Biology and Chemistry

By Alex Klein - 2014 to 2016

Whether digesting mashed potatoes after dinner, or “feeling the burn” of an intense workout, Biology and Chemistry are working together in your world right now.

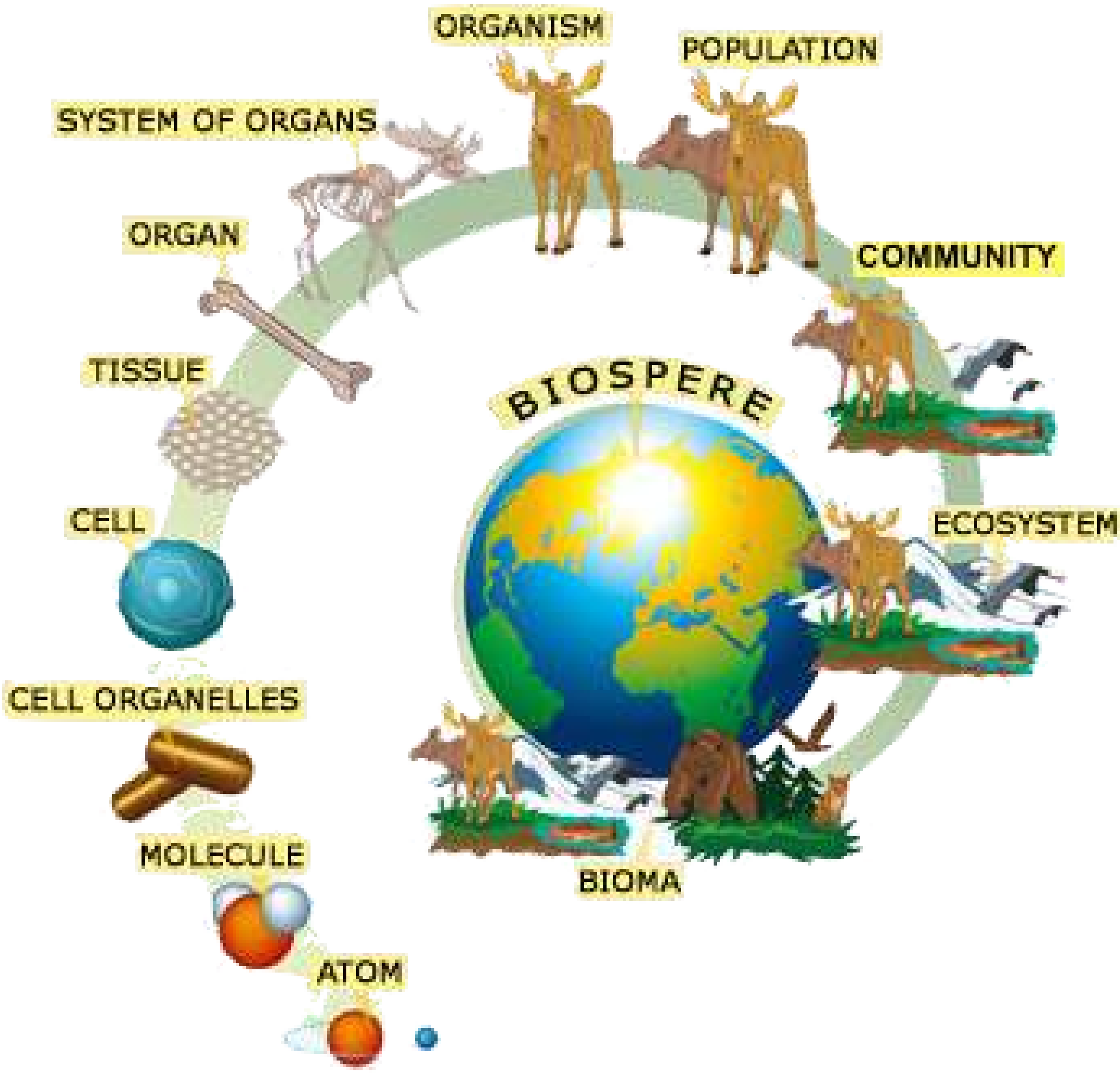
Section I

Section II

Section III

Section IV

Introduction: *The Hierarchy of Life*



Unit 1: *Behaving Like a Scientist*

Essential Questions

- How do we determine whether something is alive?
- What steps do scientists take to solve problems?
- What makes a good experiment? Talk about things such as control groups, independent variable, and dependent variable.
- Why is it important to make observations and not inferences in the lab? When are inferences helpful?

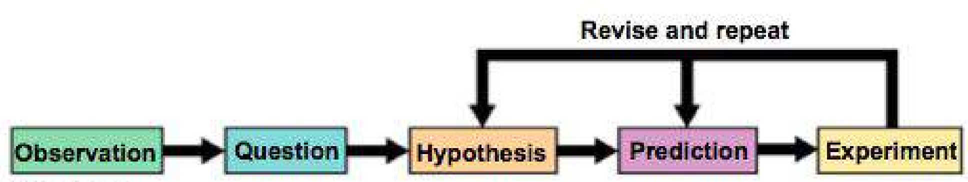
Properties of Life

1. Order = organisms exhibit a complex but ordered form of organization
2. Regulation = an organism can keep its internal body temperature within a healthy range despite external changes in temperature
3. Growth and Development = process controlled by DNA that allows organisms structure to grow and change
4. Response to Environment = organisms can respond to stimuli in the environment
5. Reproduction = an organism can create “offspring” or another organism similar to itself
6. Energy Processing = an organism can take in some form of energy which is used to grow or move
7. Evolution = organisms ability to adapt over many generations

Terms about Scientific Process

- Observation = something that can be directly observed through the five senses
- Hypothesis = tentative explanation of observations, can be proven or disproven by experiments
- Theory = a broader/deeper explanations for hypotheses or scientific laws
- Law = a brief statement that summarizes past observations and predicts future ones, can be proven or disproven by experiments
- Inference = an educated guess based on facts or past observations

The Scientific Method:



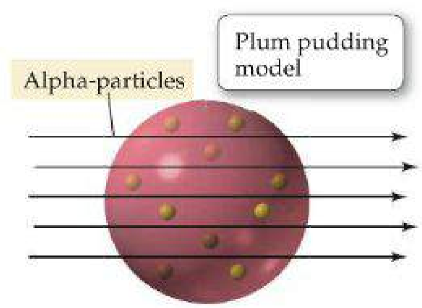
Unit 2: *Atoms and Elements*

Essential Questions

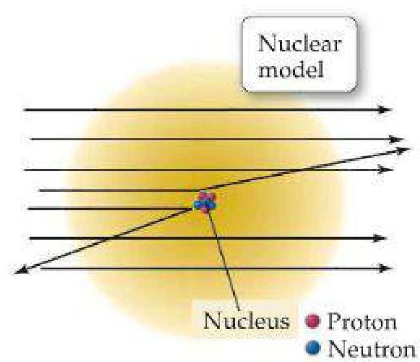
- How small is an atom?
- How has our understanding of the atom evolved? (Hint: start with Democritus and go through Rutherford).
- What makes up an atom? What do we know about each subatomic particle?
- What makes something an isotope? Give an example.
- What makes something an ion? Give an example.
- How does the organization of the elements of the periodic table provide information about the atoms of the elements?
- What's the difference between mass number and average atomic mass?
- How do we calculate average atomic mass?

Important Scientists - History of Atoms

- Democritus
  - Though that: there has to be a point when things stop breaking down
  - Came up with idea of uncuttables or (later called) atoms
- Dalton's Atomic theory:
  1. All elements are composed of tiny, indivisible particles called atoms
  2. Atoms of the same element are identical. Atoms of different elements are different.
  3. Atoms of different elements can physically mix together or chemically combine in whole number ratios
  4. Chemical reactions occur when atoms are separated, joined, or rearranged
- J.J. Thompson
  - Discovered electrons, first subatomic particle
  - "Plum pudding theory" -------------------------->>
- Rutherford
  - Trying to help prove Thompson's theory
  - Used cathode ray to Shot alpha particles at a thin piece of gold foil
  - Expected all alpha particles to go through...but:
    - most went through
    - 1/20,000 were reflected back - hitting the solid nucleus
- Nuclear Theory of an Atom
  1. Most of the atom's mass and all of it's positive charge are contained in a small core called the nucleus
  2. Most of the volume of the atom is empty space through which tiny, negatively charged electrons are dispersed
  3. The number of negatively charged particles equals the number of positively charged particles, so that it's neutral



(a) Rutherford's expected result



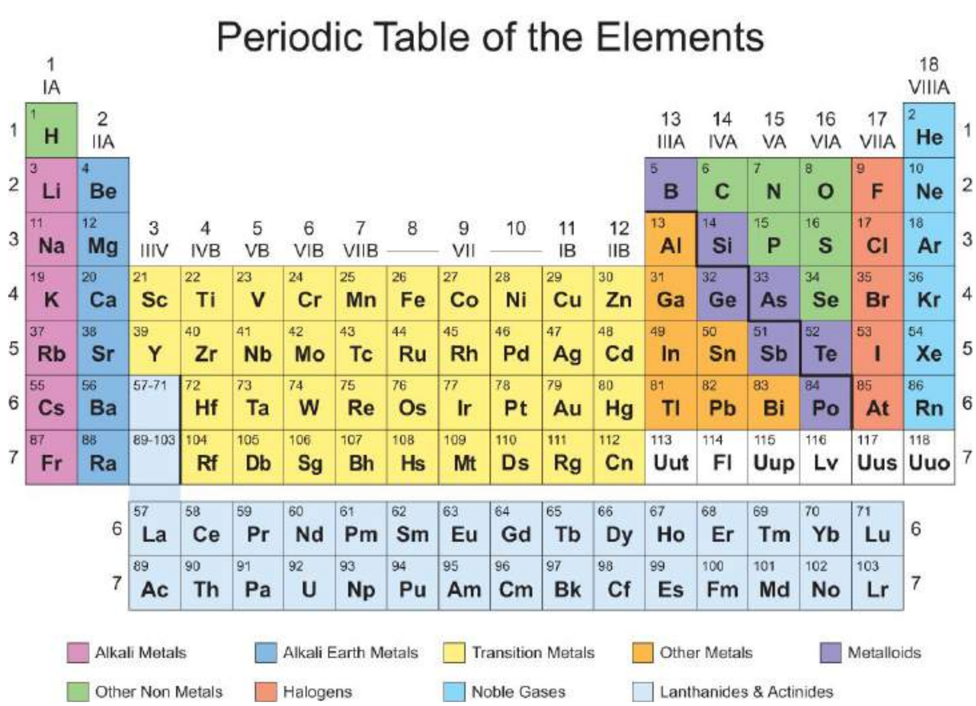
(b) Rutherford's actual result

Basic Facts about Atoms

- Made up of protons (+), electrons (-), and neutrons
- + and - charges attract
- same charges repel
- (1+) + (1-) = neutral charge
- Mass distribution in an atom
    - proton = 1.0073 amu (1)
    - neutron = 1.0087 amu (1)
    - electrons = 0.00055 amu (0)

Periodic Table

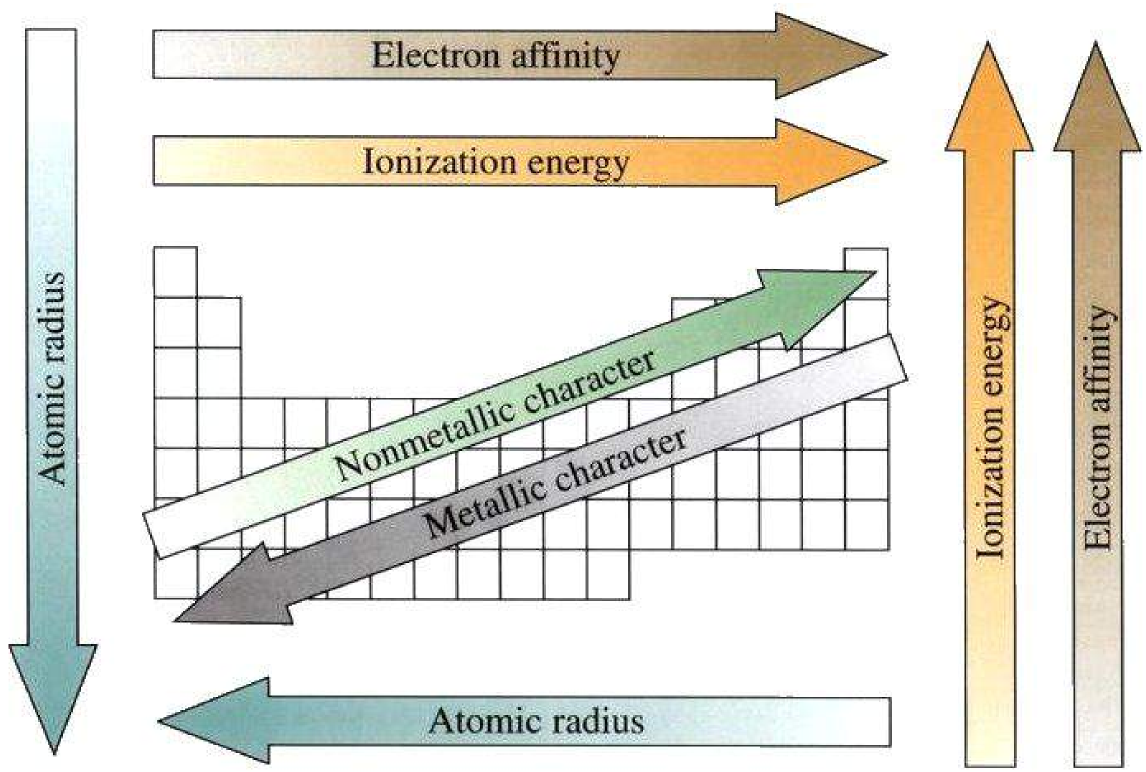
- Created by Mendeleev
- Elements are defined by the number of protons
- Valence Electrons: electrons in outermost shell
    - number of valence electrons = group number (for main group elements)
    - EXCEPTION: Helium has 2 valence electrons, but is still full
- Types of Elements:
    - Transition Metals: good conductors of heat and electricity, malleable, shiny, lose electrons when going through chemical reactions
    - Nonmetals: bad conductors of electricity, gain electrons when reacting
    - Metalloids: semiconductors (conductivity can be controlled)
    - Alkali Metals: 1 valence electron - extremely reactive metals
    - Alkali Earth Metals: 2 valence electrons - very reactive metals
    - Halogens: extremely reactive nonmetals, boiling and freezing point are close
    - Noble Gases: Have 8 valence electrons- rarely react with other elements



Trends on the Periodic Table

Periodic Law: When the elements are arranged in order of increasing relative mass, certain sets of properties recur periodically. The properties are:

- Atomic radius - radius of an atom
    - Going down: more electron rings, farther away from protons
    - Going left: less protons - less inward pull on the electrons
- Ionization energy - energy it takes to give away an electron
    - Going up: less electron rings - more pull of protons - harder to lose an electron
    - Going right: more protons for same amount of electron rings
- Electronegativity - the ability of an element to attract electrons
    - Going up: less electron rings - more pull from protons on nearby atoms
    - Going right: more protons, same amount of electron rings - more pull on nearby electrons in other atoms
- Metallic Character
    - Highest in the bottom left - furthest away from non-metals

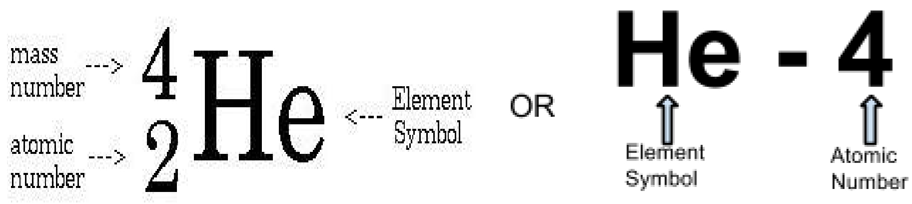


Ions

- Formed during chemical reactions
- Atom gains electrons (negative charge) or loses electrons (positive change)
- Charge of an atom = (number of protons) - (number of electrons)
- Cations: positively charged atoms
- Anions: negatively charged atoms
- Octet Rule: every atom wants 8 electrons in its outer shell

Isotopes

- Atoms of the same element with a different number of neutrons
- Symbols:



Average Atomic Mass:

- Average Atomic Mass - average mass of the different isotopes that occur in the element
- Percent Natural Abundance - percent of element that comes in a specific isotope

Calculating Average Atomic Mass with all masses known:
(mass of isotope #1 x 0.% natural abundance) + (mass of isotope #2 x 0.% natural abundance) + same equation with any other isotopes = Average Atomic Mass

Calculating Percent Abundance with masses known:
(Average Atomic Mass) = (Mass of isotope #1 x X) + (Mass of Isotope #2 x (1-X))
Solving for X = percent abundance for isotope #1.

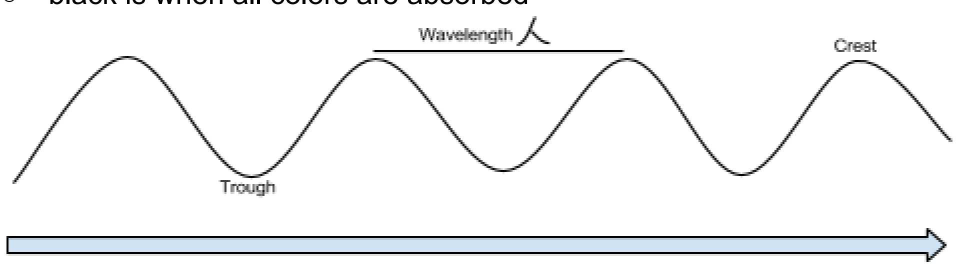
Unit 3: *The Periodic Table & Electrons*

Essential Questions

- How does the organization of the elements of the periodic table provide information about the atoms of the elements?
- What is the underlying cause of all periodic trends?
- What are valence electrons and why are they important? How do we tell how many valence electrons an element has?
- What are the different ways we can categorize the elements?
- How has our understanding of the atom evolved since Rutherford?
- What does an electron configuration tell us about an element?
- Explain this statement: Protons tell us the identity of an element but electrons tell us the personality.
- Which elements have “exceptional” electron configurations? Why?
- What is the relationship between electrons and photons?
- What is the relationship between the Flame Test and Electromagnetic Radiation?

Light

- A form of electromagnetic radiation - can be waves or particles
- Has no mass/matter
- Travels 186,000 mi/s
- Photon - a particle of light
- Frequency - waves/sec
    - larger wavelength = lower frequency, lower energy
    - shorter wavelength = higher frequency, higher energy
- Wavelength - distance between the crests in the light wave
- The colors are what light waves reflect back
    - white light is when all colors are reflected
    - black is when all colors are absorbed

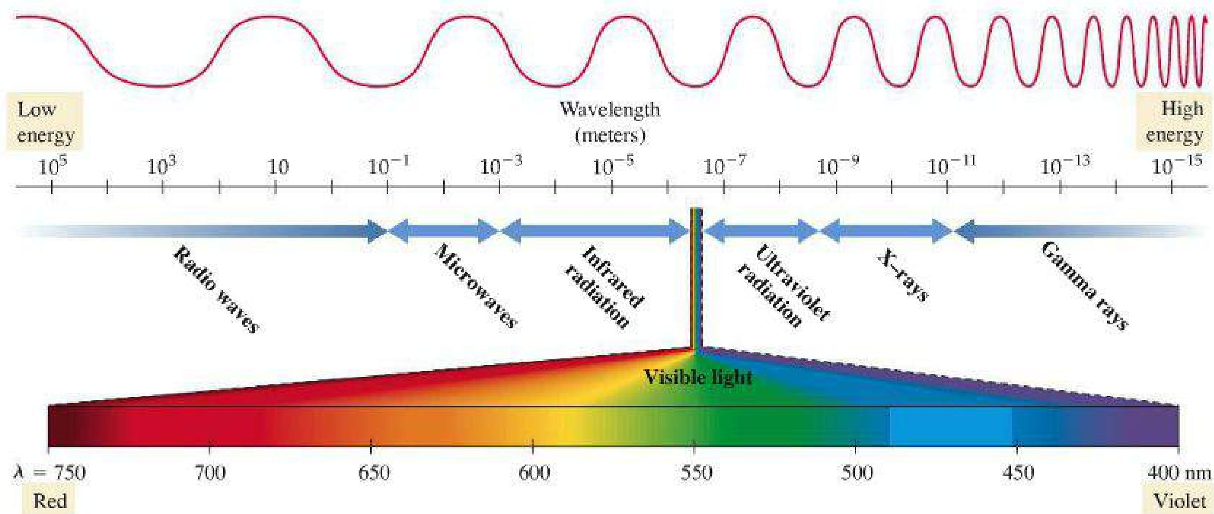


Bohr Model

- Electrons are in fixed energy levels
- The lowest energy levels are closer to nucleus
- Impossible for electrons to exist between energy levels
- Electrons “jump” between energy energy level causing a gain/loss of energy
- Quantum = amount of energy required to move an electron to the next highest level
- Excitation = electrons move up an energy level
- Relaxation = electron moves down an energy level
- Ground state = when electrons are in their usual energy levels

How atoms emit light:

1. Collision with moving particle excites atom
2. Electron jumps to higher energy level
3. Electron gains energy
4. Electron falls back down to ground state
5. Extra energy is released as a photon



RED ORANGE YELLOW GREEN BLUE INDIGO VIOLET

ROYGBIV

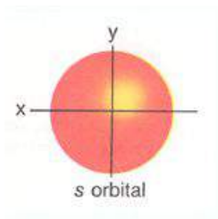
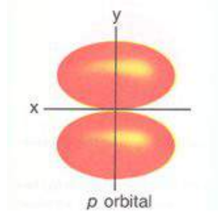
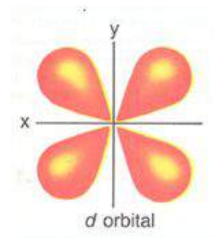
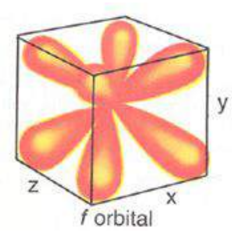
Different amounts of energy released causes different colors

- 1 level difference: red
- 2 level difference: blue-green
- 3 level difference: violet

Quantum Mechanical Model

Orbit - The path that an electron takes around an atom, all combined result in a...
Orbital - 3D area where the electron is most likely positioned (2 electrons in an orbital)

ENERGY LEVEL	# OF SUBSHELLS	SHAPE OF SUBSHELL
n = 1	1	s
n = 2	2	s, p
n = 3	3	s, p, d
n = 4	4	s, p, d, f

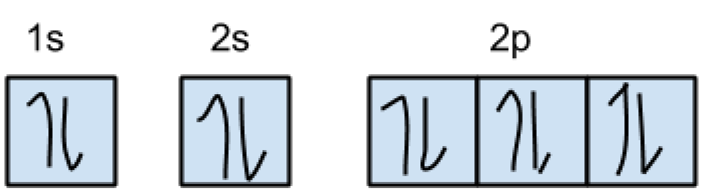
Sublevel	s - 1 orbital x 2 e- = 2 electrons	p - 3 orbitals x 2 e- = 6 electrons	d - 5 orbitals x 2 e- = 10 electrons	f - 7 orbitals x 2 e- = 14 electrons
Diagram				

Writing Electron Configurations

- Writing electron configurations
    - Follow the orbitals (on the chart below) diagonally down and go across the periodic table (in order of number of protons) until the element is reached

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d 6f
7s 7p 7d 7f

- Writing abbreviated electron configurations
    - Find the closest noble gas with a lower atomic number
    - Find the electron configuration that when added to noble gas, makes the element's electron configuration
    - FORMAT: $[Kr]4s^2 5d^{10}$
- Writing orbital diagrams
    - write out the boxes, one for each orbital
    - Fill up boxes until all electrons have been used
    - Pauli Exclusion Principle: electrons in same orbitals must have opposite spin (arrows point opposite ways)
    - Hund's Rule: every orbital in a sublevel needs an electron before any orbital can have 2 electrons - only in single sublevels



- EXCEPTIONS
    - Copper and Chromium have one of their 4s electrons in their 3d sublevel
    - $Cr = [Ar]4s^1 3d^5$
    - $Cu = [Ar]4s^1 3d^{10}$

Unit 4: *Water and Compounds*

Essential Questions

- How do you determine whether a compound is ionic or covalent?
- What are the rules for naming covalent compounds?
- What are the rules when it comes to naming ionic compounds?
- How do we determine the formula for ionic and covalent compounds?
- What does it mean if something is diatomic? Why are some molecules diatomic? Which elements exist as diatomic molecules?
- How are covalent bonds different from the bonds used to hold sodium and chlorine together?
- What determines how polar those bonds are?
- What is the Lewis Dot Structure used for? What does it show about a molecule?
- What shapes can a molecule make and how can they be predicted?
- What are coordinate covalent bonds and how do you identify them?
- What is a polyatomic ion? How do their dot structures differ from those of molecules?
- What do nitrogen dioxide, boron trifluoride, and phosphorus pentachloride have in common?
- How is the strength of a covalent bond related to its bond dissociation energy?
- What kinds of information does a structural formula reveal about the compound it represents?
- How do you determine the hybrid orbital of a molecule given its formula?
- What is the difference between bond polarity and molecular polarity?
- Compare and contrast 4 types of intermolecular forces.
- What are the five unique properties of water (from the lab/video)?
- What are the 4 properties of water that make life on Earth possible (from class/PowerPoint)
- When is water most dense?
- How does polarity explain the properties of water?
- How does each of those properties support life on Earth?

