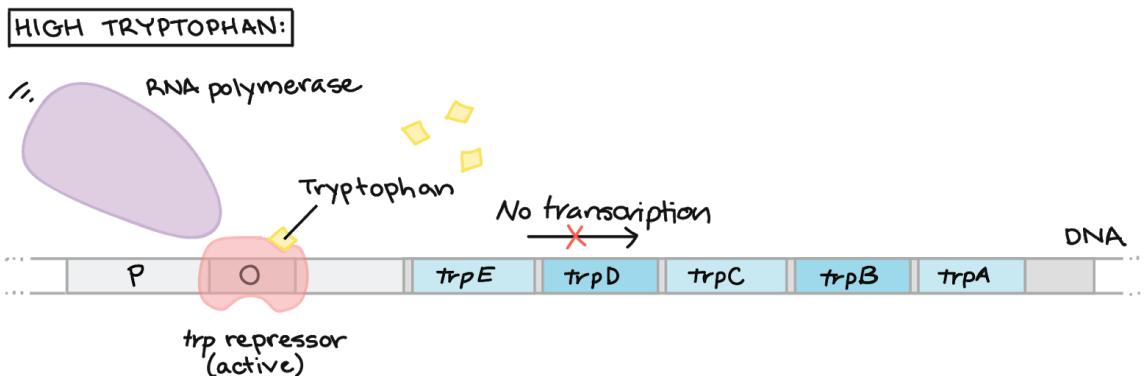


Diagram 2



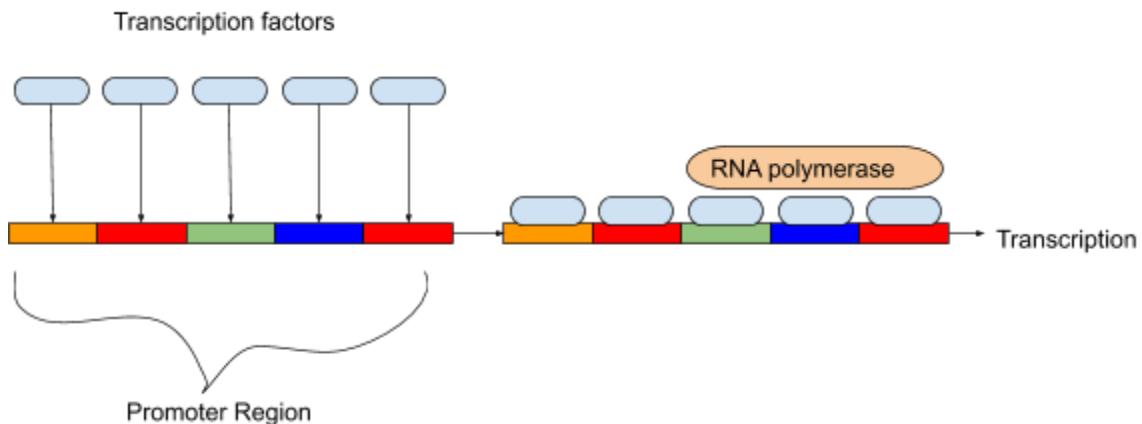
- In eukaryotic cells, transcription factors control gene regulation. Unlike in prokaryotes, where genes that are likely to be transcribed at the same time are placed together, in eukaryotes, they can be placed anywhere in the genome. Even on different chromosomes. This poses a great issue when trying to transcribe multiple genes at the same time.
 - Luckily, transcription factors evolved to solve this issue. For example, if I were to need Enzymes A, B and C to be transcribed for when I need to digest starch, their genes would all be recognized by Transcription Factor X, which would then attract RNA polymerase to transcribe these genes to make Enzymes A, B and C.

6.6 Gene Expression and Cell Specialization

- Chromosome Structure in Eukaryotes
 - Histones - These are *proteins* that are used for DNA to wrap around and thereby helping it to *condense*.
 - These carry a *positive charge*. (DNA is negatively charged, its like a magnet.)
 - Nucleosome - A *unit* of DNA wrapped around a group of histones. (Nucleotides around histones.)
 - Supercoiling – This is the process of DNA *condensing* from Chromatin to Chromosomes.
 - Heterochromatin - This refers to DNA that *remains condensed* even during interphase. – It is NOT active.
 - This CANNOT do transcription so it is *inactivated*.
 - Euchromatin - This refers to DNA that IS *loose* during interphase. – It IS active.
 - It CAN do transcription and *be expressed*.
- Cellular Differentiation- The process of making cells “different” or “special in their function”.
 - A. This process is accomplished by turning certain genes “on” or “off”. This is known as Differential Gene Expression. These genes are the Exons.
 1. The genes turned “on” end up making that *protein/enzyme* to make that cell different or special.
 - B. If control of this mechanism goes awry, terrible things may occur, such as cell death (Apoptosis) or cancer to the cell or organism.
- Promoters: DNA sequences that are upstream of the transcription start site where RNA polymerase and transcription factors bind to initiate transcription.
- Negative regulatory molecules inhibit gene expression by binding to DNA and blocking transcription
- Regulation of gene expression: Certain processes are involved in the regulation of genes
 - Gene control during transcription
 - DNA Methylation of the DNA
 - This refers to putting a heavy “coat” of methyl (CH_3) groups of the DNA, thus *preventing* transcription from occurring. The Methyl groups attach to Cytosine or Adenine nucleotides.
 - This is the source of Genomic Imprinting that occurs in gamete production. It essentially “erases” information”.
 - Histone Acetylation