Chemical and Physical Changes

- Physical Changes
    - Changing state
- Chemical Changes
    - Color Change
    - Something Disappears
    - Odor Produced
    - Heat released

Chemical Formulas

- Compound - elements combine in definite ratios - CO_2 = 1:2 ratio
- Write the most metallic elements first in a formula
- Mixture - can have any properties
    - homogeneous: equally mixed
    - heterogeneous: separated, not uniform

- Law of Constant Composition
  - All samples of a given compound have the same elements in the same proportions
- Polyatomic Ions - groups of atoms that work as a unit, usually they have a charge
- Writing Chemical Formulas

Molecular formula   Structural formula   Ball-and-stick model   Space-filling model

- Types of Pure Substances
  - Atomic Elements - single atoms
  - Diatomic Elements - diatomic molecules (H, N, O, F, Cl, Br, I)
  - Compounds
    - Ionic (cations and anions combined) - exchange of electrons
    - molecular (2 or more non-metals) - Sharing of electrons
- Formula Unit - the formula for a ionic compound (not the name)

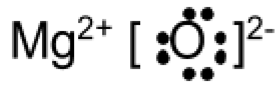
<u>Naming Compounds</u>

- Ionic Compounds
  - Compounds with metal that have only one ion
    - [name of cation (metal)] + [name of anion (nonmetal) + ide]
  - Compounds with metal that has more than one ion
    - [name of cation (metal)] + [(charge of cation in roman numerals)] + [base name of anion (nonmetal) + ide]
  - Ionic compounds with polyatomic ions
    - [name of cation (metal)] + [roman numeral] + [name of polyatomic ion]
- Molecular Compounds
  - [prefix (if more than one) + name of first element] + [prefix + name of second element + ide]
  - prefixes:

Number	Greek Prefix	Number	Greek Prefix
1	mono	6	hexa
2	di	7	hepta
3	tri	8	octa
4	tetra	9	nona
5	penta	10	deca

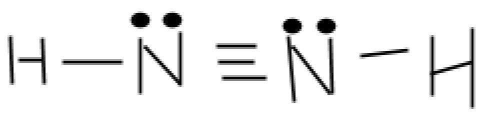
Writing Lewis Structures

- Ionic Compounds
    A. Draw the structure of each element by drawing the structure of each atom (using dots for valence electrons)
    B. Figure out what would happen for each molecule to achieve the octet rule
    C. Write the new structure of all atoms together with charges
    D. Put anion in brackets

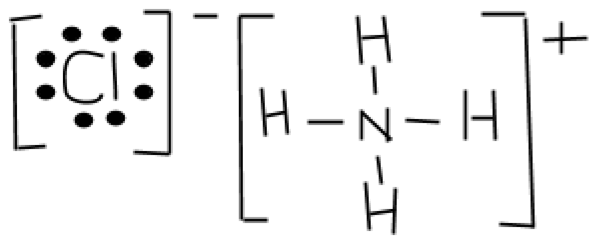


- Covalent Compounds
    A. Write the correct skeletal structure for the molecule
    B. Calculate the total number of valence electrons. If there is a polyatomic ion, add an electron for each negative charge and subtract an electron for each positive charge.
    C. Distribute the electrons, giving a full outer shell to as many atoms as possible.
    D. If any atoms lack 8 valence electrons, form double or triple bonds.
    E. Put any polyatomic ions in brackets with charge

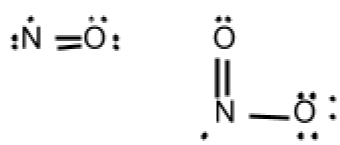
without polyatomic ion



with polyatomic ion



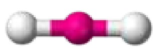
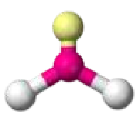
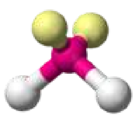
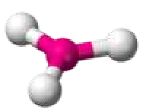
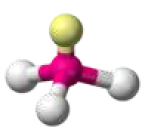
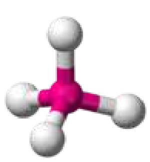
- EXCEPTIONS:
    - NO^{-} and NO_2



    - Boron tends to form compounds with 6 valence electrons
    - Phosphorus can have 10 valence electrons
    - Sulfur can have 12 valence electrons

VSEPR Theory

- A way of predicting the shape of certain molecules through their lewis structures
- Shows the geometry of the atom as they repel each other and unbonded electron pairs

Shape Name	Picture	Angles	Hybrid Orbitals	Polarity- Outside atoms **are** identical	Polarity- Outside atoms **not** identical
Linear		180*	sp	Non-polar	Polar
Linear		180*	sp	Non-polar	Polar
Bent		118*	sp2	Polar	Polar
Bent		104.5*	sp3	Polar	Polar
Trigonal Planar		120*	sp2	Non-Polar	Polar
Trigonal Pyramidal		107.5*	sp3	Polar	Polar
Tetrahedral		109.5*	sp3	Non-polar	polar

Bonds

- Inter**er**molecular bonds - weaker ones between the molecules
  - Dispersion Forces
    - electrons being shared in a covalent bond will travel throughout both atoms
    - both electrons can be in the same atom at the same time
    - the molecule will gain a slight charge when this happens
  - Dipole interactions
    - all polar molecules have slight charges on both sides
    - all polar molecules are attracted to each other

        - similar to ionic bonds, but much weaker
- Hydrogen Bonds (Look below)
- Int**ra**molecular bonds - stronger ones between atoms
    - Covalent
        - two non-metals bonded
        - electrons shared
    - Ionic
        - one metal and one non-metal
        - two metals
        - transfer of electrons

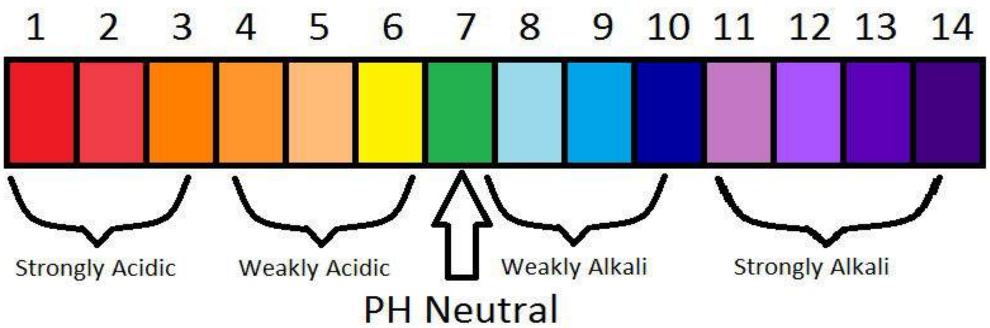
Properties of Water

- Hydrogen Bonds
    - Hydrogen only bonds with F, N, or O because of their high electronegativities
    - Very strong, but only 5% as strong as covalent bonds
    - Such strong bonds give substances unique properties, such as water's:
- Cohesion
    - Strong attraction to other water molecules
    - Surface tension is a result of cohesion
        - Mosquito Larva stick to underside of water
    - Transpiration is a result of Cohesion
        - Water's adhesive property helps it attach to other materials
        - Capillary Action- Adhesion to stick to the sides, Cohesion pulls up other water molecules below - in the xylem of plants and trees
- High Specific Heat
    - Atoms don't want to expand to break bonds
    - Initial energy goes into breaking bonds, not heating up the liquid
    - the amount of heat that must be absorbed or lost for 1g of a substance to change it's temp by 1 degree celsius
    - water contains a huge amount of energy per degree celsius
        - water's specific heat is 1 cal/g/degree celsius
    - Results of high specific heat:
        - Homeostasis - Organisms can maintain a stable body temperature
        - Water doesn't evaporate at lower temp
            - rivers and lakes are still around
            - oceans are able to moderate climate temp
- Expansion Upon Freezing (Ice Floats)
    - Hydrogen bonds are more ordered in ice
    - When water freezes, the shape of the ice forms a lattice structure
        - Molecules are further apart
    - Allows water to freeze on the surface while life can exist underneath

Unit 5: *Macromolecules*

Acids and Bases

- Measured on the pH scale
- Measures how many H+ ions there are
- Acids are a H+ donor
- Bases are a H+ receiver



Naming Acids

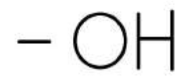
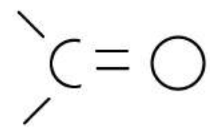
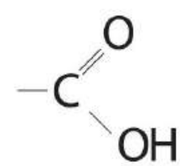
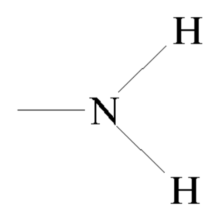
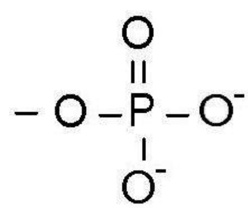
- binary acids (hydrogen + nonmetal)
  - [hydro + (base name of nonmetal) + ic] + [acid]
- oxyacids (hydrogen + anion with oxygen + nonmetal)
  - (base name of anion with oxygen + corresponding suffix + acid)
    - -ite --> -ous
    - -ate --> -ic

Macromolecules Overview

- Long "string" of molecules
- Made up of Carbon, Hydrogen, Oxygen, Nitrogen, and Phosphorus ONLY
- Carbon is the center atom and very important in all macromolecules, because...
  - It has 4 valence electrons
    - Can give or take 4 electrons to bond
    - Can bond with itself
  - Extremely abundant
- Carbon bonds in branches or rings
- Carbon is not written in the structures, just two lines touching
- Monomers: The building blocks
- Polymers: The chains of similar monomers
- Isomers: molecules with the same formula, but different structures
  - Starch and Cellulose are isomers
- R groups: variable group that determines function and polarity
- When two monomers react, the drop out a water molecule
  - Dehydration synthesis: bonding and a water molecule drops out
  - Hydrolysis: Bond breaks and water molecule used

Functional Groups

Atoms Directly involved in chemical reactions

Functional Group	Description	Diagram
Hydroxyl Group	Atoms: Oxygen and Hydrogen Formula: OH Notes: Bonds two monomers together and will drop a water molecule out (dehydration synthesis)	
Carbonyl Group	Atoms: Carbon and Oxygen Formula: CO Notes:	
Carboxyl Group	Atoms: Carbon, Oxygen, and Hydrogen Formula: COOH Notes: A Hydroxyl and Carbonyl group combined	
Amino Group	Atoms: Nitrogen and Hydrogen Formula: NH2 Notes: Amino group and hydroxyl group make up Amino Acids	
Phosphate Group	Atoms: Oxygen and Phosphorus Formula: OPO3 ^2- Notes: ATP	

Carbohydrates

- Monomer: Monosaccharides
- Specific Examples: Glucose, Fructose
- Polymer: Polysaccharides
- Specific Examples:
    - Starch: stores energy in plants
    - Glycogen: stores energy in animals
    - Cellulose: structure of a plant's cell wall

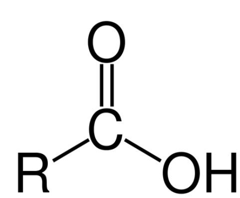
    - Chitin: exoskeletons of arthropods
- Bonds: Glycosidic Bonds
    - alpha linkages: O atom points down (starch)
    - beta linkages: O atom parallel with glucose units
    - causes dehydration synthesis
- Uses: Short term energy, Energy Storage, Structure, In plants in animals
- Naming of Monosaccharides: [Prefix (based on # of C atoms) - ose]
- Disaccharides: two monosaccharides
- Sugars are simple carbs
- Fibers are complex carbs

Proteins

- Monomer: Amino Acids
    - Central carbon atom, H, an amino group, a carboxyl group, and R group
- Specific Examples: Asparagine, Valine, Crystalline
- Polymer: Polypeptide
- Specific Examples:
    - Keratin: hair and nails
    - Actin: In muscles
- Bonds: Peptide Bonds
    - Causes dehydration synthesis
- Uses: In muscles, Hair and Nails, Enzymes, Movement, Communication
- Protein shapes
    - Primary: amino acid sequence
    - Secondary: repeated amino acid sequences
        - Forms alpha helix: amino acids wrapped in tight spiral
        - Or forms beta pleated sheet: structure forms zigzag patterns
    - Tertiary: large twists in protein structure (determined by R groups)
    - Quaternary: arrangement of large polypeptide chains within a protein
- Enzymes: Biological catalyst that speeds up chemical reactions
    - Competitive inhibitors will get in the way
    - Example: Lactose helps break down sugars in milk

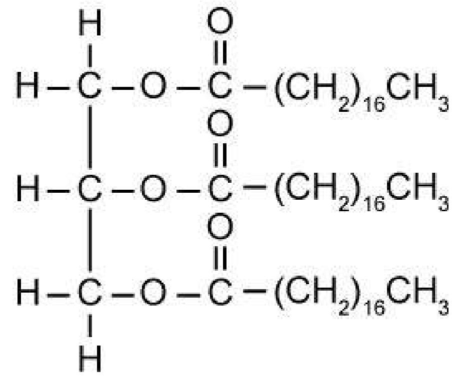
Lipids

- Insoluble in water, soluble in non-polar substances
- Two times long term energy storage as Carbs
- Fatty Acid structure:
    - A carboxyl group and a R group
    - R group can have 3-19 carbon atoms
        - Saturated Fatty acid has no double bonds
        - Monounsaturated fatty acid has one double bond
        - Polyunsaturated fatty acid has more than one double bond



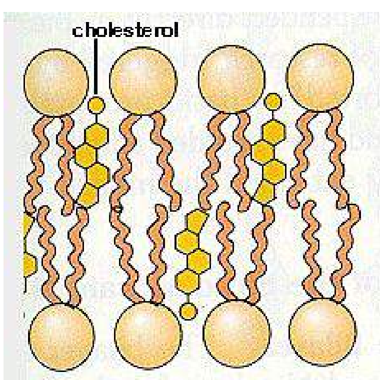
- Fats and Oils
    - Known as triglycerides
    - 3 fatty acids and a glycerol
    - Three water molecules released through dehydration synthesis in reaction
    - If the fatty acids are saturated, then the triglyceride is a saturated fat
    - If the fatty acids are unsaturated, than the triglyceride is a unsaturated fat

    - **Saturated Fats:**
        - Straight shape
        - Single bonds
        - Stackable
    - **Unsaturated fats:**
        - Not a straight shape
        - Have double bonds
        - Not stackable
        - Healthier
    - **Trans Fats** are artificially saturated fats - double bond is added in a lab

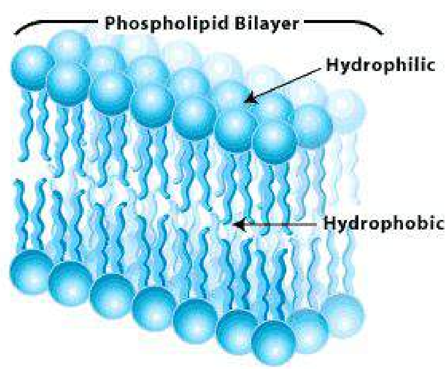


- Waxes
    - Hydrophobic: want to get away from water
    - Coats the stems of plants
    - Hives for Bees
    - Protects our ear canals
- Phospholipids (cell walls)
    - Hydrophilic (they like water) ‘heads’
    - Hydrophobic (don’t like water) ‘tails’
    - A double layer of phospholipids, tails in heads out, forms a barrier around cells
- Cholesterol
    - Holds together cell walls in between some of the phospholipids
    - Gives cells their shape even with a fever
    - Too much can cause buildups in arteries

Cholesterol



Phospholipids



Unit 6: *Cells and Transport*

Essential Questions

1. How can you tell the difference between things that are living and nonliving?
2. How do the terms biotic and abiotic relate to the terms living and nonliving?
3. In what ways are the three different types of cells similar and different?
4. What are organelles and in what type of cells are they found?
5. In what ways are plant and animals similar and different?
6. What organelles are unique to plant cells? Animal cells?
7. What is the chemical makeup of the cell membrane?
8. What are the various ways substances move across the cell membrane?
9. Which macromolecules make up the cell membrane? What is their job?

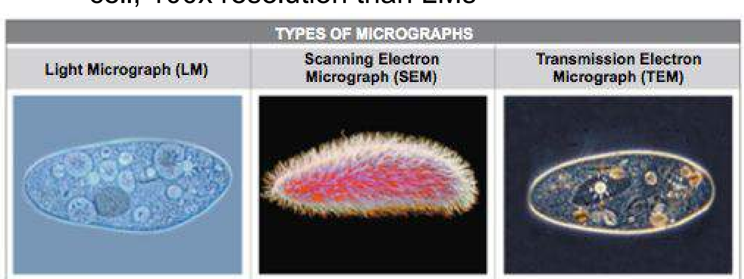
Microscopes

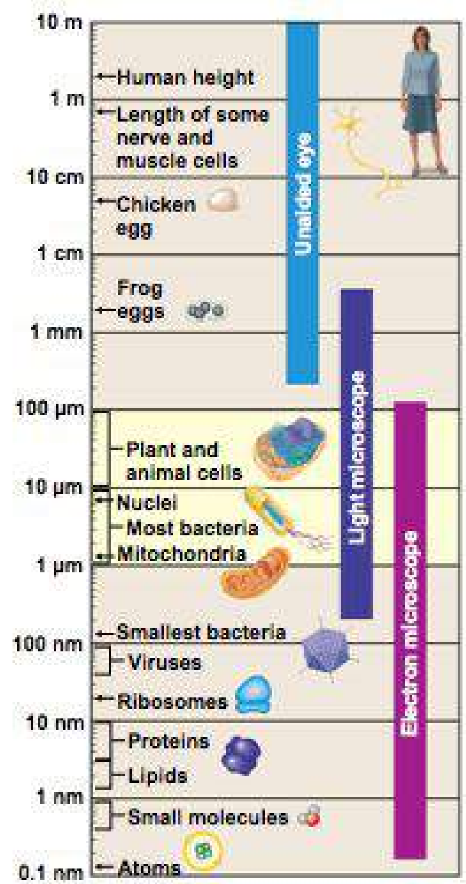
Vocabulary

- Magnification: increase in the object's image size compared to actual size
- Resolving Power: the ability of a microscope to show two objects as separate
- Resolution: Quality of picture, higher resolution means better resolving power

Types of Microscopes

- Light microscope (LM): light passes through object and magnifies it
- Scanning electron microscope (SEM): uses a beam of electrons to examine the cell's surface, 100x better resolution than LMs
- Transmission electron microscope (TEM): uses a beam of electrons to look at the internal part of a cell, 100x resolution than LMs





Cells - Overview

- Discovered by Robert Hooke (along with Cell Theory)
- Make up all living things
- Each cell performs the 9 characteristics of life
- Made up of organelles each performing a different function
- Cell Theory
  - All living things are composed of cells and
  - All cells come from other cells
- The three domains of life
  - Bacteria
  - Archaea
  - Eukarya

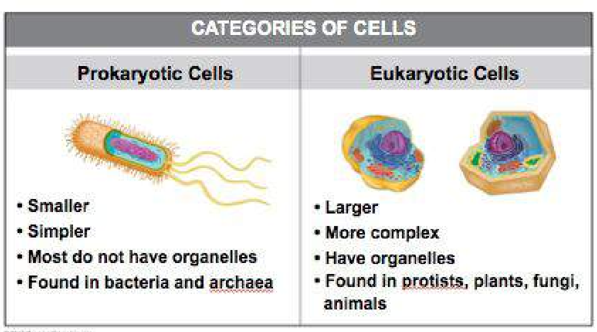
All Cells in Common

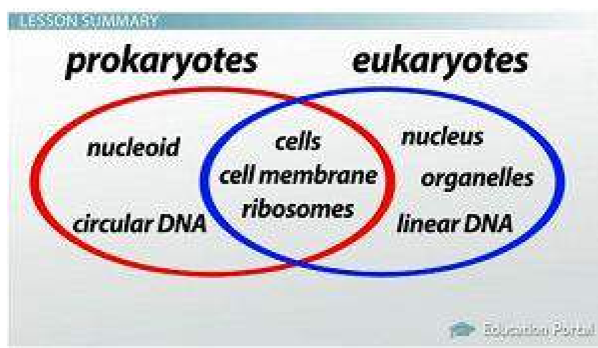
- Surrounded by cell membrane/plasma membrane
- Filled with **cytosol** - jelly like fluid inside cell
- One or more chromosomes to carry DNA
- Contain ribosomes to build proteins

Antibiotics

- Disable/kill infectious bacteria
- Naturally occur
- Also made - like Penicillin

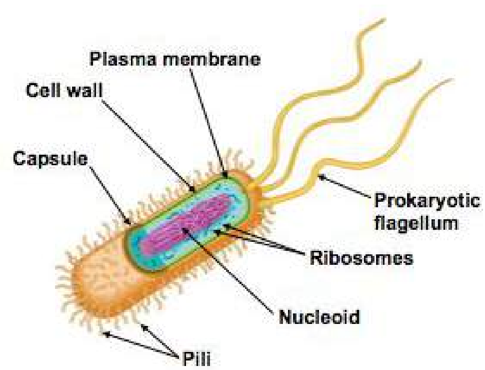
The Two Types of Cells - Compared





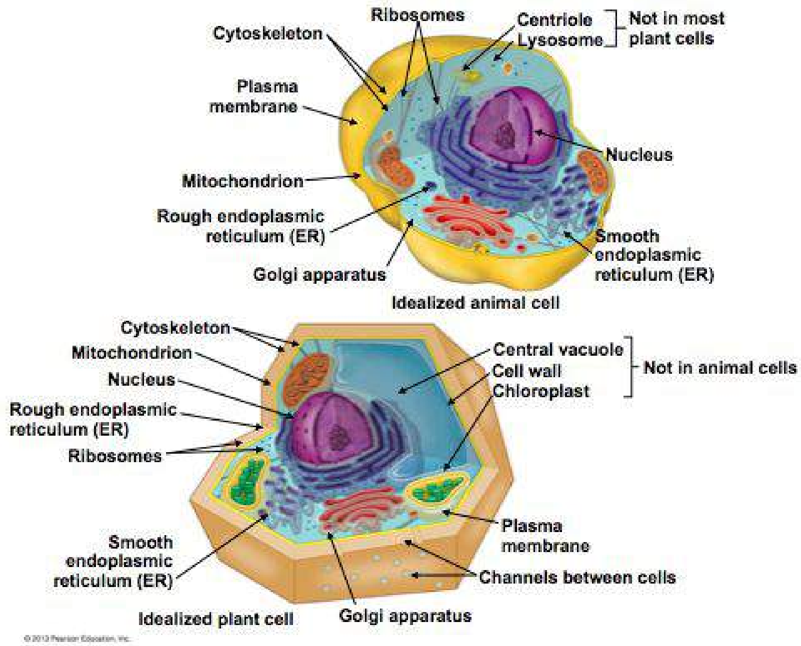
Prokaryotic Cells

- Found in:
  - Anchea
  - Bacteria
- First life on earth
- No nucleus
  - Has nucleoid to hold DNA
- Flagella help the cell move around
- 1/10 size of eukaryotic cells



Eukaryotic Cells

- Found in:
  - Animals
  - Plants
  - Protists
  - Fungi
- 10x size of prokaryotic cells
- Contain organelles to perform specific tasks/ function
- Cytoplasm: the inner area in the cell containing the organelles



Organelles - Inside a Eukaryotic Cell

Make up cells, each with a different specific function

The five main jobs of Organelles

- Creating Boundaries
- Genetic Control
- Manufacturing and Distributing Cellular Products
- Energy conversion
- Shape and Movement

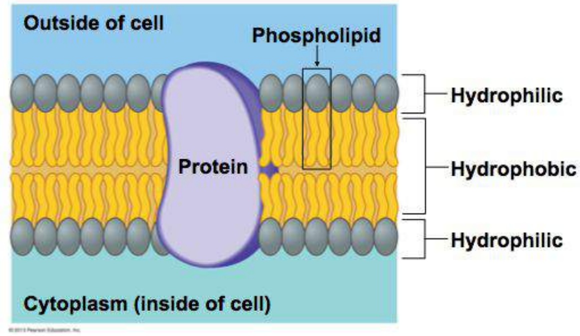
Organelle	Category of Job / Subpart	Function	Type of cells found in
Plasma Membrane	Creating boundaries	• separates the living and non-living things • made of phospholipid bilayer	In all cells
Cell Wall	Creating boundaries	• Protects plants from having too much water and bursting • Made of cellulose	Plant cells only
Extracellular Matrix	Creating boundaries	• Helps to hold cells together into tissues • On the outside of a cell	Animal cells only
Cell Junctions	Creating boundaries	• Holds networks of cells together to form tissue	Plant and animals cells only

Nucleus	Genetic Control	• Contains long DNA molecules (chromosomes) • Makes ribosomes • Double membrane with nuclear pores	In Eukaryotic cells only
	mRNA	• A copy of the DNA sent out by the nucleus • Leaves through the nuclear pores and enters cytoplasm • Ribosomes use its "code" to synthesize proteins	
	Nuclear envelope	• Separates the Nucleus from the cytoplasm • Double layer membrane	
	Nucleolus	• Create Ribosomes	
	Nuclear Pores	• Holes in the nuclear envelope allowing the mRNA to exit	
	DNA/ Chromatin/ Chromosomes	• Going from smallest to largest: • DNA and proteins create the... • long chromatin fibres, which create the... • chromosomes in the nucleus	
Ribosomes	Genetic Control	• Made in the nucleolus • All are identical • "codes" proteins (protein synthesis)	All cells
Rough Endoplasmic Reticulum	Manufacturing cellular products	• Place where ribosomes synthesize proteins • Sends proteins out	In Eukaryotic Cells only
Smooth Endoplasmic Reticulum	Manufacturing cellular products	• "Codes" lipids (synthesis of lipids)	In Eukaryotic Cells only
Golgi Apparatus	Distributing cellular products	• Receives products of the ER in transport vesicles • Refines, stores, and distributes products	In Eukaryotic Cells only
Lysosomes	Manufacturing and	• Digests food • Breaks down broken	In Eukaryotic Cells only

	distributing cellular products	organelles ● Off of the golgi apparatus	
Vacuole	Manufacturing and distributing cellular products	● Fills with water to help cells grow ● Stores nutrients ● Some store poison to protect against predators	In Eukaryotic Cells only - Plants have large one and animals have small ones
Vesical		● Transfer vesicles move the products of the ER from the ER to the golgi apparatus	In eukaryotic cells only
Chloroplast	Energy Conversion	● Preform photosynthesis ● Filled with stoma (fluid) ● Grana capture light ● Contain their own DNA	Plant and algae cells only
Mitochondria	Energy Conversion	● Responsible for cellular respiration ● Harvest energy and turn it into ATP ● Contain their own DNA	In eukaryotic cells only
Cytoskeleton	Shape	● Fibres inside cell ● Help to hold the cell's shape	Plant and animal cells only
Microtubules	Shape	● A Fibre in the cytoskeleton ● Larger, hollow ● Made of protein	Plant and animal cells only
Filaments	Shape	● Smaller parts of the cytoskeleton ● Thinner and solid	Plant and animal cells only
Cilia	Movement	● Shorter and more abundant than flangela ● Small back and forth motion	Some animal cells
Flagella	Movement	● Longer and less abundant than cilia ● Propel the cell	Some animals and prokaryotic cells

Cell Membrane

- Made of phospholipids
- Divide the non-living outside part of cell and the cytoplasm of the cell
- Hydrophilic heads and hydrophobic tails



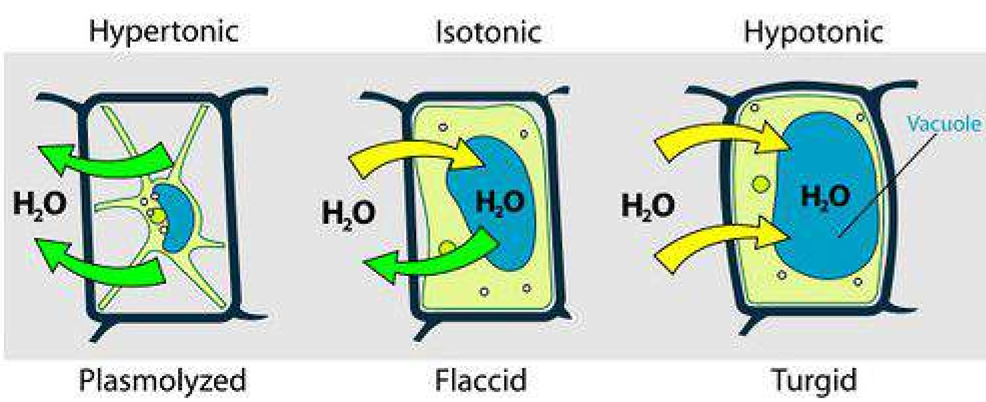
Diffusion

- Diffusion: When molecules spread out into an even concentration gradient
    - Does not use any of the cell's energy
- Passive Transport: The diffusion of molecules across the cell membrane
    - Does not use energy because the unequal concentration gradient causes the molecules to move
- Active Transport: When molecules move across the cell membrane, but going against the concentration gradient
    - Uses the cell's energy

Osmosis

The processes of a higher concentration of water moving into the area where there is a lower concentration of water

- Hypertonic solution: When a substance has more solute than water
- Hypotonic solution: When a substance has more water than solute
- Isotonic solution: When a substance has equal water and solute
- Solute: The thing being dissolved
- Solvent: Liquid that does the dissolving



More Osmosis Vocab

- Aquaporin: a membrane protein used to pump water in and out of the cell
- Plasmolysis: The process where cells lose water in a hypertonic solution
- Facilitated Diffusion: proteins assist the transport of biological molecules
- Exocytosis: the movement of materials leaving the cytoplasm by vesicles/vacuoles
- Endocytosis: the movement of materials entering the cytoplasm by vesicles/vacuoles

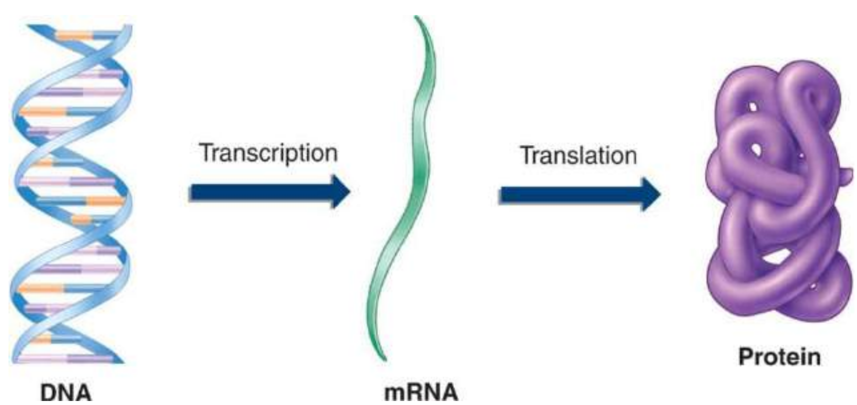
Unit 7: *Transcription and Translation*

Essential Questions

1. How does the structure of DNA store genetic information?
2. How does the structure of DNA enable efficient replication of the molecule?
3. What % of our DNA is used in the Transcription and Translation process?
4. How are DNA and RNA similar and different?
5. What role does RNA play in protein synthesis?
6. How is RNA synthesized? When is RNA synthesized? What enzymes are used in this process?
7. How is mRNA translated into a protein? Where does this process take place?
8. What determines the structure of proteins? Why is the structure of a protein so important?
9. Why are transcription and translation essential processes for all living things?
10. What types of chemical bonds are created and broken during transcription and translation?
11. What are mutations? When could they occur? What are the different types of mutations?
12. Are all mutations harmful?

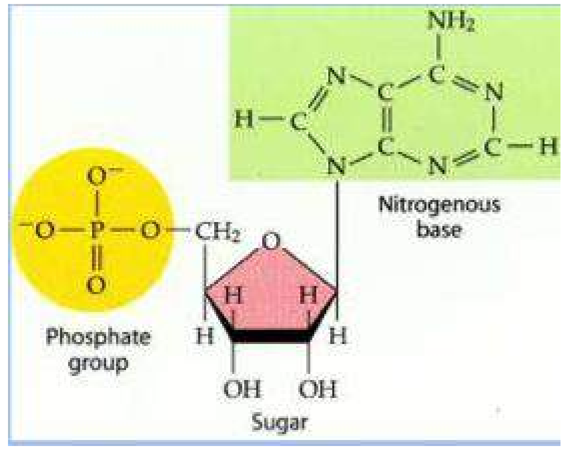
Main Vocabulary and Review Vocabulary

- Genes: A segment of a DNA molecule, 25,000-45,000 in body, each with 10,000-100,000 nitrogenous bases (a lot of DNA)
- Amino Acid: a monomer of protein
- Polypeptide: a polymer of protein
- Nuclear Envelope: Double layer membrane to separate cytoplasm from nucleus
- Nuclear Pore: holes in the nuclear pore that allow certain molecules to pass (mRNA)
- Ribosome: Synthesize proteins (made in the nucleolus, all are the same)
- The Central Dogma of Biology: Transcription and translation (diagram below)



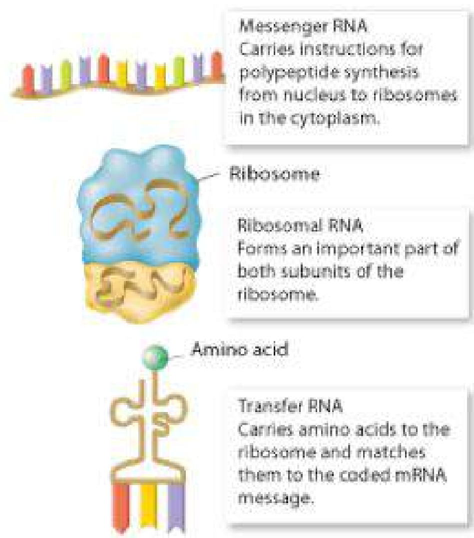
DNA - Deoxyribonucleic Acid

- Discovered in the 1800's
- DNA is made up of:
  - Polymer: Nucleic Acid
  - Monomer: Nucleotide
- Nucleotides are joined together by covalent bonds
- Two strands of a sugar-phosphate backbone
  - Deoxyribose sugar
  - Phosphate group
- In the form of a double helix
- Opposite strands joined together by nitrogenous bases (below) creating a sequence similar to binary, joined by hydrogen bonds



RNA - Ribonucleic Acid

- Single strand
- Messenger RNA (mRNA) carries the instructions for protein synthesis to the ribosome
- Ribosomal RNA (rRNA): make up ribosomes (along with proteins)
- Transfer RNA (tRNA): contain an anti codon (opposite nitrogenous bases than mRNA) which plugs into the mRNA and finds the corresponding amino acid to be released

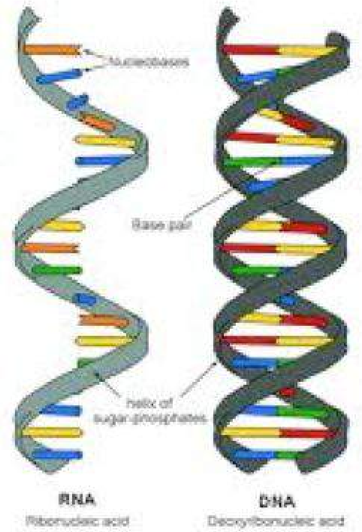


Nitrogenous Bases

- Nitrogenous bases: adenine pairs with thymine, guanine pairs with cytosine
- Joined by peptide bonds
- Purines: double ring (adenine and guanine)
- Pyrimidines: single ring (thymine and cytosine)
- Purines and Pyrimidines cannot bond with themselves, but must bond with each other so that DNA has a uniform shape

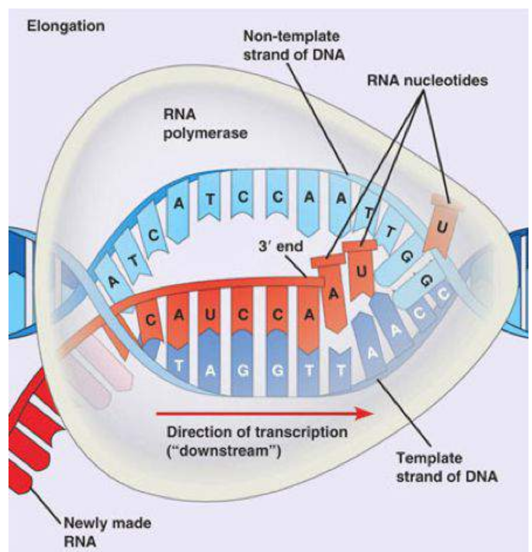
3 Differences Between RNA and DNA

DNA	RNA
Sugar: Deoxyribose	Sugar: Ribose
Double strand	Single strand - so it can fit through the nuclear pores
Nitrogenous Bases: Adenine, Thymine, Cytosine, Guanine	Nitrogenous Bases: Adenine, Uracil, Cytosine, Guanine



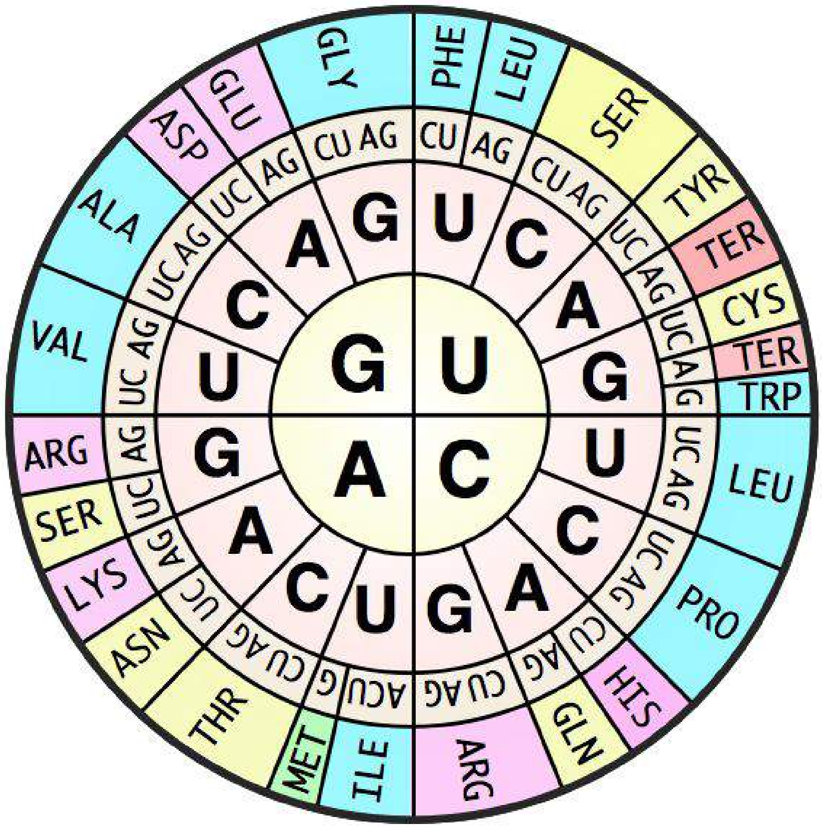
Transcription

- Transcription Unit: the piece being copied
- Transcription factors: the enzymes and proteins that help in transcription
- Requires ATP
- Initiation
    - Promoter dictates where the strand is to be copied
    - RNA polymerase binds to the TATA box (many thymine and adenine) and transcription starts
- Elongation
    - Helicase (enzyme) unzips the double helix strand of protein
    - RNA polymerase attaches to one side and travels down that strand
    - The RNA grows longer as the RNA polymerase copies one strand's nitrogenous bases
    - The two strands of DNA come back together again after the RNA polymerase has passed
- Termination
    - RNA polymerase reaches the terminator which indicates when transcription should stop



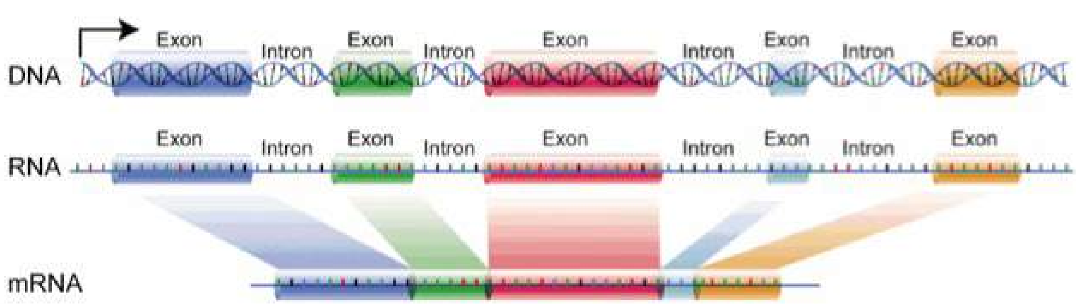
The Genetic Code

- The rules that convert a nucleotide sequence into an amino acid sequence
    - Similar to translating languages
- Methionine starts, stop codons end the sequence
- There can be more than one nitrogenous base sequence in a codon that represents one amino acid
    - 61 codons represent 20 amino acids (3 stop codons)

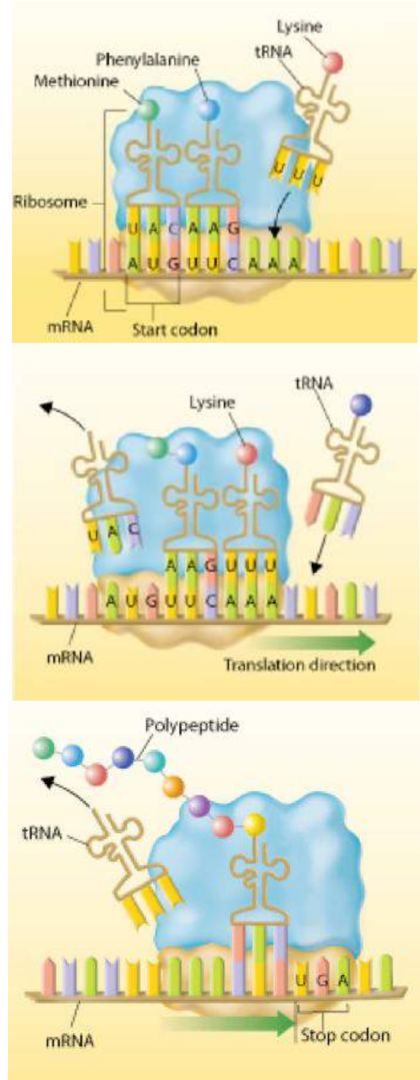


<u>**Processing of RNA**</u>

- A cap/tail of nucleotides are added on either end to protect the mRNA strand
- Introns are removed to leave only Exons during RNA splicing
- RNA splicing
    - Introns: sections of DNA removed from mRNA strand after being copied
    - Exons: sections of DNA useful to protein synthesis and therefore kept in mRNA strand
    - 3% of DNA is Exons
    - Introns are not useless, they are used in other ways
    - Mutations in the copying of introns do not matter and are silent mutations
    - RNA is shortened
- After processing, the RNA leaves the nucleus through the nuclear pores



Translation



- mRNA finds a ribosome
- The mRNA is fed into a ribosome and its code is read
- Codon: a code of three nitrogenous bases in mRNA
- There are 64 possible combinations of nitrogenous bases in a codon
    - 3 spaces each with 4 letters = 4x4x4 = 64
- The 64 different codons represent and correspond to 20 amino acids
- tRNA enters the ribosome and reads each codon
- The tRNA with the correct anti-codon releases the correct amino acid
    - Anti-codon: has the opposite nitrogenous bases than RNA
- All the proteins start in Methionine (AUG) because it is the only start codon
- Methionine can be other places in the sequence, it just will act as a normal amino acid
- The amino acids released from a polypeptide through peptide bonds
- Translation will continue until a stop codon cuts of the polypeptide chain
- mRNA floats away into cytoplasm

Mutations

- A change in the nitrogenous base sequence
- Occurs during transcription and translation
- Frame shift mutations are the worst kind
- Point mutations are not as bad

Point Mutations

- Change one nitrogenous base (letter/point)
- Silent Mutation: Mutation does not affect amino acid sequence (also mutations in introns)
- Nonsense Mutation: Mutation results changes/adds/deletes the stop codon
- Missense Mutation: Mutation results in the wrong amino acid in the sequence
    - Conservative: different amino acid, but similar characteristics (base, polar, etc.) does not change the tertiary structure
    - Non-conservative: different amino acid that has different characteristics (base, polar, etc.) that does result in a different tertiary structure

Frame Shift Mutations

- Frame shift mutations are worse than point mutations
- Insertion: inserts a nitrogenous base not previously there
- Deletion: deletes a nitrogenous base
- Insertion and deletion will result in the entire nitrogenous base sequence after the mutation changing, all of the codons will be different

Unit 8: *The Cell Cycle and The Life Cycle*

Essential Questions

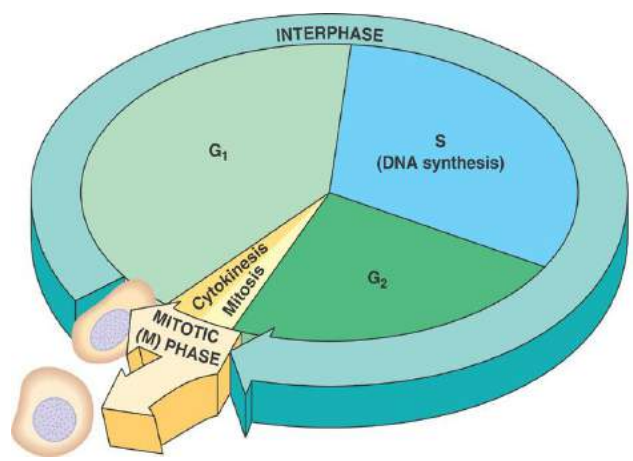
1. Why is there so much variation within the human race? How did this occur?
2. How does the physical structure of DNA change during each phase of the cell cycle?
3. How is meiosis different from mitosis?
4. Where are Mitosis and Meiosis found in the human life cycle?

Cellular Reproduction

- Allows old or unhealthy cells to be replaced by new, healthy, ones
- Allows cells to stay small and not break their cell membranes
    - Easier for the cell's products to get in and out
    - Easier for the DNA and nucleus to control the cell
- Every animal has the same sized cells because of cellular reproduction
- Asexual reproduction: a single organism copies itself, does not require egg and sperm
- Sexual reproduction: requires two organisms with egg and sperm

Eukaryotic Chromosomes

- DNA in one cell is taller than a person
- Each chromosome is a long DNA molecule containing thousands of genes
- Number of Chromosomes does not determine complexity of the species
- Humans have 46 chromosomes - 23 from egg and 23 from sperm
- Dogs have more because there is more variety between the breeds
- Nucleosome: a grouping of DNA around a histone protein
- Prokaryotic cells continuously reproduce through binary fission
- Eukaryotic cells go through the Cell Cycle
- Haploid Cell: 23 chromosomes (n)
- Diploid Cell: 46 chromosomes (2n)
- Sex Chromosomes: X and Y genes
- Autosomal Chromosomes: chromosomes 1-22



The Cell Cycle

Why Cells Stay Small

- Easier for products of the cell to get in and out
- Easier for the DNA to control the cell
- Faster relative transport of products through membrane

Contributors to Genetic Variation

- 8 million sperm and 8 million egg combinations from:
    - Crossing over during prophase I
    - Law of independent assortment during the lining up of chromosomes in metaphase
- 8 million x 8 million = 70 trillion total combinations because of:
    - Randomization of fertilization: many different sperm could attach to the egg

The Cell Cycle: Interphase (90%)

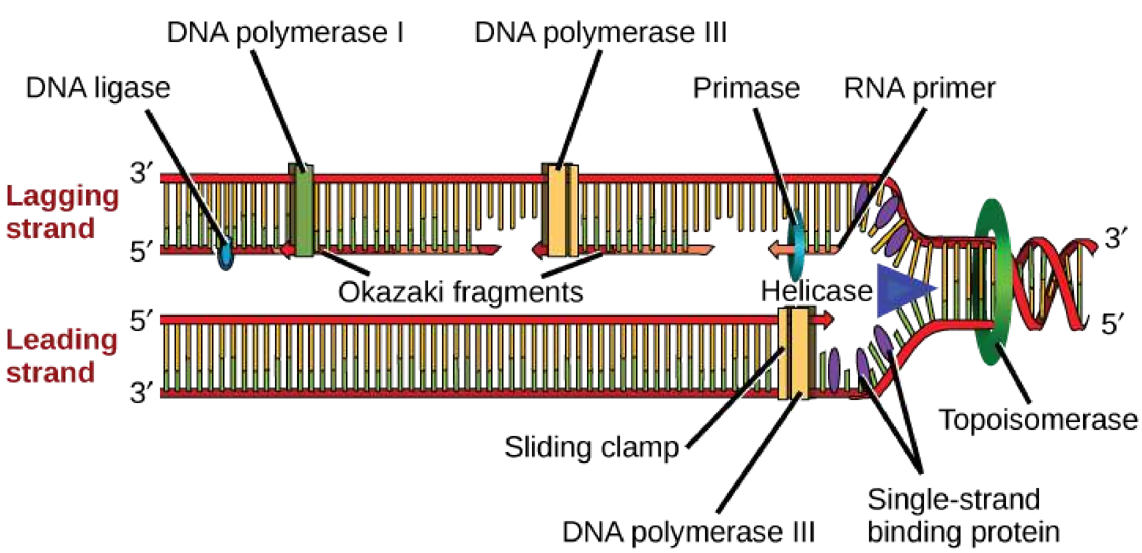
G1 - Protein synthesis, cell growth, increasing number and size of organelles

S phase - DNA Replication (diagram below)

- Stage 1: Helicase unwinds a section of the DNA, top strand is the leading strand and bottom strand is the lagging strand
- Stage 2: RNA primase adds leading nitrogenous bases
- Stage 3: DNA polymerase fills in letters quickly
    - Lagging strand takes longer because of the more pieces of primase and DNA polymerase needed, replication goes in okazaki fragments
- Stage 4: Another type of DNA polymerase replaces the U's with T's
- Stage 5: DNA ligase zips the strands of the double helix

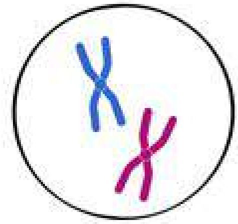
G2 - Proteins essential to cell division are produced, centrioles replicate

DNA Replication Diagram



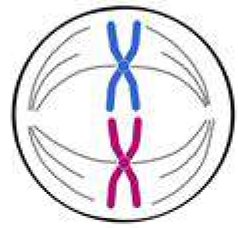
The Cell Cycle: Mitosis (10%) The process of cells dividing

Stage 1: Prophase



- Chromatin fibres coil into chromosomes
- Microtubule start to grow out of the centrosomes
- Mitotic spindle begins to form and attaches to the centromeres
- Late in prophase, the nuclear envelope breaks

Stage 2: Metaphase

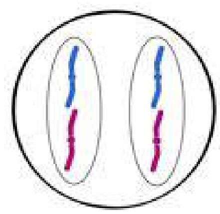


- Mitotic Spindle fully formed
- Centromeres line up in the middle of the mitotic spindle
- Microtubules hold the chromosomes in the middle of the cell
- Direction of chromosomes adds to genetic variation

Stage 3: Anaphase

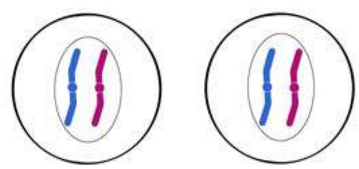
- The mitotic spindle pulls on both sister chromosomes
- Sister chromatids split to become two daughter chromosomes
- Microtubules not attached to chromosomes push on the opposite cell walls apart
- Cell is elongated

Stage 4: Telophase



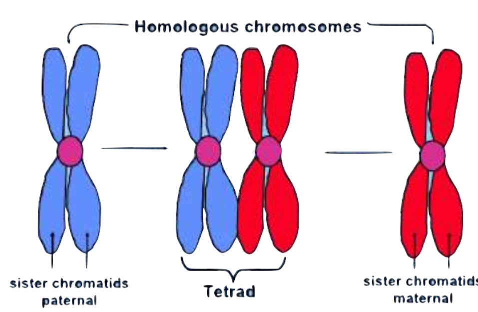
- Microtubules pull the daughter chromosomes to the centrosomes
- Nuclear envelope forms around the groups of chromosomes
- In plant cells: A cell plate forms to divide the cell into two
- Chromosomes uncoil in their new nucleus

Stage 5: Cytokinesis



- Occurs with Telophase
- Cleavage furrow pinches the cell in the middle
- Cell is divided into two daughter cells

The Life Cycle

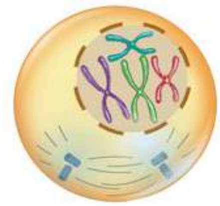


- Gametes: Haploid cells that come together during fertilization
- Zygote: Two gametes after fertilization (sperm with egg make a diploid cell)
- Sister Chromatids: two sister chromatids meet at a centromere to form homologous chromosomes
- Homologous Chromosomes: one maternal and one paternal set of chromosomes that pair up with each other
- Tetrad: Two sets of homologous chromosomes

Meiosis

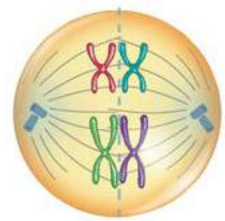
The process of cell division that produces haploid gametes in diploid organisms

Stage 1: Prophase I



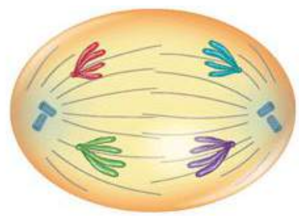
- Proteins cause the Chromosomes to stick together in pairs of 4 chromatids
- Two chromosomes crossover and exchange genetic information
- Creates homologous pairs, called tetrads, after exchanged segments

Stage 2: Metaphase I



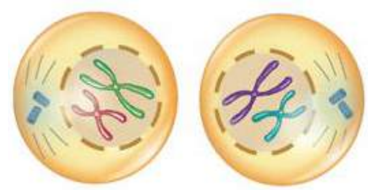
- Homologous pairs aligned in the middle of the cell
- Centromeres attached to spindle microtubules
- Law of Independent Assortment - homologous pairs can be lined up facing either side

Stage 3: Anaphase I



- Tetrads split up and move towards opposite ends of the cell
- Sister Chromatids still together

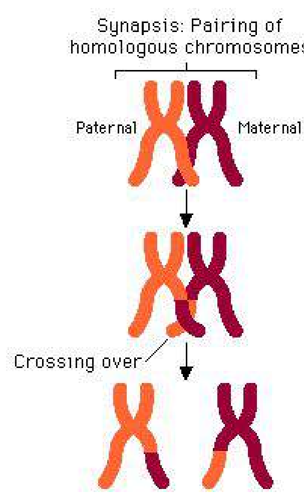
Stage 4: Telophase I and Cytokinesis



- Chromosomes arrive at the poles of the cell - still in duplicated form
- Two haploid daughter cells are formed by cleavage furrow

Stage 5: Meiosis II

- Same as Mitosis, except...
  - Starts with a haploid cell that has undergone chromosome duplication
  - Results in four haploid daughter cells with single chromosomes
  - One of the four products is larger - the gametes
  - The other three are smaller and are useless “polar bodies”



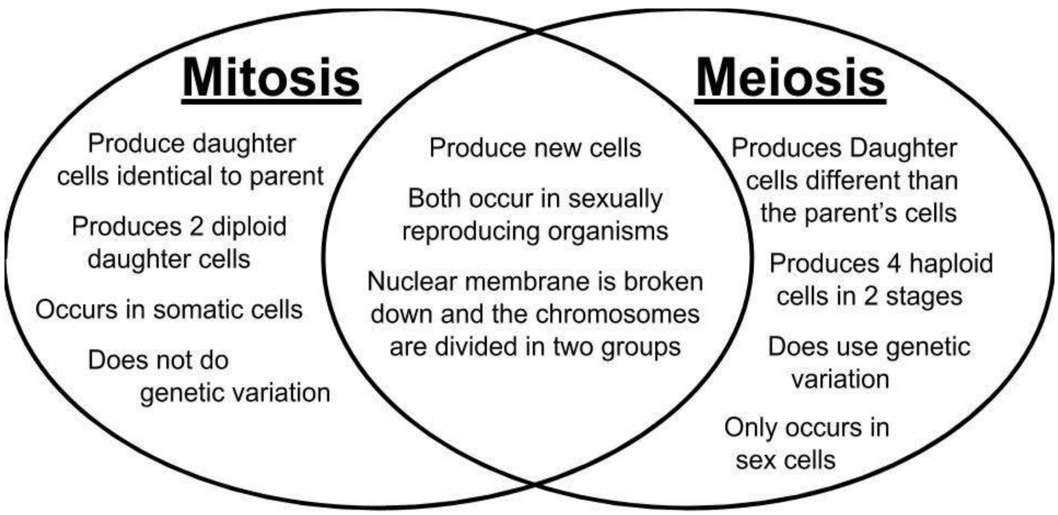
Non-Disjunction

- The failure of homologous chromosomes (in meiosis I) or sister chromatids (in meiosis II) to separate correctly
- More detrimental in meiosis I because it affects 50% of the resulting gametes (2/4), meiosis II affects 25% (1/4)

Crossing Over

- Adds to genetic variation
- Crossover and exchange of DNA coding at the chiasma
- Occurs during Prophase I and Metaphase I
- Two sister chromatids have been genetically recombined and are called the "recombinants"
- The other two sister chromatids have the same original genetic information
- None of the four resulting gametes of Meiosis have the same genetic information

Comparing Mitosis and Meiosis



Unit 9: *Genetics*

Essential Questions

1. Why is there so much variation within the human race? How did this occur?
2. How are we able to predict the phenotypes and genotypes of an offspring based on their parents?
3. What are some human genetic disorders and how are they inherited?
4. How does the surface area change when a large cell divides into smaller cells that have the same overall volume? How does this benefit the cell?