- This is the attaching of acetyl (COCH_3) groups to the histones lysine amino acids.
- This attaching *breaks the bond* between the DNA and the histones by covering up the positive charges thus creating NO attraction for each other.
- This allows for RNA Polymerase and transcription factors to attach to the "*freed*" DNA so that transcription may occur.
- Enhancers and Activators - These help control *the rate* of transcription.
- They are segments of DNA that basically "grab" the factory, using a bending protein, and move it down the DNA faster thus *enhancing* the process of transcription.
- Repressor or Silencer - These *control* proteins sit on the TATA box – they *prevent* transcription from occurring. This *silences* or *represses* the gene from being expressed.
- Coordinated Control of gene families
 - The *same chemical signal* causes the simultaneous expression of multiple copies of the *same* gene. These multiple copies of the *SAME* gene are referred to as a gene family.
- Micro RNA (miRNA) and small interfering RNA (siRNA)
 - These are *little pieces of RNA* that attach to mRNA and thus *control transcription* of the mRNA
- Post Translational Control Mechanisms
 - Chaperonin or SRP for RER.
 - Phosphorylation of the protein/enzyme (*activating* the molecule by using ATP to *add* a phosphate.) On vs. Off basically.
 - Transport through the inner-membrane system (As the protein moves through the RER and Golgi, controlling the folding and modification of the protein.)
 - Proteasomes (special protein digesting Lysosomes) control **HOW LONG** the protein lasts.
- Once a transcription factor *binds* to a promoter region, it affects gene expression by ensuring that the cell *expresses the right genes*, so that the cell is able to work effectively and correctly.

- How Transcription Factors help with Transcription



- Transcription Factors can help determine the phenotype (the physical characteristics of an organism)

6.7 Mutations

- Phenotypes are determined by: Function and amount of genes present
 - Any *change* to the phenotype results from the:
 - Epigenetics: *Changes* in the gene expression
 - Different genes can be turned off/on
 - The rate of transcription can be modulated
 - Mutation: *Changes* to the genotype
 - Mutations can be:
 - Beneficial: change in the genotype will help organism
 - Detrimental: A change will cause a negative affect towards the organism, whether its limiting the function of that organism.
 - Neutral: The change will not cause anything to occur
 - Determined through the effect on the nucleic acids (mRNA) or protein
 - Can also depend on the environment
 - Errors can occur in processing genetic info
 - Errors can take the form of
 - DNA replication
 - DNA repair mechanisms (DNA Polymerase I)
 - External factors of the process (ex:
 - Radiation
 - Reactive Chemicals
 - Infectious agents
 - Phenotypic variation can arise from natural selection
 - Phenotypic Variation can also arise from:

- Transformation: horizontal acquisitions of genetic info
 - prokaryotes take in DNA/RNA from environment
- Transduction: genetic info passed on from viruses
- Conjugation: genetic info passed from one individual to another
- Transposition: movement of segments of DNA within and between an organism's DNA
- Changes in the Chromosome
 - Chromosomal Mutations, such as the changes in the number of chromosomes can give rise to phenotypic variation.

6.8 Biotechnology

- Bacterial Genome
 - Plasmids:
 - These are small, circular, *exchangeable pieces* of DNA.
 - These are *in addition* the main large circular DNA strand.
 - These help to *increase variation and survival*.
 - Bacterial Replication
 - *100% Identical clones* are produced through binary fission (think of asexual reproduction). Allows them to reproduce *very quickly*.
 - Ribosomes are needed to create proteins; but they do NOT possess any organelles
- Bacterial Variation Processes (Remember, variation *increases survival* chances in a *changing* environment.)
 - Transformation: A bacteria took in DNA from an external source. (Recombination of DNA occurred.)
 - Transduction: This is when a new DNA has been *carried in* by a virus thus creating the "change".
 - Phage introduced the new DNA into the bacterial DNA.
 - Conjugation: Bacteria exchange plasmids through a conjugation tube from the "male" to the "female"
 - R Plasmids
 - These plasmids exchange *antibiotic Resistance genetic information*. This *helped* in the evolution of MRSA (Methicillin-Resistant Staphylococcus aureus)
- Genetic Engineering - The field of science dealing with *manipulating* genomes.