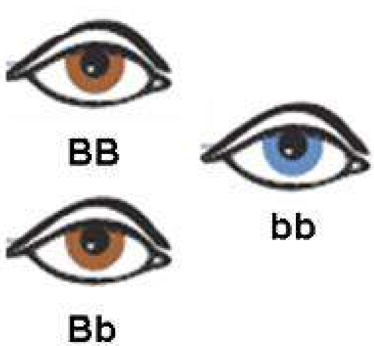
Genetics Vocabulary

- Genetics: scientific study of heredity
- Heredity: transfer of traits from one generation to the next
- Traits: specific characteristics of an individual
- Gene: DNA sequence passed from parent to offspring
- Purebred: bred from parents of the same breed or variety
- Hybrid: the offspring of two different purebred varieties

Genetic Cross Vocabulary

- Dominant: A dominant trait received from a parent (one from each)
- Recessive: A recessive trait received from a parent (one from each)
- Alleles: Different forms of a gene (homozygous dominant/recessive, heterozygous)
- Homozygous Dominant: allele is dominant from both parents (two capital letters)
- Heterozygous: The allele is dominant from one parent, and recessive from the other parent (one capital and one lowercase letter)
- Homozygous Recessive: allele is recessive from both parents (two lowercase letters)
- Genotype: The two alleles, one from each parent, that are homozygous dominant, heterozygous, or homozygous recessive
- Phenotype: The physical attributes of the offspring based on the genotype
- Testcross: determines the genotype when it is unknown

Genotype and Phenotype Examples
(the capital A is dominant in these cases)



Genotypes	Phenotypes
AA	Yellow
Aa	Yellow
aa	Green

Gregor Mendel

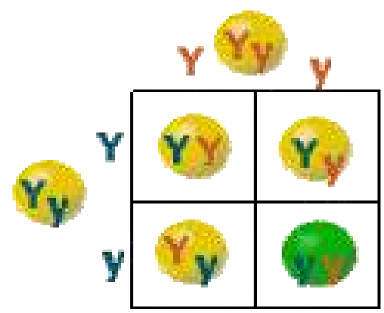
- German scientist in the 1800’s
- Studied peas and how they changed colors based on their parents
- Discovered hidden attributes that could skip a generation
- Created Mendelian Genetics
- Discovered the punnett square

Mendel’s Hypothesis

1. Alleles are alternate versions of genes, resulting in variations in inherited characters
2. For each inherited character, an organism inherits two alleles, one from each parent
3. If two alleles of an inherited pair differ, the one that determines the organism’s appearance is called the dominant allele, the other has no noticeable effect and is called the recessive allele
4. A sperm or egg carries only one allele for each inherited character because the two alleles for a character segregate themselves during the production of gametes

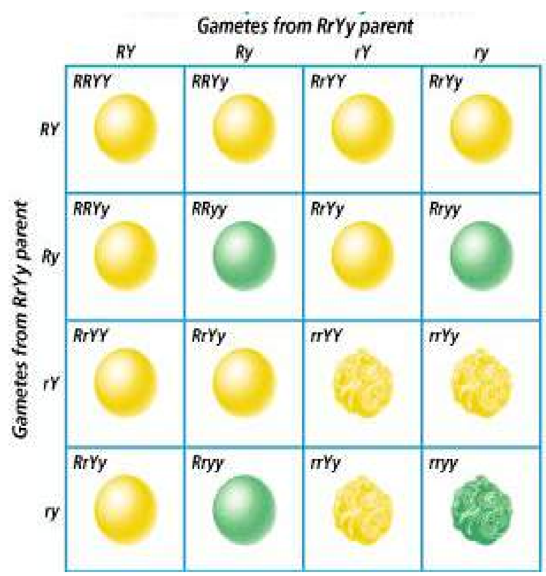
Punnett Squares - Monohybrid Crosses

- Shows the resulting traits of the offspring
- Plug in the alleles of the parents into the top and left side of the 2x2 square
- Combine the corresponding gametes to form genotypes in the boxes
- The genotypes can be translated into phenotypes and the probability of certain traits can be determined



Punnett Squares - Dihybrid Crosses

- Shows the resulting offspring’s traits - for two genes
- FOIL the parent’s gametes and plug the answers into the top and side of the box
- Combine the corresponding FOILed gametes to form genotypes in the boxes
- The genotypes can be translated into phenotypes and the probability of certain traits can be determined
- If a two people heterozygous for both traits are crossed, the ratio of dominant, dominant : dominant, recessive : recessive, dominant : recessive, recessive will always be 9:3:3:1

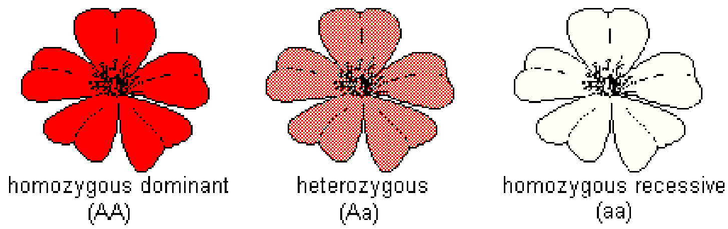


FOILing example: Aabb x AABb = (Ab, Ab, ab, ab) x (AB, AB, Ab, Ab) æ **2** = Ab, ab x AB, Ab
****In this example the number of foiled gametes and the size of the punnett square can be reduced because of repeatedness of the foiled gametes*

Incomplete Dominance

The intermediate alleles (heterozygous) is <u>a blend</u> between the two homozygous traits

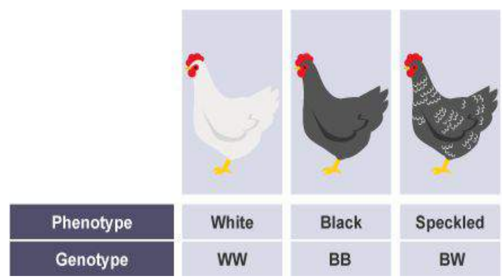
Examples: color and height



Codominance

There is <u>no dominant gamete</u> in the allele - both traits are shown, even in heterozygous

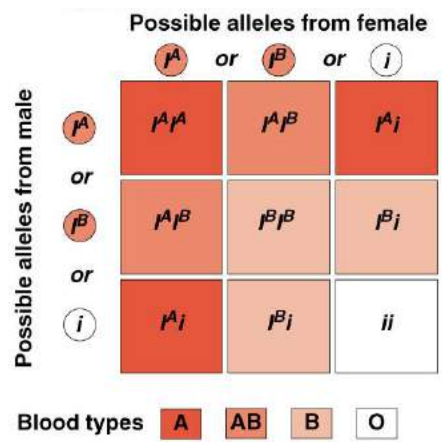
Example: Multiple skin tones in heterozygous animals (spots on cows)



Multiple Alleles

There are multiple genotypes that can express <u>more phenotypes than the original genotypes</u>

Example: Blood Typing

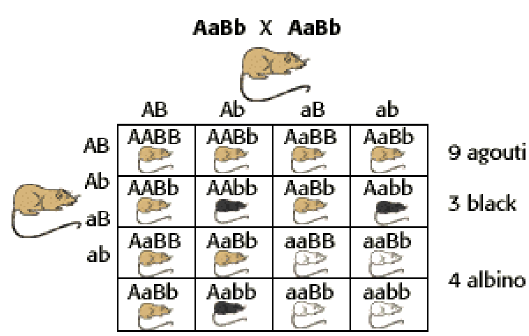


Epistasis

A gene at one locus <u>alters another gene</u>'s presence

In this example (right), the dominant B gene controls if the color will be agouti or black.

The A gene controls if the color of the B gene will be shown at all.

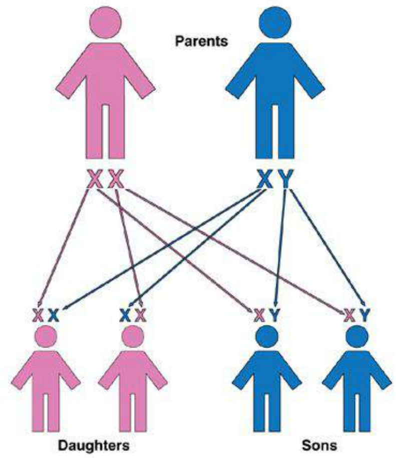


Polygenic Inheritance

When one characteristic is controlled by two or more genes

Sex-linked genes

- Always X from egg
- Father's X/Y determines sex
- XX = girl, XY = boy
- X^CX^C = affected female
- X^CX = carrier female
- XX = normal female
- X^CY = affected male
- XY = normal male
- Males cannot be carriers of sex-linked traits



Blood Types

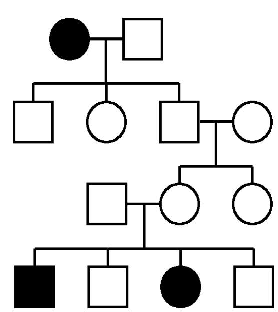
- Determined by the proteins on the outside of the blood cell
- Wrong blood cells can cause blood clots and can be fatal
- RH factor:
  - A persons blood cells may have the RH protein on their blood cells
  - If they do, then they are RH positive
  - If they do not, then they are RH negative
- I^A and I^B are codominant, i is recessive

ABO blood groups

Blood Type (phenotype)	Genotype	Can donate blood to:	Can receive blood from:
O	ii	A, B, AB, and O (universal donor)	O
AB	I^AI^B	O, AB	A, B, AB, and O (universal receiver)
A	I^AI^A or I^Aii	AB, A	O, A
B	I^BI^B or I^Bii	AB, B	O, B

Pedigrees

- Shows how a trait is inherited over time
- Females represented by circles, males represented by squares
- Shade the shapes of the individuals that have been affected
- Cross out the deceased
- P, F1, F2 generations



Unit 10: *Evolution*

Key Questions

- What does the phrase “survival of the fittest” mean?
- What are some pieces of evidence that support the theory of evolution?

Earth’s History

- Radiometric dating: dates rocks based on the decay of radioactive isotopes
- All of Earth was created by CHNOPS

Geologic Time Scale: divides earth’s history into time periods

4.6 bya - Earth is created
4.0 bya - First prokaryotes
3.5 bya - Photosynthesis begins
2.3 bya - Extinction by oxygen
2.1 bya - Eukaryotic cells evolve
1.5 bya - First multicellular organisms
0.5 bya - Cambrian explosion
0.2 bya - Arrival of flowering plants
150 mya - Arrival of dinosaurs
2-5 mya - Arrival of homosapiens

The Earth’s Era’s

4.6 - 3.8 bya - Hadean Era
3.8 - 2.5 bya - Archean Era
2.5 - 0.5 bya - Proterozoic Era
500 - 250 mya - Paleozoic Era
250 - 65 mya - Mesozoic Era
65 mya - Present - Cenozoic Era

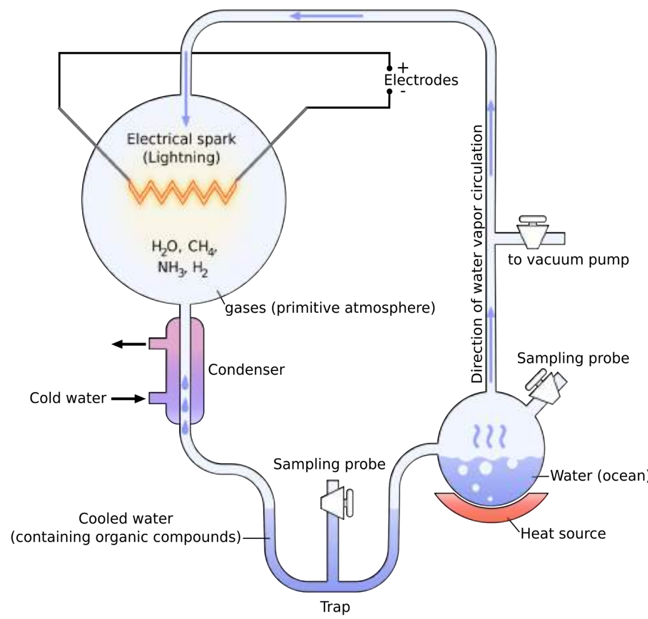


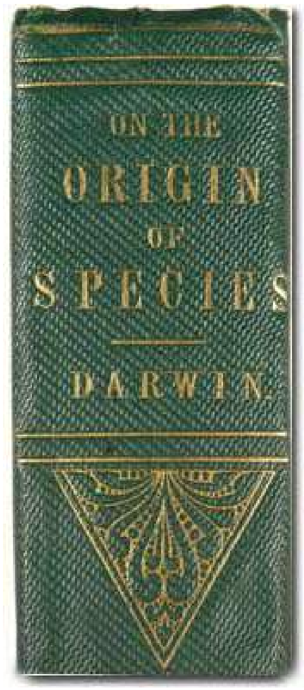
Diagram of Miller Urey Experiment

Miller-Urey Experiment

- No oxygen as a gas, but it was present as an element
- Miller and Urey created, in a lab, the atmosphere that was present billions of years ago
- By adding electricity (lightning) the elements rearranged themselves into complex molecules, then rearranged themselves into amino acids, without oxygen gas

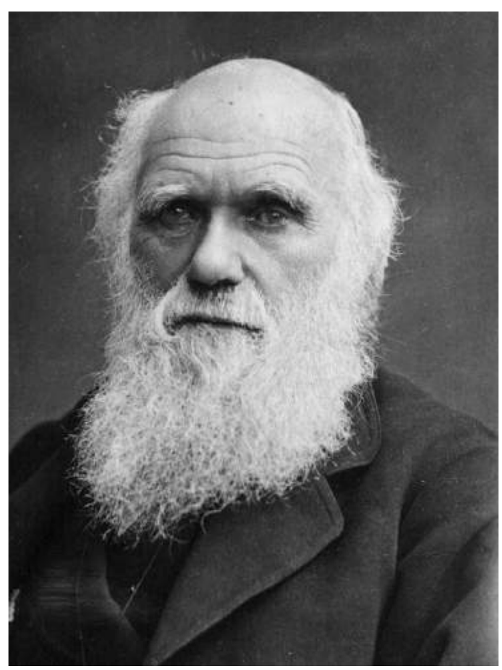
Charles Darwin

- 1730's - Linnaeus found adaptations in different species
- 1780's - Hudson and Lyell said that slow changes happened on the Earth's surface was caused by slow continuous actions
- Early 1800's - Lamarck believed that species evolve through use of their body parts
- 1859 - Darwin's Book: On the Origin of Species
    - Voyaged on the H.M.S. Beagle
    - Collected fossils of the South American Coast for evidence
    - Discovered finches had adapted differently to separate islands they inhabited
    - A.R. Wallace had similar ideas
    - Darwin received a copy of A.R. Wallace's book and published his own first, receiving all the fame
    - Darwin was hated at the time he published because his ideas were opposite of the religious ones
    - Does not mention the word "evolution" because it would be too much for the world to handle



Darwin's Four Main Principles

1. More offspring are born than survive
2. Variation within a population
    a. No individuals have equal traits
    b. Only the individuals with the traits better suited for the environment will survive
3. Survival of the fittest
    a. Only the best traits will be passed on throughout the generations
4. Natural Selection
    a. Eventually, only the individuals with <u>favorable traits</u> will survive

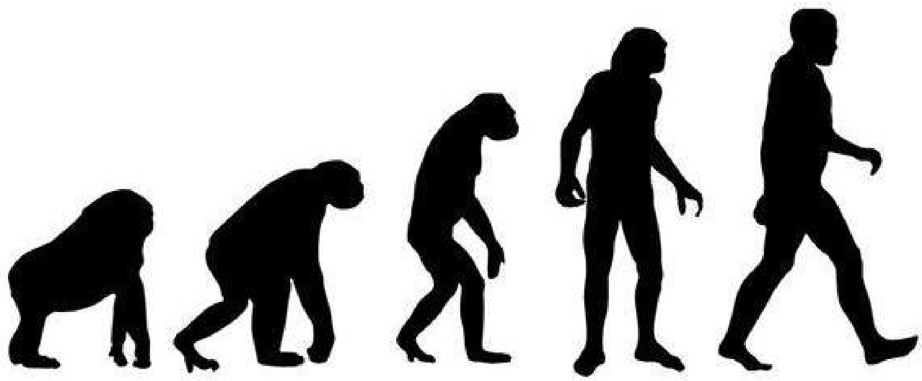


Favorable Traits

- Traits to survive
    - Avoid predators
    - Survive diseases
    - Compete for food and territory
- Traits to reproduce
    - Ability to attract a mate
    - Successfully raise young

Evolution and Natural Selection

- “Struggle for existence” - only the best suited for the environment will survive
- A species changing over time as organisms become better adapted
- Evolution acts on phenotype, but eventually changes the genotype
- Natural Selection causes evolution

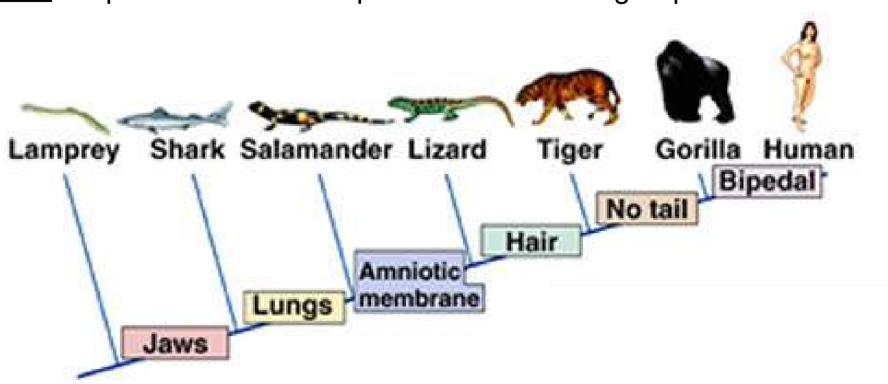


Evidence for Evolution

- Fossil Records: Comparing fossil ages and features
- Biogeography: Comparing patterns in fossils and living species
- Comparative Anatomy: Comparing bone structures from a common ancestor
- Comparative Embryology: Comparing development stages of animals
- Molecular Biology: Comparing DNA and RNA common in all cells

More Evolution

- Homologous Structures: Similar structures inherited from a common ancestor, but not used for the same purposes
- Analogous Structures: Similar structures because of similar environments, but not inherited from a common ancestor
- Vestigial Structures: Parts of living things that have lost their function, but are still present because of evolution (such as an appendix or tailbone)
- Embryology: Biology that has to do with fertilization of eggs and fetuses
- Molecular Data: Analyzes heritable DNA and RNA
- <u>Cladogram</u>: Depicts the relationship between different groups of animals



Populations

- Population: A localized group within a species
- Not all individuals will come into contact with all others in a species
- Genepool: All the alleles in a population
- Allele frequency: how common a allele is

Hardy-Weinberg Equilibrium

- Model of a population and its gene pool with no evolution (does not happen in real life)
- Conditions for non-evolving:
  - Large population - more accurate
  - No natural selection
  - No genetic drift/mutations
  - No migration in or out of population
  - No birth or death
  - No sexual selection - random mating
- Variables and equations
  - P = frequency of dominant allele
  - Q = frequency of recessive allele
  - P^2 = frequency of homozygous dominant individuals
  - 2PQ = frequency of heterozygous individuals
  - Q^2 = frequency of homozygous recessive individuals
  - P + Q = 1 (100%)
  - P^2 + 2PQ + Q^2 = 1 (100%)

Unit 11: *Chemical Reactions*

Essential Questions

- What evidence signals that a chemical reaction has occurred?
- How do chemical and physical properties differ?
- What are the five types of reactions?
- Why do we need to write balanced equations?
- What are net ionic equations?
- What are the laws of conservation of matter/mass? Why are they important?

Chemical Reactions

- Products: The resulting compounds and elements from a reaction
- Reactants: The compounds and elements which react
- Catalyst: Helps to speed up a chemical reaction
- Types of Chemical Reactions
  - Combustion: Hydrogen, oxygen, and carbon yield H2O and CO2
  - Combination: simple substances combine to form complex ones
  - Double Replacement: two elements/groups exchange places
  - Single Replacement: One element/group replaces another in one compound
  - Decomposition: Complex substances break down into simpler ones
- Evidence of Chemical Reactions:
  - Color change
  - Formation of a solid or gas
  - Heat absorption or emission
  - Light emission

Aqueous Solutions

- Aqueous Solution (aq): Mixture in water
- Soluble: if compound dissolves in liquid
- Insoluble: if compound does not dissolve in liquid
- Solubility rules determine if a substance will be soluble or insoluble
- Precipitate: the solid formed by a reaction - only formed by insoluble compounds

Balancing Chemical Equations

- Conservation of Matter: No atoms can disappear or appear
- Conservation of Mass: Must be the same amount of each atom on each side of the equation
- Add numbers in front of the element, group, or compound

Writing Chemical Equations

Molecular Equation: Shows neutral formulas for each compound

- Step 1: Translate the names of the elements and compounds to a formula
    - Write (aq) after both compounds to show that they are in solution
    - Any individual groups or elements are (aq)
- Step 2: Determining the products
    - Double replacement: Pair the cations of the first compound with the anions of the second compound, and the anion of the first compound with the cations of the second on the products side of the equation
    - Single replacement: The lone element pairs with the group or element in the compound with the opposite charge
    - Decomposition: Break reacting compound into individual elements or groups
    - Synthesis: Combine the two reactants
    - Combustion: The products are always H2O and CO2
- Step 3: Check if the charges are equal for newly created compounds
- Step 4: Determining precipitates
    - Double Replacement: Use the solubility chart to see with compounds are soluble. Write (aq) after the soluble compounds and (s) after the insoluble ones. If all products are still in solution, then no reaction has occurred.
    - Single replacement: Use the Activity Series list to determine if the lone element is able to replace the existing one. No reaction if it cannot.
- Step 5: Balance the equation

Complete Ionic Equation: Shows reactants and products as individually charged ions

- Step 1: Using the molecular equation, write each element or group as its ion
- Step 2: Add the subscript of any element or group before it
- Step 3: Write (aq) for all of the reactants and the products that are not soluble (double replacement) or cannot 'steal' the other element (single replacement)
- Step 4: Write the precipitates as a compound with (S)

Net Ionic Equations: Shows only the ions involved in the reactions

- Rewrite the complete ionic equation with only the ions that take place in the reaction

Spectator Ions: Ions that do not participate in reaction and are left out in net ionic equations

Molecular Equation

$Pb(NO_3)_2\,(aq) + 2KI\,(aq) \dashrightarrow PbI_2(s) + 2KNO_3(aq)$

Complete Ionic Equation

$Pb^{2+}(aq) + 2NO_3^-(aq) + 2K^+(aq) + 2I^-(aq) \dashrightarrow PbI_2(s) + 2K^+(aq) + 2NO_3^-(aq)$

Net Ionic Equation

$Pb^{2+}(aq) + 2I^-(aq) \dashrightarrow PbI_2(s)$

Unit 12: *Ecology*

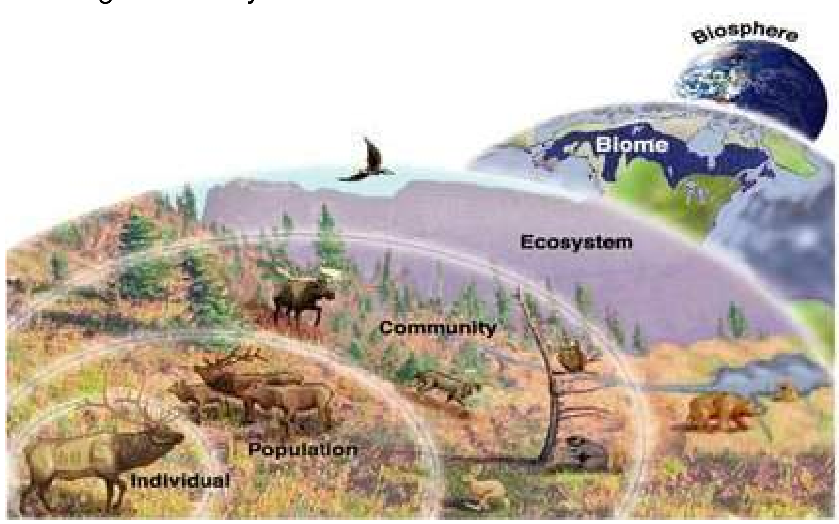
General Vocabulary

- Ecology: the scientific study of interactions between organisms and their environment
- Biotic factors: all living, or once-living, organisms that make up an environment
  - Birds, worms, leaves, bacteria...
- Abiotic factors: all non-living things in an environment
  - Energy source: how available and accessible is to the organisms?
  - Temperature: warmer temperatures are better for an animal’s metabolism
  - Inorganic nutrients: nitrogen and phosphorus
  - Aquatic factors: tides and water salinity
  - Terrestrial factors: wind
- Habitat: all biotic and abiotic factors of an organism's surroundings
- Biomass: mass of all living organic material in an ecosystem
- Energy flow: the pass of energy through an ecosystem from level to level
- Primary production: the rate at which an ecosystem converts solar energy to chemical energy stored in biomass
  - Only about 1% of sunlight is converted to chemical energy by photosynthesis

Environments

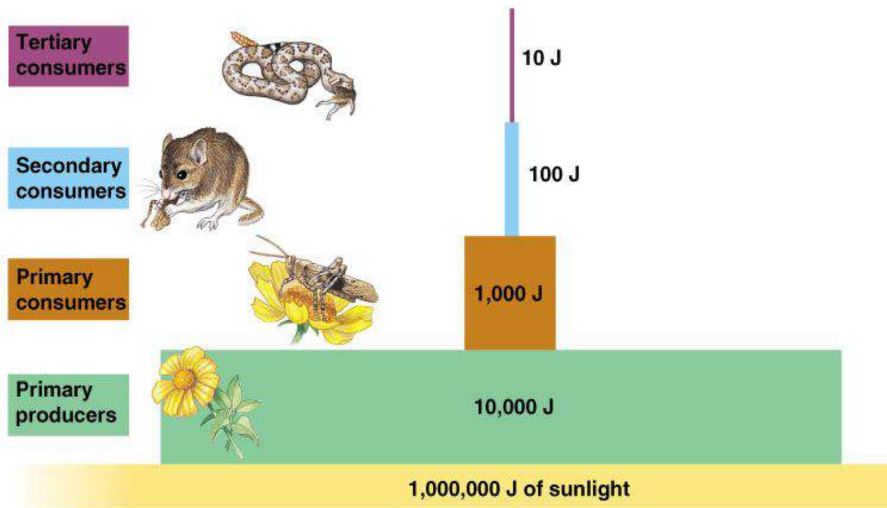
(Increasing in size)

- Organism: individual living thing
- Population: group of individuals in the same species living the the same geographic area
- Community: all organisms that inhabit an specific area
- Ecosystem: a community and all the abiotic factors in the area
- Biome: Ecosystems grouped in biomes by vegetation type and inhabitants
  - Tropical forest, desert, temperate grassland coniferous forest, arctic tundra...
- Biosphere: the global ecosystem



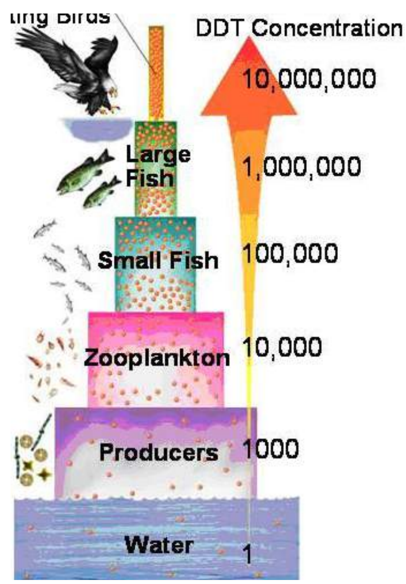
Energy Exchange in the Ecological Pyramid

- Each level of the energy pyramid onlys gets 10% of the energy as the one below it
- When an animal gets energy:
  - 50% waste
  - 35% cellular respiration
  - 5% growth
  - 10% passed on



Biological Magnification

- When an organism receives toxins, they stay in the body
- Energy passed down by 10% because some is used while toxins passed down by 100%
- Small amounts of fertilizers on the grass can't hurt a human, but after the toxins go up the food chain to us, it can be deadly
- Equivalent to 10x the toxins after each level moved up on the pyramid



Chemosynthesis

When water, hydrogen sulfide, and carbon dioxide come together on the seafloor where there is no light in order to make energy

Food Webs

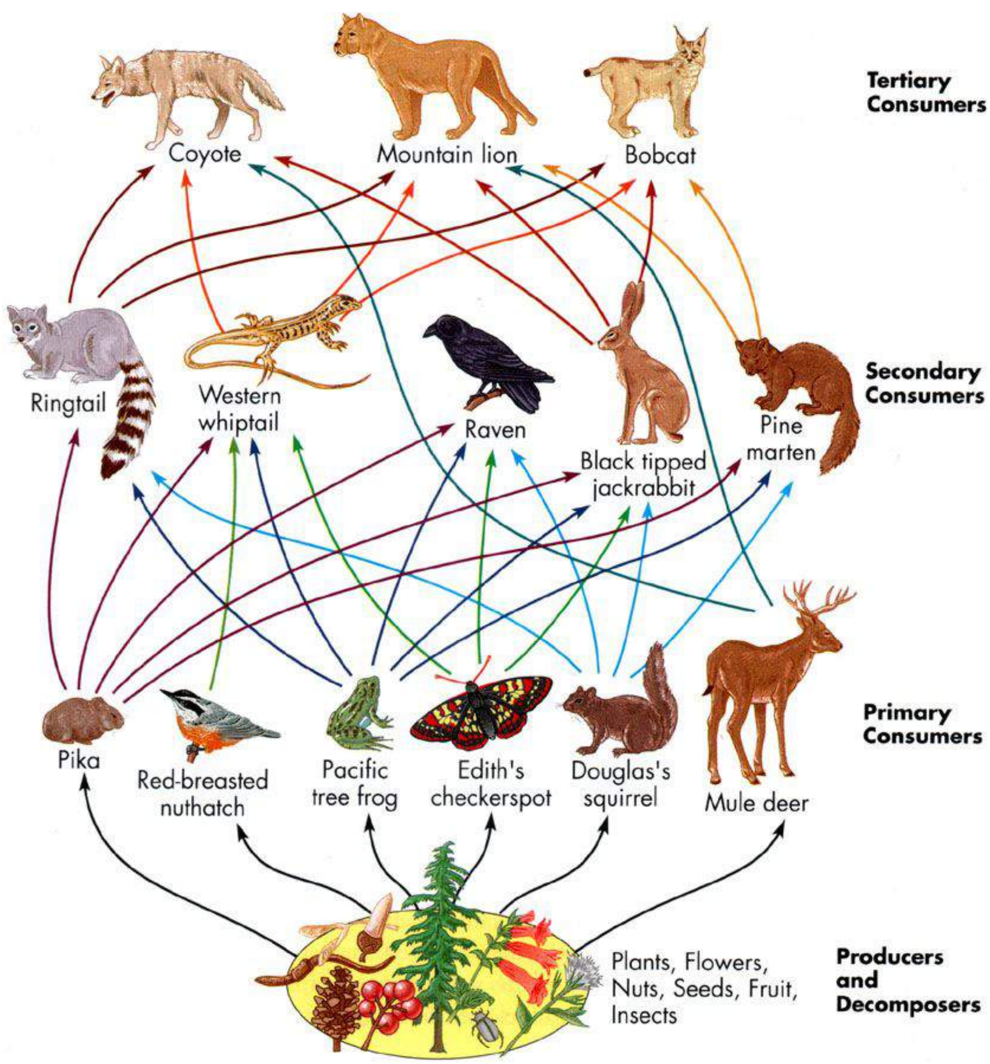
- Food chain: a branch of who eats who
- Food web: a lot of food chains combined
- Show the feeding relations in a community

The levels of a food web

- Auto troughs (producers): plants that take in sunlight and convert it to energy
- Herbivore (primary consumer): animals that only eat plants
- Omnivore (secondary and tertiary consumers): animals that eat plants and meats
- Carnivore (secondary and tertiary consumers): animals that only eat meat

More factors of a food web

- Scavenger: eats dead and decaying animals
- Decomposers: decompose dead animals
- Detrivores: digest the decomposers



Unit 13: *Biogeochemical Cycles*

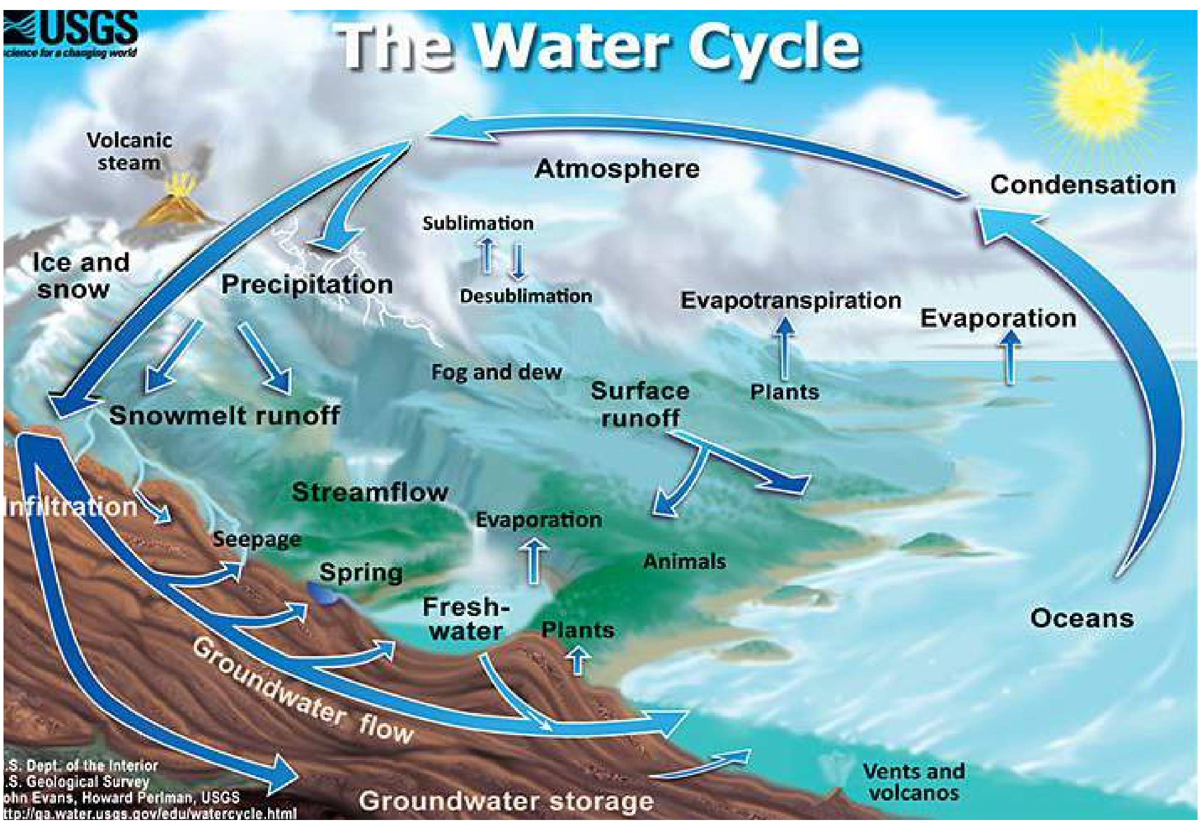
Chemical Cycles

- The use and reuse of chemicals through the ecosystem
- Unlike the sun's continuous energy supply, the amount of chemicals in the world is fixed, so they need to be recycled
- The general scheme of chemical cycling
  - Abiotic reservoir: place where the chemical accumulates outside of living organisms (oceans for water, atmosphere for nitrogen)
  - Producers, consumers, and decomposers, then back to the abiotic reservoir

The Water Cycle

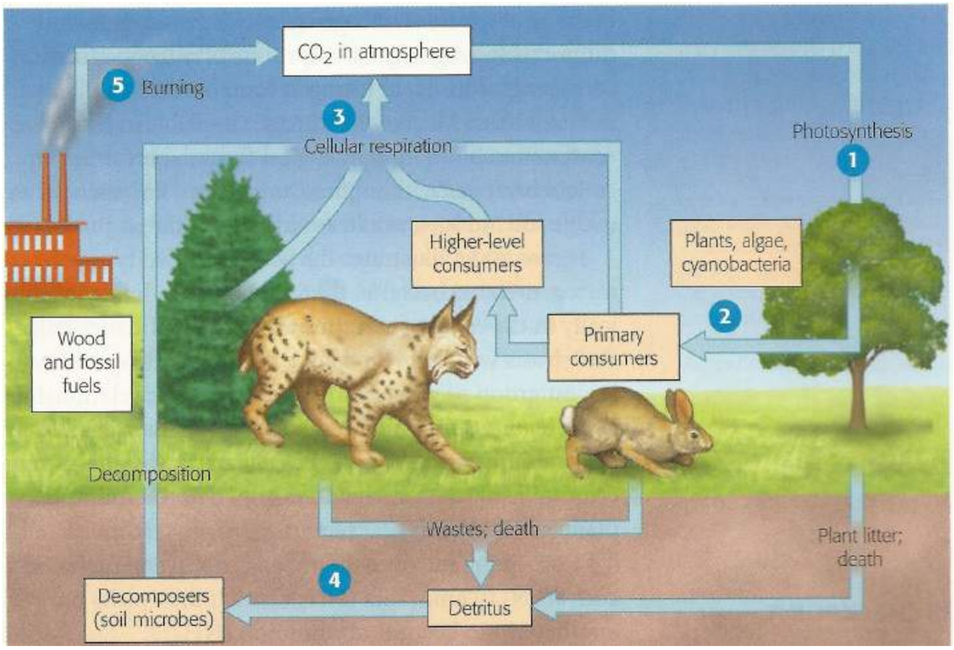
Overview: evaporation and transpiration, condensation, precipitation

Abiotic reservoir: ocean



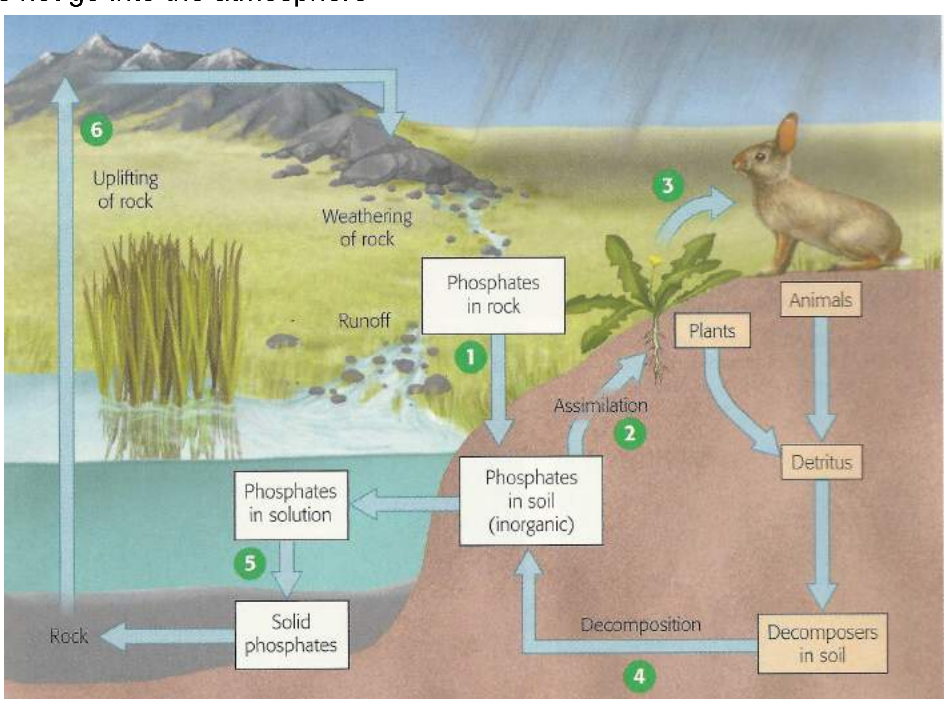
The Carbon Cycle

Overview: atmosphere, photosynthesis, decomposers and cellular respiration and burning
Abiotic reservoir: atmosphere (as carbon dioxide, which is 0.04% of the atmosphere)



The Phosphorus Cycle

Overview: rock, soil, plants, animals, decomposers, soil, rock
Abiotic reservoir: rock
NOTE: does not go into the atmosphere



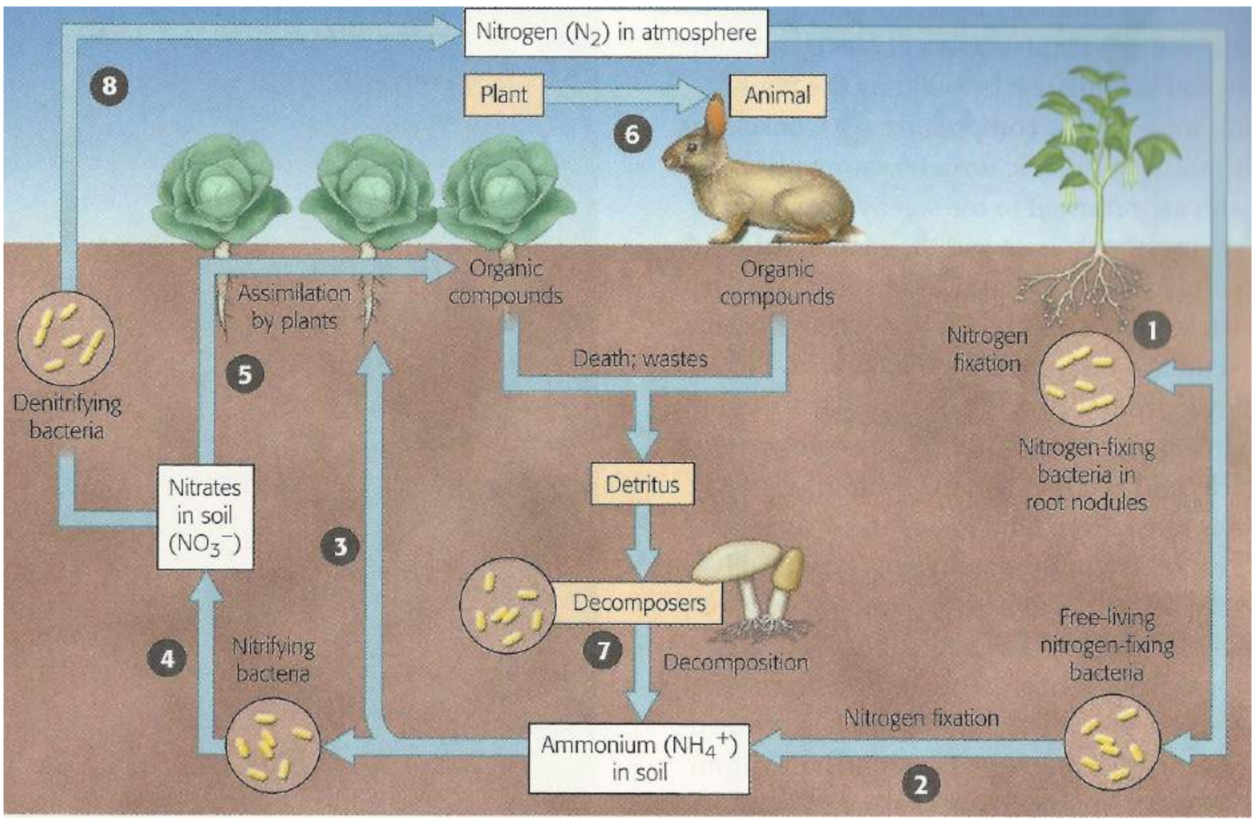
The Nitrogen Cycle

Overview: atmosphere, ammonium, nitrates

Abiotic reservoir: atmosphere (80%) and the soil (as ammonium)

Nitrogen fixation:

- Bacteria convert nitrogen gas to ammonia (NH_3)
- Picks up another H+ to become ammonium (NH_4+)
- Nitrifying bacteria convert ammonium to nitrate (NO_3-) which is easier for plants to use
- After going through the food chain and back into the soil, denitrifying bacteria convert the ammonium back to nitrogen gas that is released into the atmosphere



Unit 14: *Moles and More*

Significant Figures

Relative digits that can be reported from calculations of a reaction

The Sig Fig rule: can report all the numbers known for sure, then estimate one more digit

Counting Sig Figs

1. Every non-zero digit is significant
2. Zeros appearing between nonzero numbers are significant
3. Zeros at the beginning of a number are not significant
4. Zeros at the end of a number to the **right** of a decimal are significant
5. Zeros at the end of a number to the **left** of a decimal are not significant
6. Quantities have an infinite number of sig figs

Calculating with sig figs:

- Can only use the same amount of sig figs in the answer as the least amount of sig figs in the problem
- Wait until the last step to count sig figs, don't do that after every step

4.56	×	1.4	=	6.384	Round off →	6.4
Three significant figures		Limiting (two significant figures)				Two significant figures

Counting Sig Fig Examples

1. 23.50 — 4 sig figs
2. 402 — 3 sig figs
3. 5,280 — 3 sig figs
4. 0.080 — 2 sig figs

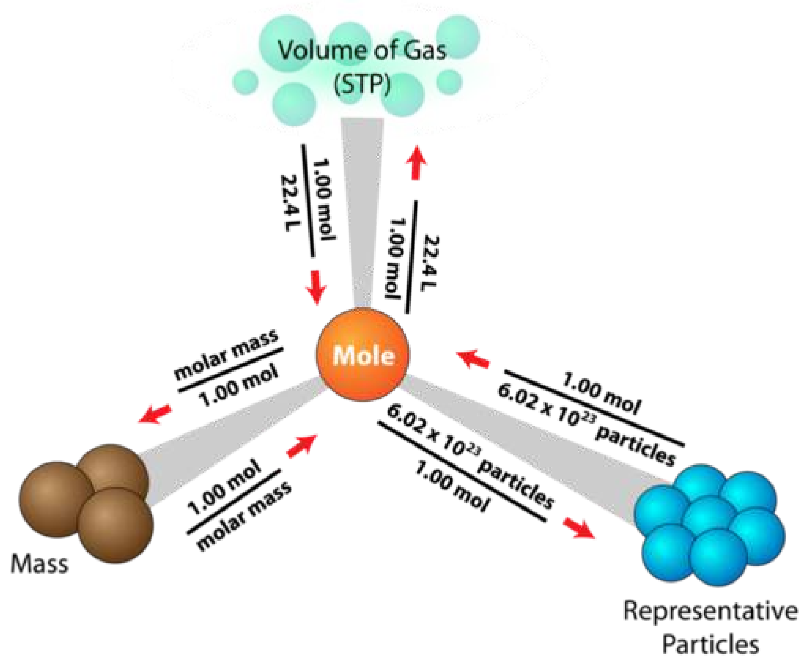
Metric Measurements

King Henry Died by Drinking Chocolate Milk

Mnemonic	King	Henry	Died	Base Unit	Drinking	Chocolate	Milk
Length: Abbreviation:	Kilometer km	Hectometer hm	Decameter dam	Meter m	Decimeter dm	Centimeter cm	Millimeter mm
Weight: Abbreviation:	Kilogram kg	Hectogram hg	Decagram dag	Gram g	Decigram dg	Centigram cg	Milligram mg
Volume: Abbreviation:	Kiloliter kL	Hectoliter hL	Decaliter daL	Liter L	Deciliter dL	Centiliter cL	Milliliter mL
How many are in **1** meter/gram/liter	.001	.01	.1	1	10	100	1000
How many meters/grams/liters are in this unit?	1000	100	10	1	.1	.01	.001
	⟸	BIGGER			SMALLER	⟹	

Moles

- Unit of measurement for an amount of a substance
- One mole = the molar mass of the element or the molecule
- One mole of any substance contains 6.022×10^{23} particles (atoms or molecules)
- At STP (0C, 1 atm), one mole of a gas will be 22.4L



Formulas

- Empirical formula: lowest whole number ratio of atoms in a molecule
- Molecular formula: formula of a molecule (can be the same as the empirical formula)

Finding an empirical formula:

1. Find the percent composition of each element in the formula
2. Change the % to grams
3. Change grams to moles
4. Find mole to mole ratio (divide the smallest mole amount into the other elements)
5. Write empirical formula using mole to mole ratio

Finding the molecular formula:

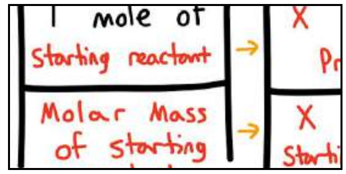
1. Find the empirical formula (above)
2. Find the molar mass
3. Divide the mass of the empirical formula over the molar mass of the molecule
4. Multiply the subsets of the empirical formula accordingly

Mass composition / Mass percent / Percent composition: the molar mass of one part of a molecule divided by the total molar mass of the molecule

Stoichiometry

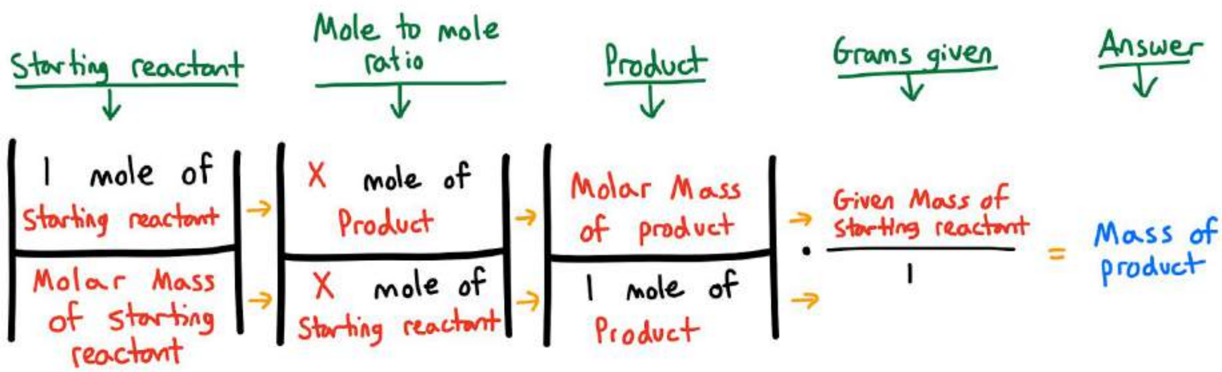
Used to find the amount of a reactant or product that can be produced based off the amount of reactant or product given

Key to image below



Step to Stoich

1. Balance equation
2. Write out what is given
3. Write out stoich problem
4. Calculate



Limiting reactant problems

1. Stoich for both reactants to the same product
2. The one that produces the smaller amount of product is the limiting reactant

Example limiting reactant problem:

93. Urea (CH_4N_2O), a common fertilizer, can be synthesized by the reaction of ammonia (NH_3) with carbon dioxide:

$$2\,NH_3(aq) + CO_2(aq) \longrightarrow CH_4N_2O(aq) + H_2O(l)$$

An industrial synthesis of urea produces 87.5 kg of urea upon reaction of 68.2 kg of ammonia with 105 kg of carbon dioxide. Determine the limiting reactant, theoretical yield of urea, and percent yield for the reaction.