- Recombinant DNA is the major focus of genetic engineering.
 - In this process, DNA from *two different sources* is combined into *one* molecule of DNA.
- Biotechnology - study of computers and other devices to help in performing science.
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- Bacterial Cloning Process
 - The *first step* in this process uses restriction enzymes to create "Sticky Ends" on a plasmid *and* DNA from another source.
 - These are enzymes that cut DNA at *specific nucleotide sequences*.
 - This specific DNA sequence is referred to as the *restriction site*.
 - These enzymes create restriction fragments as the DNA source is cut up into *fragments*.
 - The *same restriction enzyme* must be used on *both* the bacterial plasmid and the DNA source.
 - The *second step* is to *introduce the fragments* to the "open" plasmids for *recombination* to occur.
 - The "sticky ends" base pairs will match allowing for recombination to occur.
 - The *third step* uses the enzyme Ligase to *seal* the DNA fragments together.
 - The *fourth step* is to introduce the *recombinant* plasmids *back into* the bacteria.
 - The bacteria are also called a Cloning Vector.
 - A vector is a DNA molecule used as a vehicle to carry foreign genetic material into a cell
 - The *fifth step* is to allow the bacteria to *reproduce*, by binary fission, to achieve a *large working population*.
 - The *sixth step* is to *identify* the bacteria of interest using Nucleic Acid Hybridization.
 - First, *create radioactive* nucleic acid probes using radioactive Phosphorus. This will have the complementary nucleotide sequence to the *Genetic gene of interest*.
 - Remember the Hershey- Chase Experiment.
 - Then *denature* the DNA double helix using *heat*. (The DNA double strand *separates*.)
 - The radioactive probe *seeks out* the gene of interest and attaches to it, as the nucleotide sequences *match*.
 - The next step is to use film filter paper to identify radioactive colonies of bacteria.

- The radioactivity will cause a *color change* on the film. This will tell where within the Petri dish the important bacteria are located.
- Now *separate the colonies* of interest from "trash" colonies. These bacteria *will make* our protein of interest. (For example, making human insulin or human growth hormone.)
- The last step is to culture (grow) the bacteria for experimentation and perform protein screening (PAGE) to *verify* the protein is being produced by the bacteria.
- Polymerase Chain Reaction (PCR) (Requires *no organism* in the production of *new DNA molecules*.)
 - The process was developed in 1983 by Kary Mullis. He won a Nobel Prize in 1993 for this.
 - The process is used to turn a *single* molecule of DNA into a *large, workable sample* of 100% identical DNA molecules.
 - This is widely used in criminal forensics (Murder cases).
 - The process:
 - Put the DNA sample in a PCR Thermal Cycler machine.
 - The machine uses *heat*, DNA Primers, enzymes and a constant supply of nucleosides to build DNA molecules that are *identical* to the original molecule in nucleotide sequence.
 - First step: *Heat* is used to *separate* the DNA double helix so that replication can occur.
 - Second step: The attachment of a DNA Primer to the template DNA strand will occur to start replication.
 - Third step: The DNA polymerase enzyme *works 5'3'* attaching nucleosides to the growing "new" side of the replicated DNA molecule.
 - Fourth step: *Cool* the mixture to recombine DNA back into a double strand.
 - *Repeat the cycle many times* to get a large, workable sample of the DNA.
- Genomics - The study of *large* amounts of genetic information (genomes).
- Gel Electrophoresis
 - This process is used to create a "DNA fingerprint".
 - Take *different* DNA samples and expose them to the *same* restriction enzyme to cut the DNA into *fragments*.
 - This creates Restriction Fragment Length Polymorphisms (RFLPs)

- These are *fragments* of DNA having *different lengths*.
- Then take the DNA RFLPs and load them into the agar gel.
- Turn on the *electricity*. (Remember, DNA is *negatively charged* because of the phosphate backbone, so it will be repelled on the negative end [Black] and pulled by the positive end [Red].) Electricity *will flow* from the Black Red strips.
- The RFLPs will *separate* according to *length/size of the fragments*.
 - Big pieces move *slowly* through the gel.
 - Small pieces move *quickly* through the gel.
- Stain the gel with Blue Dye to see the DNA fragments *within* the gel.
- The DNA Bands *create a unique “fingerprint”* of the individual's DNA.