Limiting reactant: NH_3

Theoretical yeild: 120 Kg

% yeild : 72.9 %

$2NH_3 \rightarrow CH_4N_2O$

$$\frac{1\text{ mole of }NH_3}{17.031g} \cdot \frac{1\text{ mole }CH_4N_2O}{2\text{ mole }NH_3} \cdot \frac{60.056g}{1\text{ mole }CH_4N_2O} \cdot \frac{68200g}{1} = \frac{4095819.2g}{34.062g} = 120{,}245g$$

$CO_2 \rightarrow CH_4N_2O$

$$\frac{1\text{ mole }CO_2}{44.009g} \cdot \frac{1\text{ mole }CH_4N_2O}{1\text{ mole }CO_2} \cdot \frac{60.056g}{1\text{ mole }CH_4N_2O} \cdot \frac{105000g}{1} = \frac{6305880g}{44.009g} = 143{,}286g$$

$$\%\text{ yeild} = \frac{87.5Kg}{120\text{ Kg}} = 0.729$$

Errors and Yields

Error:
|Experimental value - theoretical value|

Percent Error:

$$\% \text{ Error} = \frac{|\text{Experimental} - \text{Theoretical}|}{|\text{Theoretical}|} \times 100$$

Percent Yield:

$$\% \text{ Yield} = 100 \times \frac{\text{Actual Yield}}{\text{Theoretical Yield}}$$

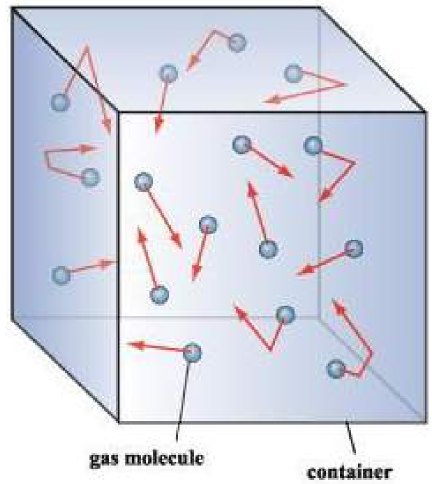
Hydrates

Ionic compound with water in its crystals

In the example to the right............ $MgSO_4 \cdot 7H_2O$

- There are 7 water molecules for every molecule of magnesium sulfate
- The name of the hydrate is magnesium sulfate heptahydrate

Unit 15: *Gas and Pressure*



Kinetic Molecular Theory

Only “ideal gases” follow the theory, “real gases” do not

1. Molecules are in constant motion
2. No attraction or repulsion between molecules
3. A lot of space is between the molecules
4. The molecules speed increases when the temperature increases
    a. Kinetic energy is proportional to the temperature in Kelvin
    b. Ex. 100K -> 200K will double the speed of the molecules

Pressure

Pressure is caused by the collisions of molecules with each other or the wall of the container

- Pressure = force / area

Units to measure pressure

- Atmosphere: 1 atm at sea level
- Kilopascals: 1 atm = 101.3 kpa
- PSI (pounds per square inch): 14.7 at sea level
- Torr: mm of Hg (1 atm = 760 torr)

Barometer

Ways to measure pressure

- Barometer measures air pressure
    - Air pressure lowers when it is about to rain
- Manometer measures pressure of gasses

Why can’t there be a really long snorkel?

- The diaphragm muscle in the lungs is not strong enough to inhale against the pressure of the water surrounding the body
- Coming up quickly underwater is harmful because the change in pressure pushes nitrogen gas into body tissues
- When scuba diving, the lungs adjust to the high pressure
- Every 10 meters underwater = 1 atm more

Gas Laws

- Temperature increase, pressure increases (direct)
- Number of particles increase (moles), pressure increases (direct)
- Volume increases, pressure decreases (indirect)

Combined Gas Law

- Used when there is a change in condition
- Variables that stay the same can be crossed out

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

Ideal Gas Law

- Used when the conditions do not change
- R is the gas law constant - volume must be litres
- R = 0.0821 atm = 8.314 kpa

$$\mathrm{PV} = n\mathrm{RT}$$

P = Pressure   V = Volume   n = Number of Moles   T = Temperature (must be Kelvin)

<u>Combined Gas Law Example</u>

55. A gas sample with a volume of 5.3 L has a pressure of 735 mm Hg at 28 °C. What is the pressure of the sample if the volume remains at 5.3 L but the temperature rises to 86 °C?

$$\frac{735\text{mm Hg} \cdot 5.3\text{L}}{(273+28)°\text{K}} = \frac{\text{P} \cdot 5.3\text{L}}{(273+86)°\text{K}} \rightarrow 12.942 = \frac{5.3\text{P}}{359}$$

$$= 0.01477\text{P}$$

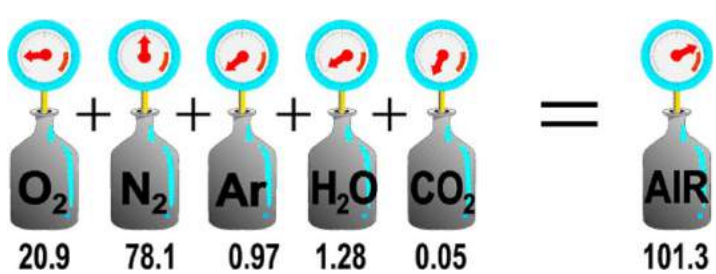
$$\frac{}{0.01477}$$

876 mm Hg $876.236 = \text{P}$

Partial Pressure

Total pressure exerted by a mixture of gases is the sum of the partial pressure of each individual gas present (assuming they are all ideal gases)

$$P_{total} = P_1 + P_2 + P_3 \ \ldots$$



Example of the partial pressure in air

Collection of Gases over Water

- Gas involved in a reaction is collected in an inverted beaker of water
- The pressure inside and out will naturally equalize
- Gas displaces the water and the volume can be determined
- Use the pressure of water (found on the table below) and the pressure of the atmosphere to find the pressure of the gas

Equation:

$$P_T = P_{gas} + P_{H_2O}$$

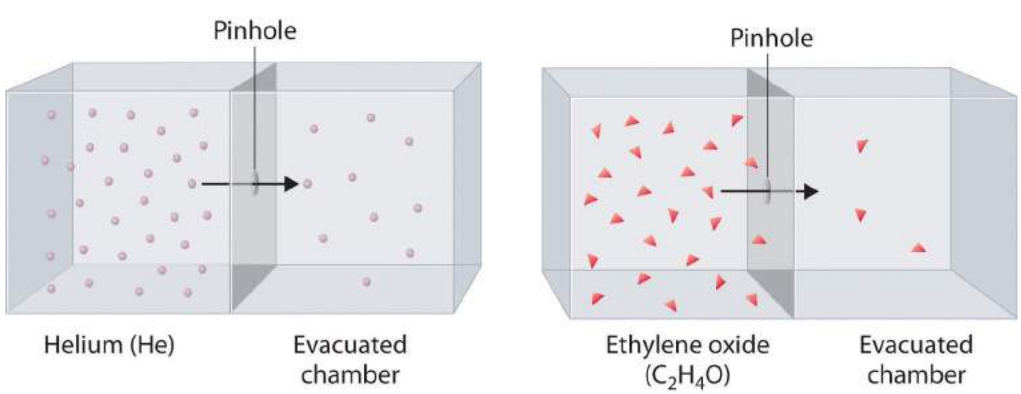
Water Vapor Pressure (torr)							
T(°C)	P	T(°C)	P	T(°C)	P	T(°C)	P
0	4.58	21	18.65	35	42.2	92	567.0
5	6.54	22	19.83	40	55.3	94	610.9
10	9.21	23	21.07	45	71.9	96	657.6
12	10.52	24	22.38	50	92.5	98	707.3
14	11.99	25	23.76	55	118.0	100	760.0
16	13.63	26	25.21	60	149.4	102	815.9
17	14.53	27	26.74	65	187.5	104	875.1
18	15.48	28	28.35	70	233.7	106	937.9
19	16.48	29	30.04	80	355.1	108	1004.4
20	17.54	30	31.82	90	525.8	110	1074.6

Graham's Law

- Finds the experimental rate of effusion of a gas
- Proportional to the square root of the mass
- Lighter gases travel faster

$$\frac{r_1}{r_2} = \sqrt{\left(\frac{MM_2}{MM_1}\right)}$$

Rate of effusion between different gases

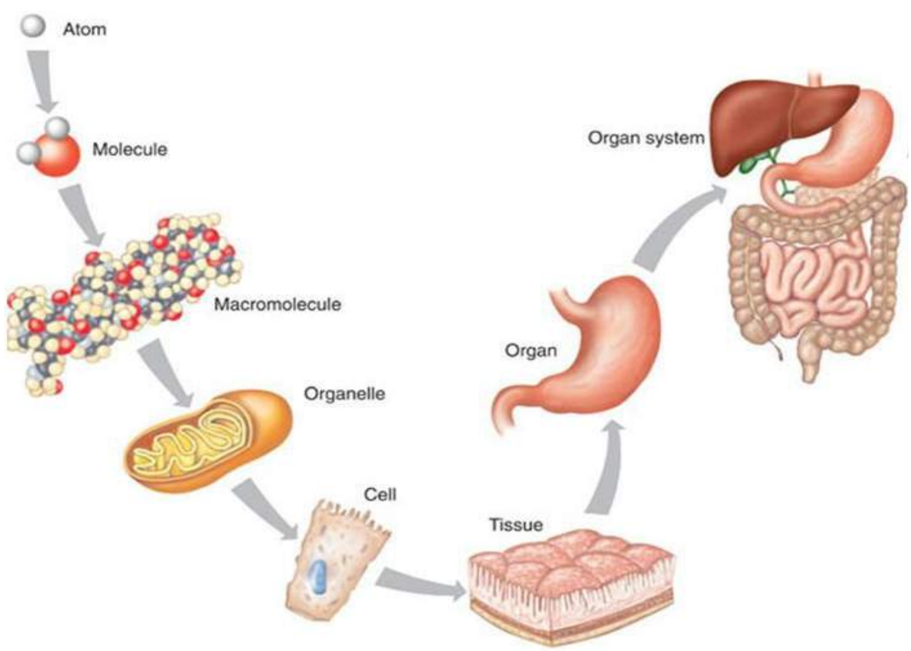


Unit 16: *Organ Systems*

Organization of Human Body

(Increasing size)

- Cells: smallest living thing
- Tissue: group of similar cells that perform a specific function
- Organ: two or more tissues packed together into one working unit
- Organ system: teams of organs that work together to perform vital body functions



Tissues

- Epithelial tissue (epithelium or epidermis): tissue that covers the surface of the body
- Connective tissue: sparse population of cells in the extracellular matrix
  - Loose connective tissue: holds organs and skin in place
  - Adipose tissue: stores fat and energy, insulates body
  - Blood: tissue with red and white blood cells in the plasma
  - Fibrous connective tissue: tendons attach to muscles and bones
  - Cartilage: shock absorbing pads for bones and is ears
  - Bone: rigid tissue used to skeletal support
- Muscle tissue: Many muscle fibres (meat)
  - Skeletal muscle: attached to bones by tendons, voluntary movements (striped)
  - Cardiac muscle: found in heart tissue, produces a heartbeat
  - Smooth muscle: intestines and blood vessels, involuntary
- Nervous tissue: communication
  - Neuron: nerve cell that transmits signals

Homeostasis

Body's involuntary act of keeping internal conditions the same even when the external conditions change

- Set point: the conditions that the body is supposed to be at, can change
- Negative feedback: does opposite of what is happening to get back to set point
- Positive feedback: (less common) process of intensifying the same process
    - Contractions during pregnancy
    - Blood flowing to cut
- Thermoregulation: the body keeping a constant temperature, despite external changes
- Endotherms: animals that obtain their heat from their metabolism
- Ectotherms: Absorb heat from surroundings
- Fever: abnormally high internal temperature

The Eleven Organ Systems of the Body

- Digestive: process food for energy
- Reproductive: helps make offspring
- Respiratory: taking in oxygen and releases carbon dioxide
- Nervous: transfers signals throughout the body
- Skeletal: Provides support and structure to the body
- Circulatory: Circulates blood throughout the body
- Integumentary: skin, hair, nails
- Endocrine: in charge of hormones
- Urinary: deposits waste
- Lymphatic/Immune: fights disease
- Muscular: movement

Unit 17: *The Respiratory System*

<u>The Respiratory System</u>

- Involuntary breathing: in order to release carbon dioxide
- Voluntary breathing: in order to obtain more oxygen when needed
- Coughing and sneezing are in order to get rid of things in the lower respiratory system
- After entering the bloodstream, the oxygen is transported to cells in *The Circulatory System*

Respiratory Surface: allows for rapid diffusion of oxygen between body and environment.

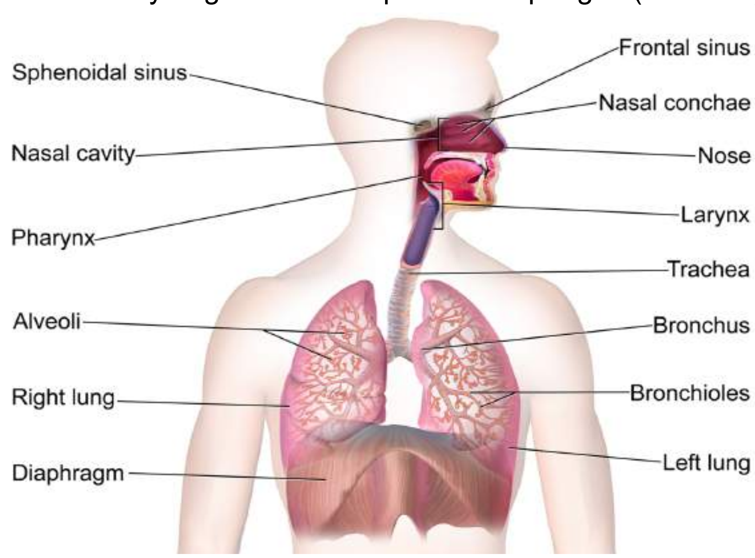
Examples:

- The entire body in some animals
- Gills in fish
- Tracheal system in insects
- Lungs in humans

<u>The Steps of the Upper Respiratory System</u>

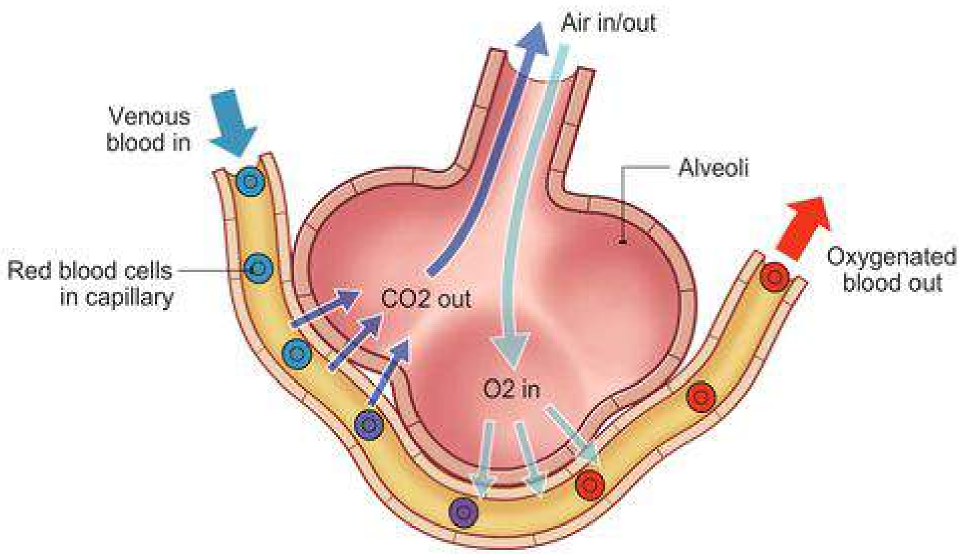
Inhaling air containing oxygen (~21%) through the mouth or nose

1. Diaphragm and rib cage expand, leaving the air pressure in the lungs lower than in the atmosphere
2. Air wants to move passively into lungs in order to equalize pressure (negative pressure breathing), passing through the following places:
3. Nose: mucus collects “junk” that is breathed in
4. Pharynx (also part of the digestive system)
5. Epiglottis: closes over larynx when food is eaten
6. Larynx: Vocal cords, more air escaping = louder sound
7. Trachea: surrounded by rings in order to protect esophagus (behind it)



Steps of the Lower Respiratory System
Air enters lungs and then the blood stream

1. Air enters the lungs and into the bronchi (large tubes)
2. Bronchi tubes split into smaller tubes called bronchioles
3. Bronchioles branch off into smaller and smaller tubes to carry air
4. Air reaches the alveoli
5. Oxygen is diffused across surface into the body as the carbon dioxide from the last breath is diffused out
6. Oxygen molecules are entered into red blood cells in capillaries
7. Hemoglobin helps in the transport of oxygen through the body
    a. When oxygen is not in the hemoglobin, a heme (contains iron) is instead
    b. Iron deficiency can cause less hemoglobin to be produced, reducing the ease of oxygen being carried in the bloodstream



Unit 18: *The Circulatory System*

Facilitates the movement of materials, including oxygen and carbon dioxide throughout the body

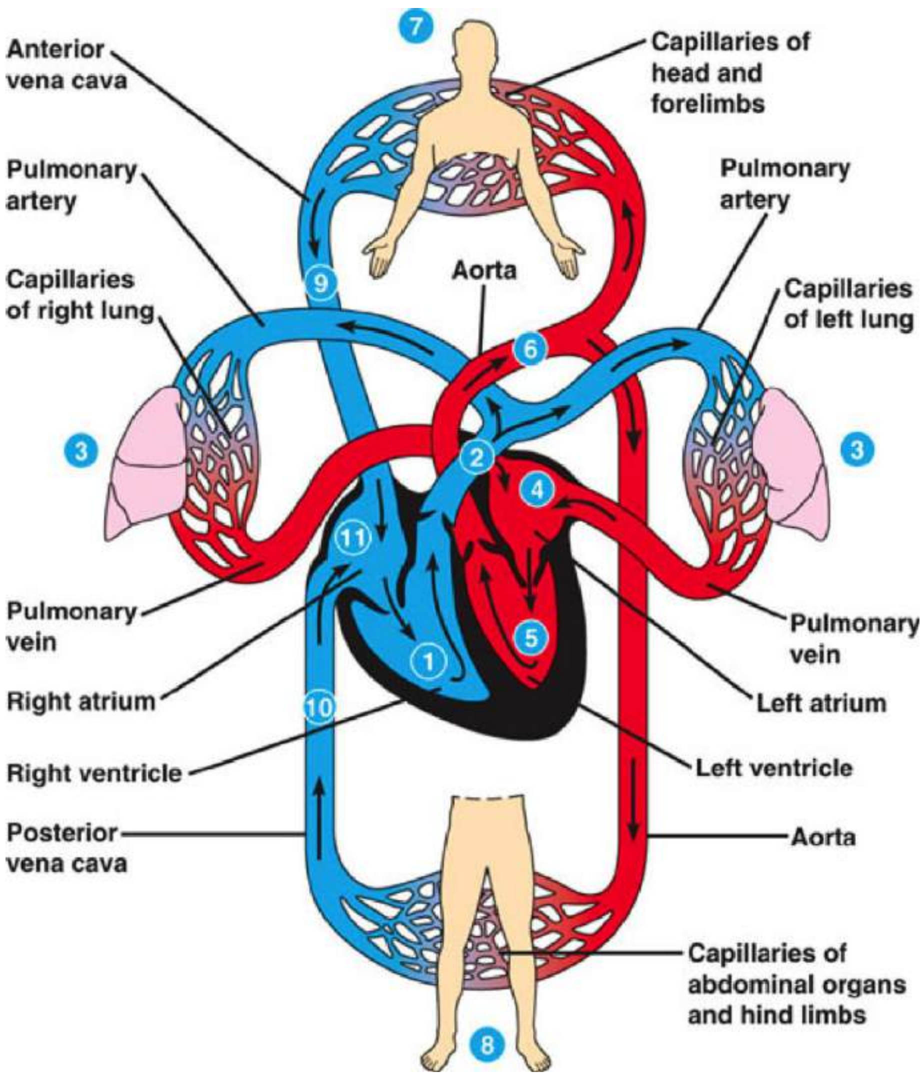
- Open circulatory system: fluid pumped through tubes into the cells
- Closed circulatory system: (most common) fluid stays in the tubes and materials are unloaded at the cells, through diffusion in humans

Cardiovascular System

Closed circulatory system in humans and other vertebrates

- Double circulatory system: (present in humans) carries blood throughout the body
  - Pulmonary circuit: heart to lungs and back
  - Systemic circuit: heart to cells in the body and back

Diagram of the double circulatory system and heart with steps:



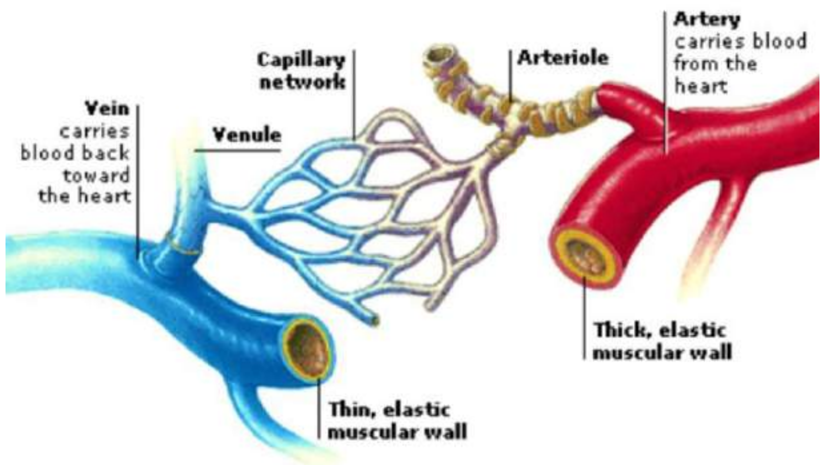
Blood Vessels and Capillaries

Carry the blood to and from the heart, lungs, and cells

- Arteries and Arterioles: carry blood away from the heart
- Veins and Venules: carry blood to the heart
- Capillaries: carry blood to the cells
    - Only 5-10% have a steady flow of blood at any given time
- Note: blood can be oxygenated or deoxygenated if it is going to or away from the heart

Arteries VS. Veins

Attribute	Arteries	Veins
Purpose	Carry blood to heart	Carry blood away from heart
Muscle	Contain more muscle in order to push out blood	Less muscle
Valves	No valves	Have valves so that blood does not go backwards



Cardiovascular diseases

- Heart attack: occurs if the coronary arteries are blocked
    - Coronary arteries: supply blood to the muscles of the heart
    - Bypass surgery takes an artery from the leg and bypasses a blocked coronary artery in the heart
    - Risk factors for heart attack: obesity, smoking, stress, no exercise
- Stroke: when an artery is blocked that goes to the brain
    - Oxygen cannot reach brain and it malfunctions
- High blood pressure: no symptoms, leads to stroke and heart attack (more below)
    - Aspirin thins blood to prevent clogs that lead to strokes and heart attacks
- Brain aneurysm: when there is a ruptured artery in the brain

Blood
Blood is always red, not blue, even when it is deoxygenated
About 5L of blood in the average human body

Ageing effects on blood
- Blood thin
- Less RBC and WBC
- Heart muscles become weaker, more prone to failure

Contents of blood:
- 55% Plasma
    - 90% water
    - 10% dissolved proteins and salts
    - Red blood cells, white blood cells, and platelets are suspended in the plasma
- 43% Red blood cells
    - In charge of carrying oxygen and other nutrients around the body
        - Present in the respiratory system
    - Contain around 250 million hemoglobin molecules to transport oxygen
        - Anemia: low amounts of hemoglobin the RBCs
    - Blood type is determined by carbohydrates on the surface of red blood cells
- 1% White blood cells
    - Fight infections
    - Contain nuclei and organelles, but no hemoglobin
    - Amount of white blood cells increase when the body is fighting infection
    - Leukemia: white blood cells cancer
- 1% Platelets
    - Begin clotting when blood tissue is damaged
    - Without clotting, junk would get into the heart

Cholesterol in the Blood
- Low density lipids (LDL)
    - Bad cholesterol that forms on the walls of arteries and veins
- High density lipids (HDL)
    - Good cholesterol that breaks up LDL when it forms and sends it to the kidney

Diabetes
- Type 1: no insulin produced, from birth
- Type 2: limited insulin produced, from being overweight

Blood Pressure
Force of blood on the walls of the blood vessels

How to measure blood pressure:

- Systolic number: (top number) peak pressure produced by contracting ventricles
- Diastolic number: (bottom number) pressure when the ventricles are relaxed

American Heart Association Blood Pressure Chart

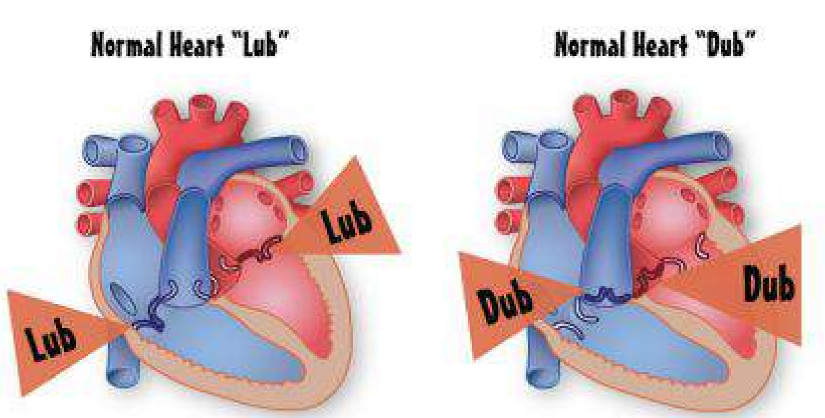
Blood Pressure Category	Systolic mm Hg (upper #)		Diastolic mm Hg (lower #)
Normal	less than 120	and	less than 80
Prehypertension	120 – 139	or	80 – 89
High Blood Pressure (Hypertension) Stage 1	140 – 159	or	90 – 99
High Blood Pressure (Hypertension) Stage 2	160 or higher	or	100 or higher
Hypertensive Crisis (Emergency care needed)	Higher than 180	or	Higher than 110

Cardiac Cycle

- The muscles of the heart relaxing and contracting
- Heart rate: complete cardiac cycles (beats per minute)

Sounds made by the heart

- Lub: blood forced against the closing of the AV valves
- Dub: blood forced against the closing of the semilunar valves
- Murmur: when valves do not close and blood flows backwards

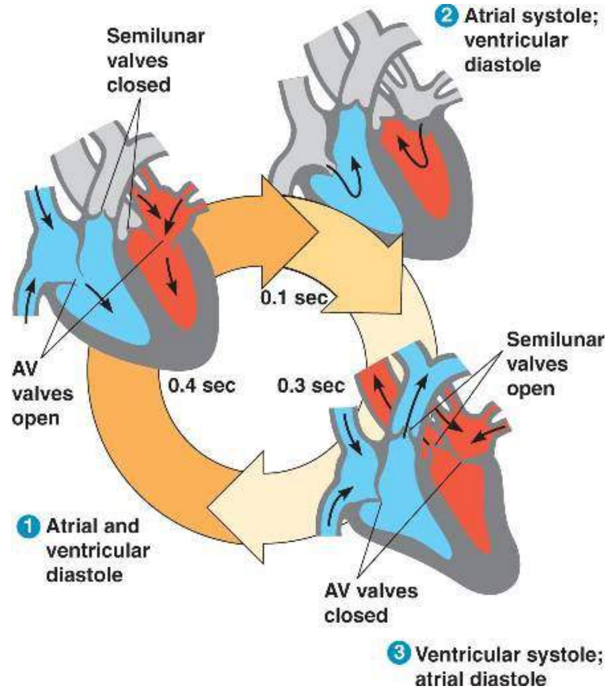


Steps in the cardiac cycle

1. Diastole in ventricles and atriums - 0.4 sec.
   - Relaxation phase
   - Blood fills up chamber

2. Systole in atriums - 0.1 sec.
   - Contracts more blood into all chambers
   - Pressured into atrium, then ventricle

3. Systole in ventricles - 0.3 sec.
   - Blood is pushed out of ventricles

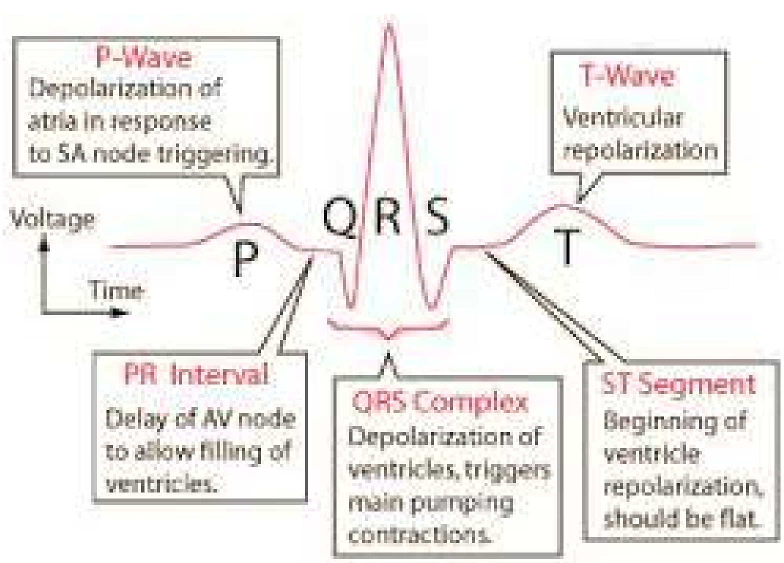


Control of the Heart Rate

- SA node (pacemaker): sends electrical signals to conduct the heart muscles, located in the right atrium
- AV node: delays the signals for different lengths of time in different sections of the heart in order to time everything correctly, located where the atriums and ventricles meet

Electrocardiograms (EKG)

Reads the electrical signals emitted by the SA node and checks for problems

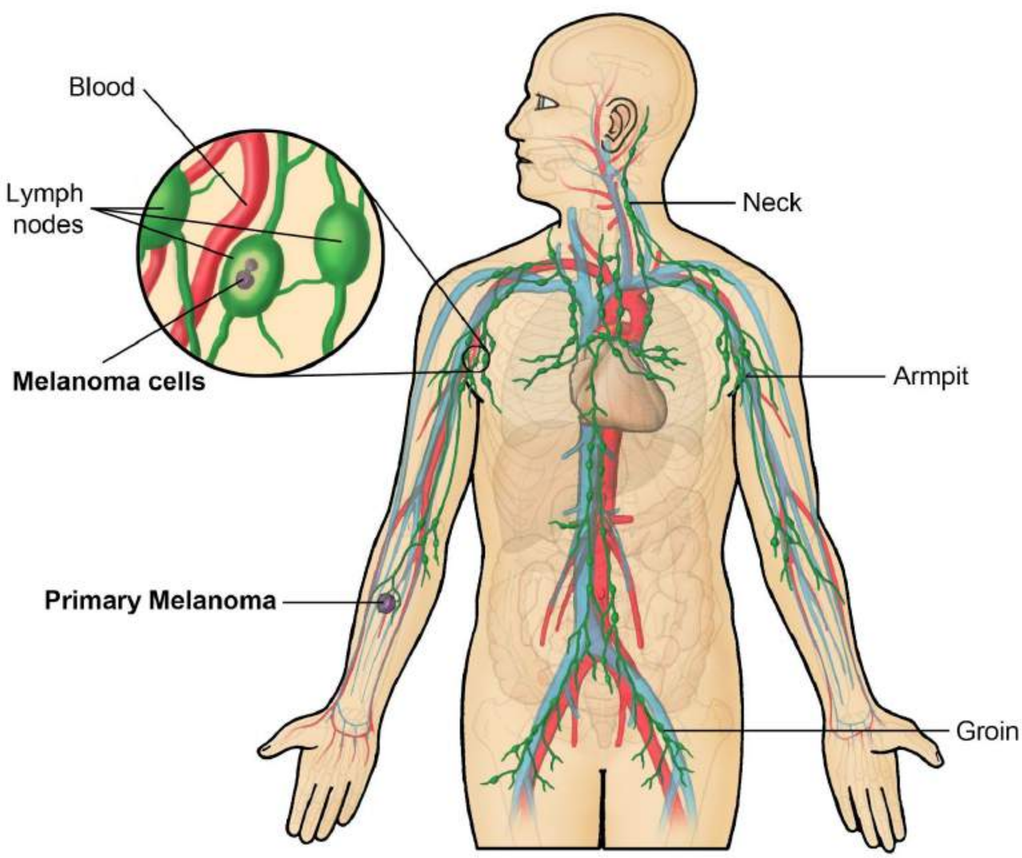


Unit 19: *More Organ Systems*

The Lymphatic System

- 15% of blood escapes the circulatory system and gets into the interstitial fluid
- The lymphatic system returns the blood back to the heart, through the vena cava
- Similar to capillaries, but contains valves
- Located close to veins to catch escaping blood
- Lymph nodes: blood passes through for and is scanned for infections
    - If infectious, white blood cells come and fight the infection
    - This process triggers someone getting sick
    - Lymph nodes are checked to see if cancer has spread
    - Cancer cells in the lymph nodes means that cancer has spread throughout the entire body

Lymph Nodes in the Body



Unit 20: *Solubility and Temperature*

Solubility

Terms

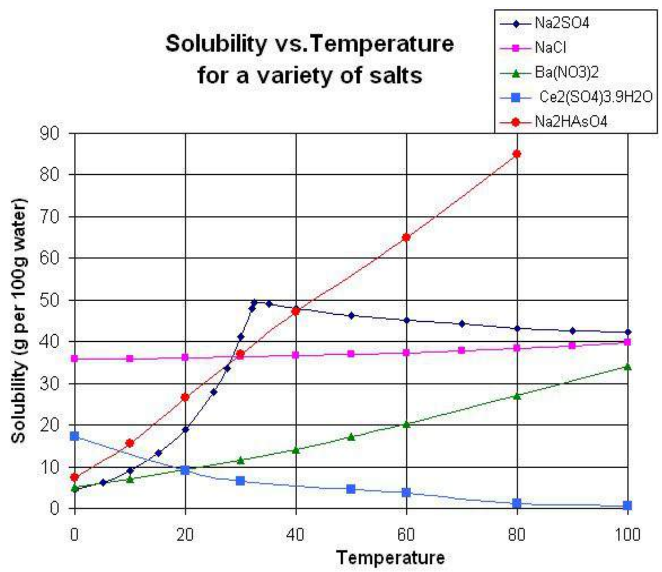
- Solute is dissolved into the solvent
- Solvent dissolves the solute
- Solution is the mixture of solute and solvent

Saturation

- Saturated: when the solvent holds a maximum amount of solute
    - The next crystal falls out of solution
- Unsaturated: more solute can be dissolved in the solvent
- Supersaturated: When a solid is dissolved in a liquid at an increased temperature, then the temperature is decreased so the liquid holds more solid than normal at that temperature

Saturation Point

- The point at which a solution becomes saturated
- Changes with temperature
- Solid in liquid: increase in temperature, increase in solubility
- Gas in liquid: increase in temperature, decrease in solubility



Measuring Solubility

- Mole Fraction: moles of one compound over by the total moles in the solution or mixture, expressed as a fraction
- Mole %: mass of solute over the mass of the total solution, expressed as a percent
- Molar concentration (molarity, or *M*): moles of the solute divided by litres of the solution, expressed as a number
- Molality (*m*): moles of solute divided by kilograms of solvent, expressed as a number
    - Need to write a balanced equation when solving molarity and molality problems

$$\text{mole fraction, X} = \frac{\text{moles of solute}}{\text{moles of solution}}$$

$$\text{molarity, M} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$\text{molality, m} = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

Colligative Properties
Based on the number of particles, not the type of particles

More particles, when added to solutions, will:
- Raise the boiling point
  - Escaping molecules, when trying to become a gas, have a harder time escaping because there is a larger chance they will hit one of the particles and be knocked back down and stay a liquid
- Decrease vapor pressure
  - *Same reason as above*
- Decrease freezing point
  - Harder to molecules to come together and freeze because of more particles in the way

Examples:
- Salt or sand is put on ice in the winter to decrease the freezing point so it will melt faster
- Salt is placed in water when cooking *pasta al dente* so that the water can be hotter without boiling, and the pasta is cooked quicker

Calculating Boiling Point and Freezing Point
The following equation calculates the change in boiling and freezing points, remember to add or subtract the product from the actual boiling or freezing point

The freezing point depression of a solution

$$\Delta T_f = m \times K_f$$

The boiling point elevation of a solution:

$$\Delta T_b = m \times K_b$$

where

- ΔT_b is change in temperature of the boiling point in °C (from the boiling point of the pure solvent).
- m is the molality of the solution in $\frac{\text{mol solute}}{\text{kg solvent}}$.
- K_b is the boiling point elevation constant for the solvent.

Note:
- An ionic bond is considered two particles because the ions split
- A covalent bond does not split and is considered one particle

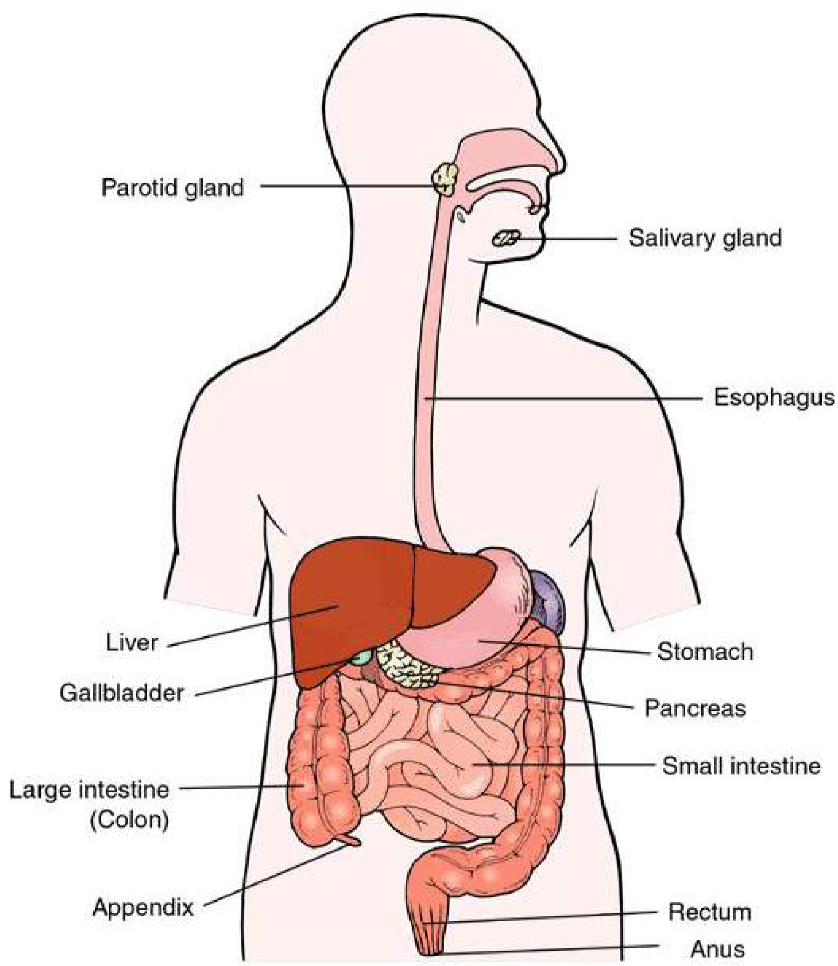
Unit 21: *The Digestive System*

General

- Steps of the digestive system: ingestion, digestion, absorption, elimination
- Chemical digestion: break down molecules by chemical reactions
- Mechanical digestion: muscles mechanically break down food into smaller pieces
- Digestive Tract: food moves through the different regions of the digestive tract to be digested from one end to the other
- Alimentary Canal: the entire passage which the foods passes from mouth to anus
- Gastrovascular Cavity: digestive tract with one opening for ingestion and one opening for elimination

Main Functions

- Absorb essential nutrients, minerals, and vitamins
- Obtain water
- Sort out waste products
- Break food down into small useable pieces to be absorbed into the body



The Mouth

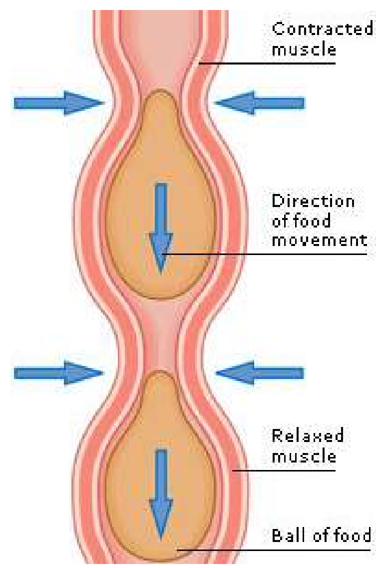
- Food enters body and begins to digest
- Chewing (mechanical digestion) makes food easier to swallow and exposes more surface area of the food
- Amylase (enzyme): breaks down starch (chemical digestion), present in saliva
- Tongue pushes food to the back of the mouth
- Food and drink at this stage is called “bolus”

The Pharynx

- The intersection of pathways for breathing and digestion
- When not swallowing, the entrance to the trachea is open for breathing so that air can reach the lungs
- Epiglottis closes over the trachea when swallowing so that food is directed down the esophagus and not into the lungs, which is when a heimlich maneuver would have to be performed

The Esophagus

- Smooth muscular tube that moves food down the alimentary canal
- Peristalsis: alternating waves of contracting muscles push food down the esophagus
    - Contributes to mechanical digestion
    - Allows animals to swallow when its head is lower than its stomach



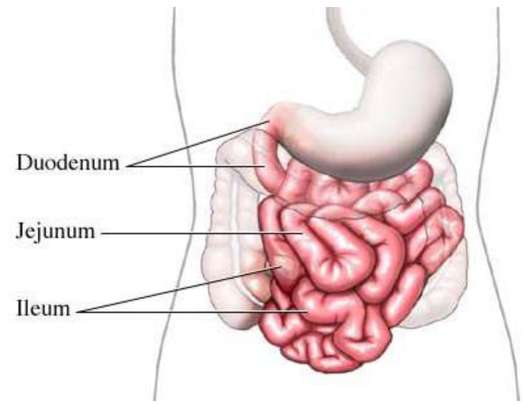
Peristalsis

The Stomach

- Stores enough food for several hours
- Can stretch to hold more than 2 litres of food and drink
- It takes about 2-6 hours for the stomach to empty
- Food and drink is called “chyme” at this stage
- Inside is covered in rugae, a smooth muscle that helps with churning of the chyme
- Stomach muscles turn to mechanically digest chyme
- Cardiac region: area of the stomach closer to the heart
- Pyloric region: lower area of the stomach
- Pyloric sphincter: muscular valves at the bottom of the stomach to control when chyme leaves to enter the small intestine
- Mucosa lines the inside of the stomach so that the gastric acids cannot eat away at the already present nutrients in the body
- Gastric juice: made up of hydrochloric acid and digestive enzymes to chemically break down the chyme, also has a high pH to kill bacteria

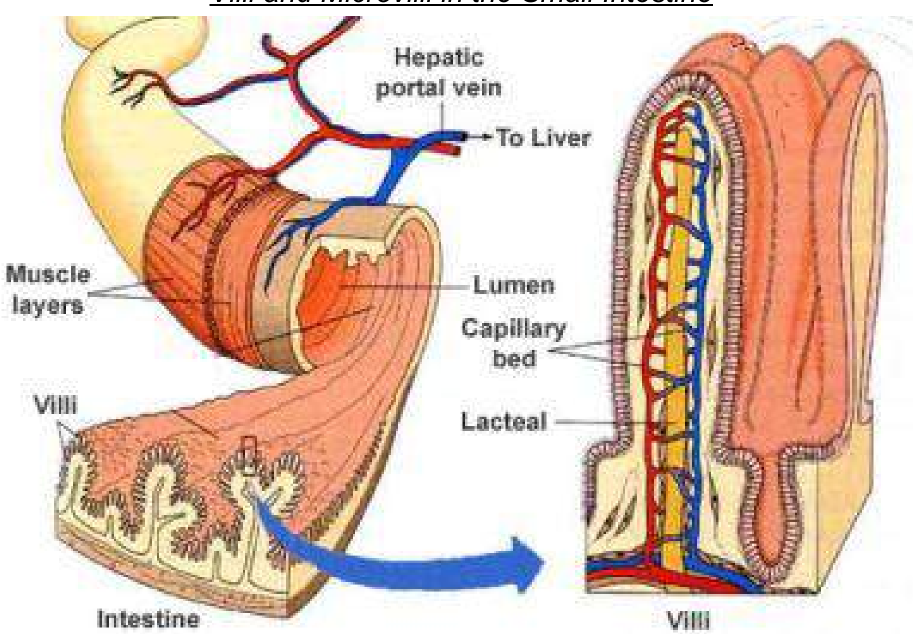
- Heartburn: backflow of the gastric juice into the esophagus
- Ulcers: sores in the stomach caused by the gastric juice eating away at the stomach walls
- Gastric bypass: surgery to lose weight that reduces the size of the stomach, giving the effect that someone is full before the used to be

The Small Intestine



- 20 Feet long (longest part of alimentary canal)
- Site of absorption of of nutrients into the body
- Duodenum Region: first part of the small intestine where enzymes break down food into even smaller pieces
- Jejunum: middle part of the small intestine
- Ilium: lower part of the small intestine
- Ileitis: inflammation of the ilium
- Sodium bicarbonate neutralizes the gastric juice that enters the small intestine
- Bile breaks up fats in the duodenum
- Gallstones: when bile crystallizes and surgery is required for them to be removed
- Villi: finger like outgrowths on the inside of the small intestine
- Microville: even smaller finger like outgrowths on the villi
- Villi and Microvilli both serve the purpose of increasing surface area that the chyme touches as it goes through the small intestine, allowing a maximum amount of nutrients to be absorbed

Villi and Microvilli in the Small Intestine

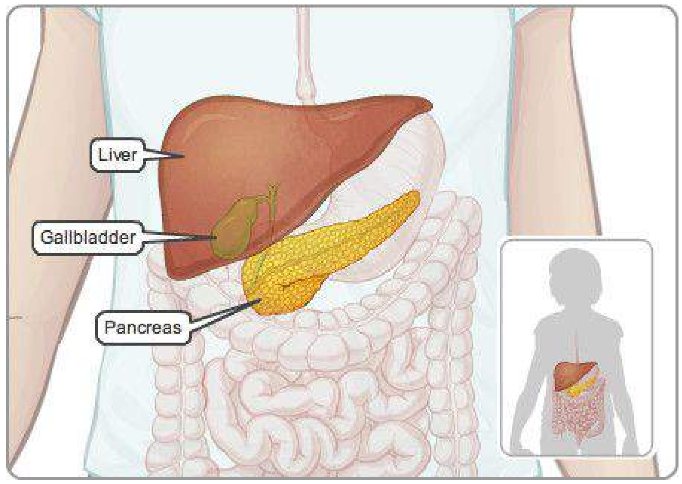


The Large Intestine

- Twice the width of the small intestine, but only 5 feet long
- Also called the colon
- White blood cells are present (from the appendix) in order to fight diseases
- Water is removed from the chyme so that it becomes more solid, eventually turning into feces which is stored in the rectum and eliminated from the body through the anus
- Removing too much water causes constipation, too little causes diarrhea
- Colitis: inflammation of the colon

Accessory Organs

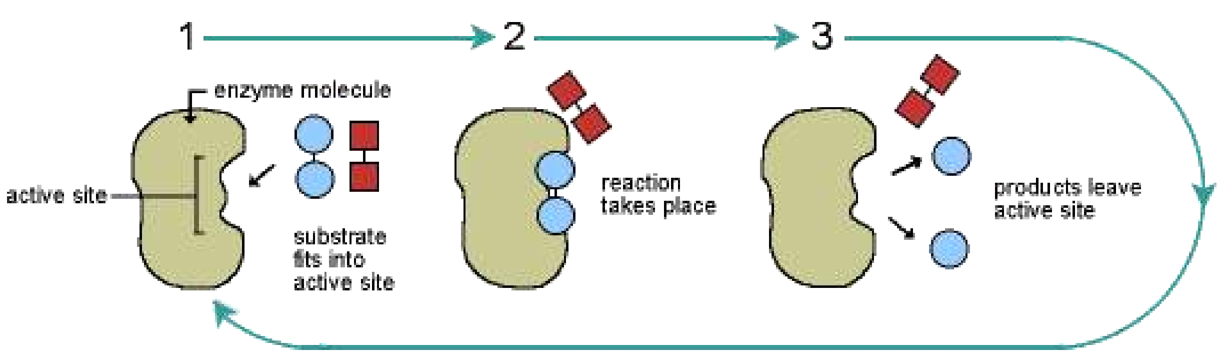
- Gallbladder: stores bile (which is made in the liver)
- Pancreas: makes and secretes enzymes into the small intestine
- Liver: over 200 functions, such as: regulates amount of nutrients that enter blood stream, stores vitamins, detoxifies alcohol



Digestive Enzymes

Enzymes only work at specific pH levels and temperatures

Enzyme	Purpose	Location
Amylase	Break down starch	Mouth (saliva)
Pepsin	Break down proteins into polymers	Stomach
Trypsin	Breaks down polypeptides into amino acids	Small intestine
Lipase	Breaks down lipids	Small intestine



Unit 22: *Nutrition*

<u>6 Essential Things our Bodies Need (Nutrients)</u>

- Water
- Minerals
    - Chemicals needed in very small amounts which help enzymes to work
    - 21 inorganic materials are required, such as calcium, iron, and zinc
- Vitamins
    - Organic molecules required in the diet
    - Water soluble vitamins (B, C) : dissolves into the body if not used, need to keep replenished
    - Fat soluble vitamins (A, D, E, K): do not leave the body if not used, do not need every day
- Proteins
    - 8 required amino acids that have to be obtained from food and cannot be made in the human body
- Carbohydrates
    - Converted to ATP during cellular respiration
- Fats
    - Unsaturated fats: consist of at least one double bond - healthier
    - Saturated fats: consist of single bonds
    - Fatty acids can only be obtained by eating and cannot be made in the body

Superfoods: contain many of the 6 essential things that our body needs

Calories

- 1 <u>c</u>alorie is the amount of energy required to raise the temperature of 1 gram of water by 1 degree celsius
- 1 <u>C</u>alorie / kilocalorie / kcal is equal to 1000 <u>c</u>alories and is what is on food labels

Metabolism

- Metabolic rate: rate of energy consumption by the body
  - depends on activity, stress, body size, and heredity
- Basal metabolic rate: amount of energy needed to maintain basic body functions
  - Average BMR: 1400-1700 Calories

Nutritional Disorders

Malnutrition

- Insufficient diet
- 14000 children under 5 starve to death each day
- Anorexia: self starving because fear of gaining weight

Fat and Sugar Cravings

- The need to unhealthy foods
- Before a large supply of food, it was good to eat fats and sugars to gain weight when food was not as reliable, so it is embedded into humans brains to eat fats and sugars

Obesity

- To high body mass index (BMI)
- 1/3 of Americans are obese
- Another 1/3 of Americans are overweight
- BMI does not take into account body mass from muscle vs. body mass from fat
- Bulimia: binge eating and purging

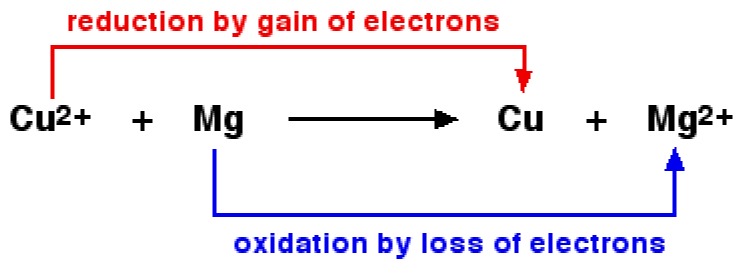
Underweight Healthy Overweight Obese Extremely obese

WEIGHT lbs	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215
kgs	45.5	47.7	50.0	52.3	54.5	56.8	59.1	61.4	63.6	65.9	68.2	70.5	72.7	75.0	77.3	79.5	81.8	84.1	86.4	88.6	90.9	93.2	95.5	97.7
HEIGHT in/cm																								
5'0" - 152.4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
5'1" - 154.9	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	36	37	38	39	40
5'2" - 157.4	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	33	34	35	36	37	38	39
5'3" - 160.0	17	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	32	32	33	34	35	36	37	38
5'4" - 162.5	17	18	18	19	20	21	22	23	24	24	25	26	27	28	29	30	31	31	32	33	34	35	36	37
5'5" - 165.1	16	17	18	19	20	20	21	22	23	24	25	25	26	27	28	29	30	30	31	32	33	34	35	35
5'6" - 167.6	16	17	17	18	19	20	21	21	22	23	24	25	25	26	27	28	29	29	30	31	32	33	34	34
5'7" - 170.1	15	16	17	18	18	19	20	21	22	22	23	24	25	25	26	27	28	29	29	30	31	32	33	33
5'8" - 172.7	15	16	16	17	18	19	19	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	32	32
5'9" - 175.2	14	15	16	17	17	18	19	20	20	21	22	22	23	24	25	25	26	27	28	28	29	30	31	31
5'10" - 177.8	14	15	15	16	17	18	18	19	20	20	21	22	23	23	24	25	25	26	27	28	28	29	30	30
5'11" - 180.3	14	14	15	16	16	17	18	18	19	20	21	21	22	23	23	24	25	25	26	27	28	28	29	30
6'0" - 182.8	13	14	14	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29
6'1" - 185.4	13	13	14	15	15	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28
6'2" - 187.9	12	13	14	14	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27
6'3" - 190.5	12	13	13	14	15	15	16	16	17	18	18	19	20	20	21	21	22	23	23	24	25	25	26	26
6'4" - 193.0	12	12	13	14	14	15	15	16	17	17	18	18	19	20	20	21	22	22	23	23	24	25	25	26

Unit 23: *Redox Reactions*

Overview

- Oxidation-Reduction reaction (redox): a reaction where there is an exchange of electrons
- Oxidation: loss of electrons
- Reduction: gain of electrons
- One substance must lose electrons, the oxidized substance, while the other must gain electrons, the reduced substance
- Oxidising agent: the substance being reduced
- Reducing agent: the substance being oxidized



Oxidation States

Used to track the number of electrons for each element and compound

Rules for Assigning Oxidation States	Examples
1. The oxidation state of an atom in a free element is 0.	Cu: 0 ox state; Cl_2: 0 ox state
2. The oxidation state of a monoatomic ion is equal to its charge.	Ca^{2+}: +2 ox state; Cl^-: −1 ox state
3. The sum of the oxidation states of all atoms in:	
• a neutral molecule or formula unit is 0.	H_2O: 2(H ox state) + 1(O ox state) = 0
• an ion is equal to the charge of the ion.	NO_3^-: 1(N ox state) + 3(O ox state) = −1
4. In their compounds,	
• Group I metals have an oxidation state of +1.	NaCl: +1 ox state
• Group II metals have an oxidation state of +2.	CaF_2: +2 ox state

Balancing Redox Reactions

1. Find each element's oxidation state
2. Determine which reactants are oxidized or reduced
3. Rewrite the equation into two half reactions: one oxidation and one reduction reaction
4. Balance all elements in the half reactions that are not hydrogen or oxygen
5. Balance each half reaction in terms of their charge by adding electrons to the reactants or products
6. Balance the oxygens by adding H_2O in the appropriate spots, and then balance the hydrogens by adding H^+ in the appropriate spots
7. If it is a basic solution, add OH^- <u>to both sides</u> to neutralize the reaction; if the solution is acidic, do nothing (the problem will say if it is an acidic or basic solution)
8. Multiply the oxidation or reduction reaction so that the number of electrons are equal
9. Add the two half reactions together and cancel out anything on both sides

<u>Example</u>

(Basic Solution)

Step

① $\underset{+1\ -2}{ClO^-}(aq) + \underset{+3\ \ -1}{Cr(OH)_4^-}(aq) \longrightarrow \underset{+6\ -2}{CrO_4^{2-}}(aq) + \underset{-1}{Cl^-}(g)$

② Reduced: Cl   Oxidized: Cr

③ $ClO^-(aq) \rightarrow Cl^-(g)$ $Cr(OH)_4^-(aq) \rightarrow CrO_4^{2-}(aq)$

④⑤ $ClO^- \rightarrow Cl^- + 2e^-$ $3e^- + Cr(OH)_4^- \rightarrow CrO_4^{2-}$

⑥ $+2H^+$ $+H_2O$ $+4H^+$

⑦ $+2OH^-$ $+2OH^-$ $+4OH^-$ $+4OH^-$

⑧ $3\times[ClO^- + 2H^+ + 2OH^- \rightarrow Cl^- + H_2O + 2e^- + 2OH^-]$

$= 3ClO^- + 6H^+ + 6OH^- \rightarrow 3Cl^- + 3H_2O + 6e^- + 6OH^-$

$2\times[4OH^- + 3e^- + Cr(OH)_4^- \rightarrow CrO_4^{2-} + 4H^+ + 4OH^-]$

$= 8OH^- + 6e^- + 2Cr(OH)_4^- \rightarrow 2CrO_4^{2-} + 8H^+ + 8OH^-$

⑨ $3ClO^- + \cancel{6H^+} + \cancel{6OH^-} + \cancel{6e^-} + 2Cr(OH)_4^-\ \overset{2}{\cancel{8}}OH^- \rightarrow$

$3Cl^- + 3H_2O + \underset{2}{\cancel{8}}\cancel{OH^-} + \cancel{6e^-} + 2CrO_4^{2-} + \underset{2}{\cancel{8}}\cancel{H^+} + \cancel{6OH^-}$

$2H_2O$

$2OH^- + 3ClO^- + 2Cr(OH)_4^- \rightarrow 3Cl^- + 5H_2O + 2CrO_4^{2-}$

Unit 24: *Electrochemistry*

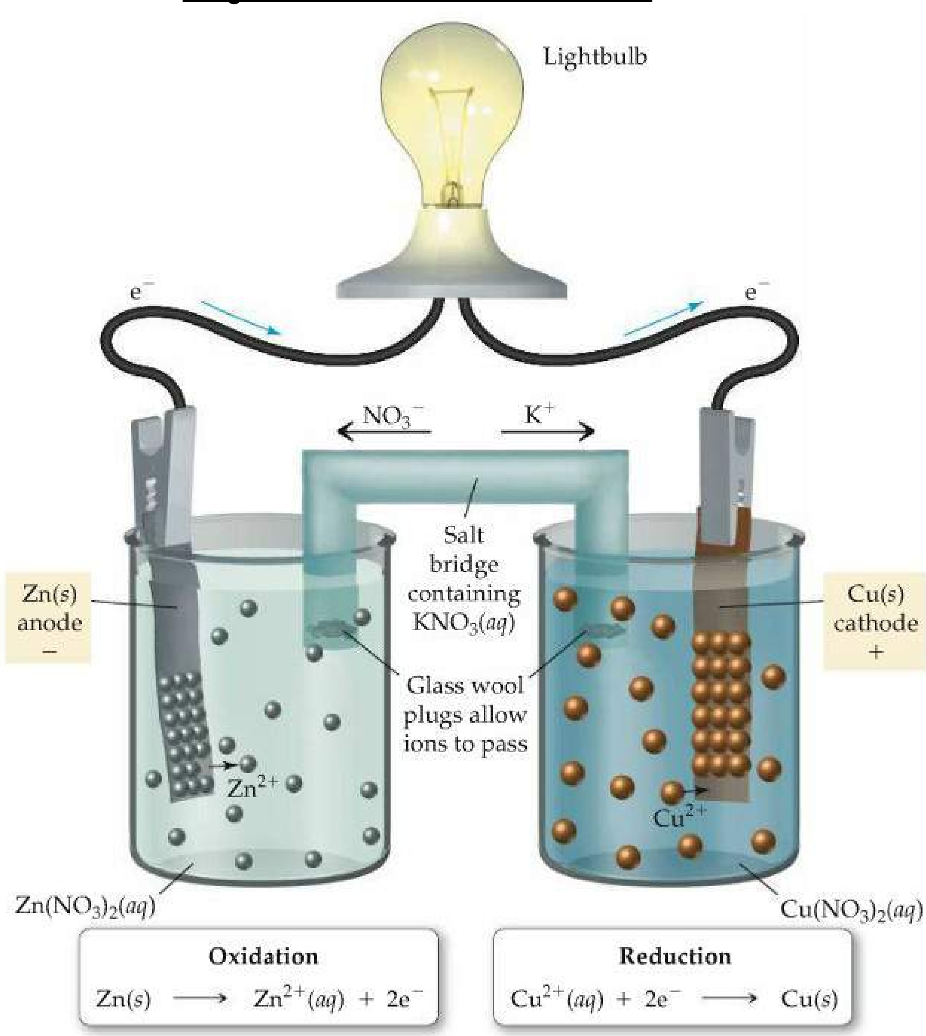
Overview

- Electrical current: flow of electrical charge
- Electrochemical cell: device that creates electrical current from a spontaneous reaction
- Two half reactions cause electrons to move between them, creating a current
- Voltage: measure of the electron flow between the anode and cathode

Voltaic / Galvanic Cell

- Spontaneous reaction
- Oxidation occurs in the anode
- Electron flow from anode to cathode (anode is oxidized, cathode is reduced)
- Salt bridge: joins the two half cells and contains a strong electrolyte to allow the flow of electrons to neutralize and replenish the ions

Diagram of a Voltaic / Galvanic Cell:



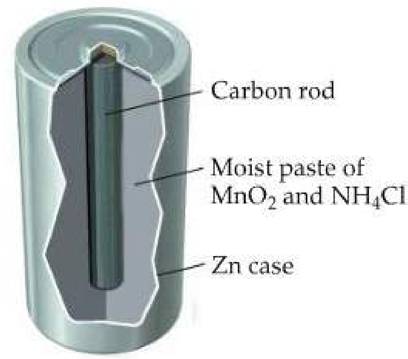
<u>Applications of a Voltaic / Galvanic Cell</u>

- Corrosion: oxidation of iron
- Rechargeable batteries reverse the current when charging in order to send the electrons back to the anode from the cathode
- Lead acid storage batteries: in most cars, leaving it for too long long causes the built up of $PbSO_4$ and a jump start is needed to get the electrons going

<u>Other Batteries and Cells</u>

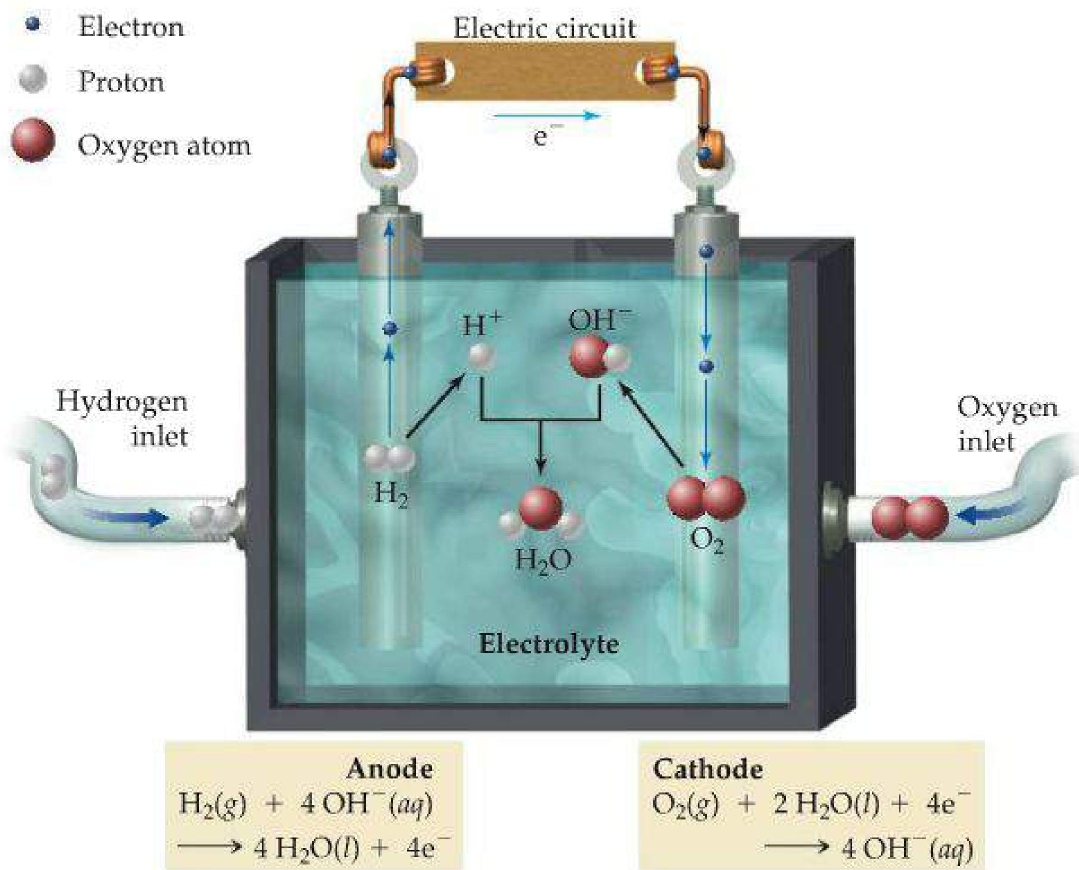
<u>Dry Cell Batteries</u>

- Do not contain large amounts of liquid
- Uses a wet moisture to carry the current
- Can be oriented in any direction without spilling



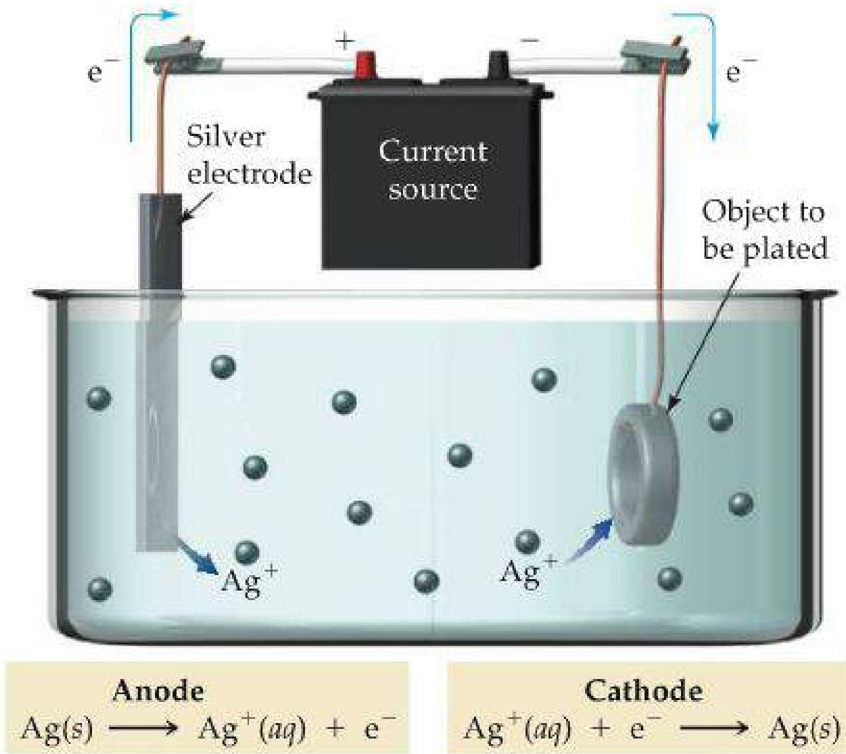
<u>Fuel Cell</u>

- Reactants are constantly replenished
- Transfer of electrons from hydrogen to oxygen



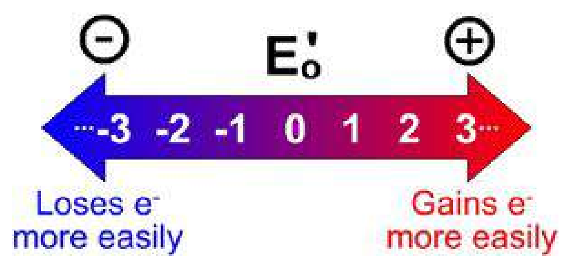
Electroplating

- Uses electrolysis to deposit a metal onto another metal
- Electrolysis: when energy is added to a non-spontaneous reaction to cause the reaction
- Used for gold or copper plating



Reduction Potential

- Potential of an element, compared to hydrogen (0), to accept electrons
- The higher the E^O, the stronger an oxidizing agent it is, and weaker reducing agent
- Unit: volts (v)



Finding the Reduction Potential:

$$E^\circ_{cell} = E^\circ_{reduced} - E^\circ_{oxidized}$$

If $E^\circ_{cell} > 0$, then it is a spontaneous reaction

If $E^\circ_{cell} < 0$, then it is not a spontaneous reaction

Unit 25: *A Balanced Environment*

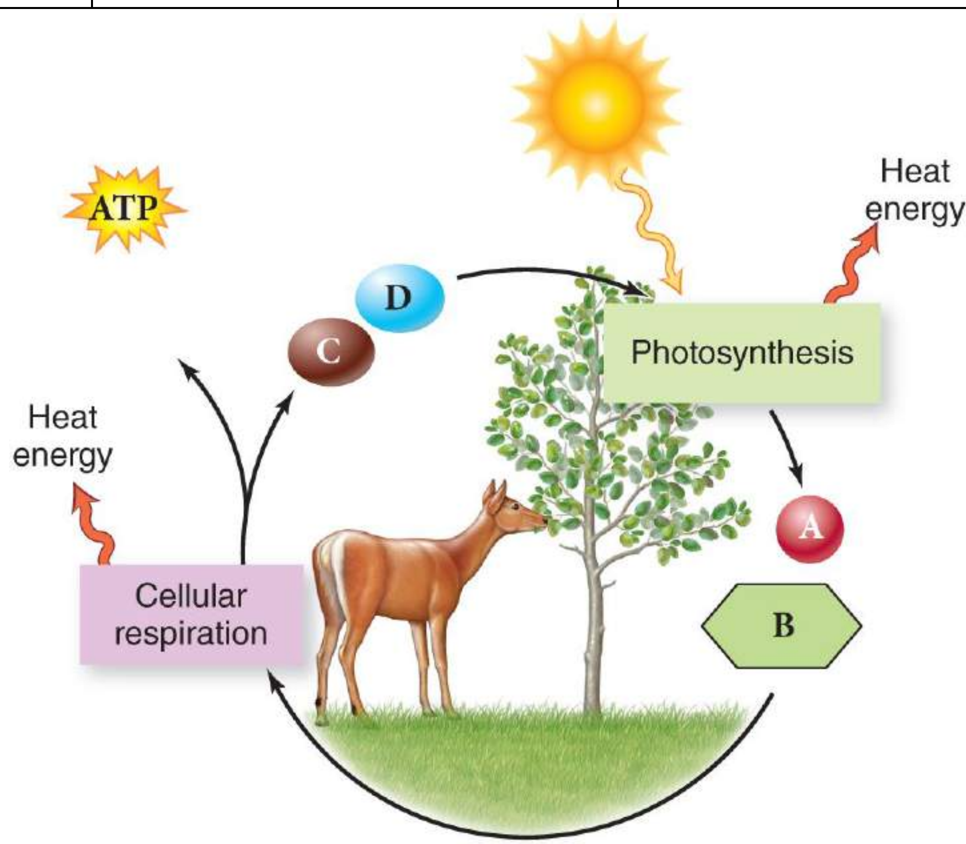
Autotrophs and Heterotrophs

Autotroph	Heterotroph
Organisms that produce their own organic matter from inorganic material	Organisms that cannot produce their own organic matter from inorganic material - must consume autotrophs for organic matter
Go through photosynthesis and cellular respiration	Go through cellular respiration only

Cellular Respiration and Photosynthesis

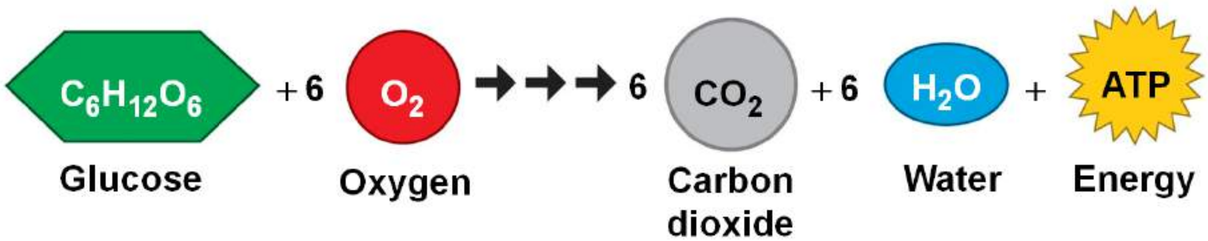
Photosynthesis and cellular respiration balance each other out in the environment so that each one's products are the others' reactants:

	Cellular Respiration	Photosynthesis
Reactants	Glucose, Oxygen	Carbon dioxide, Water
Products	Carbon dioxide, Water	Glucose, Oxygen



Unit 26: *Cellular Respiration*

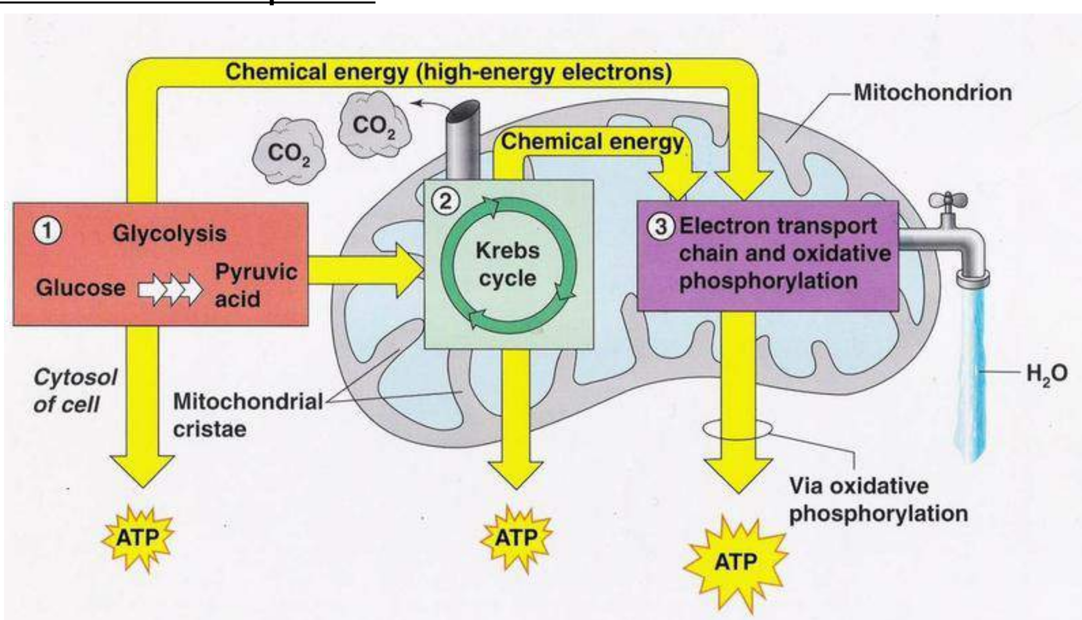
Overall Reaction for Cellular Respiration



This reaction does not happen all at once it needs to complete the following stages to happen:

- Glycolysis
    - Fermentation
    - Transport reactions
- Citric Acid Cycle (Krebs Cycle)
- Electron Transport Chain

Overview of Cellular Respiration



More Information

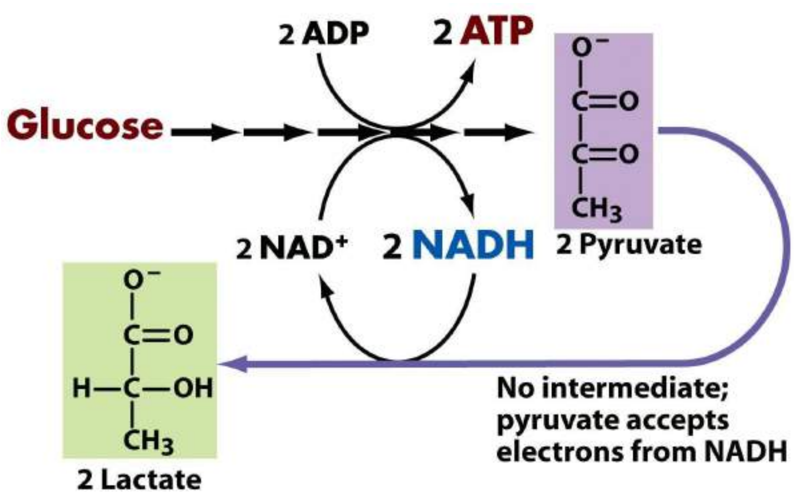
- ATP: Adenosine Triphosphate
- ADP: Adenosine Diphosphate
- NADH and FADH2 are created at different stages and then sent to the ETC
- NADH can produce 3 ATP
- FADH2 can produce 2 ATP
- Glucose is oxidized and oxygen is reduced

Glycolysis
1 glucose is broken down into 2 pyruvates

Location	'Ingredients'	Products
Cytoplasm of the cell	- 1 glucose molecule - 2 ATP - 2 NAD+	- 2 3-carbon pyruvate molecules - 2 NADH formed from high energy electrons adding to NAD+ - 4 ATP molecules (net gain of 2)

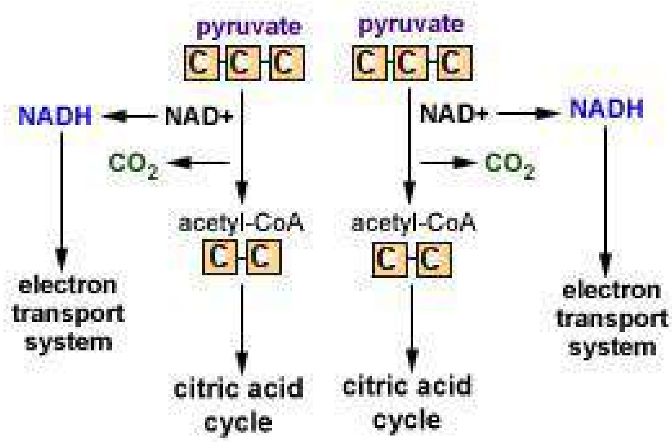
Fermentation

- Cellular respiration occurs in an aerobic environment (with oxygen)
- When no oxygen is available, such as when not enough can be obtained from breathing, cellular respiration is in an anaerobic environment (without oxygen)
- 2 ATP can be produced from one glucose molecule in glycolysis, but very inefficiently: 2 ATP from a glucose molecule vs. 38 total from the entire completed process
- The extra electron from NADH is added to the pyruvate to form lactic acid (2x for each glucose molecule used)
- The buildup of lactic acid will begin to hurt the bodies muscles in about 90 seconds
- In yeast cells, anaerobic respiration produces ethyl alcohol instead of lactic acid



Transition Reactions
3-carbon pyruvates are turned into 2-carbon pyruvates

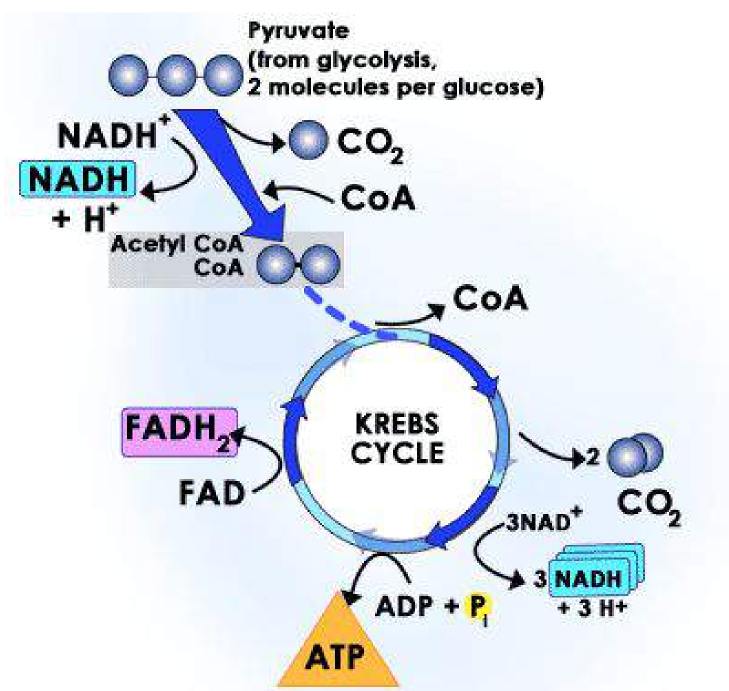
Location	'Ingredients'	Products
Outer membrane of mitochondria	- 2 3-carbon pyruvate molecules - 2 NAD+ - 2 O2	- 2 2-carbon acetyl-CoA molecules - 2 CO2 molecules (where the extra carbon atoms go) - 2 NADH formed from high energy electrons adding to NAD+



Citric Acid Cycle (Krebs Cycle)

Uses Acetyl CoA to make NADH and FADH

Location	'Ingredients'	Products
Matrix of the mitochondria	- 2 Acetyl CoA molecules - 6 NAD+ - 2 FAD - 4 O2	- 2 ATP molecules (1 from each time around the cycle) - 6 NADH formed (3 from each time around the cycle) - 2 FADH2 produced (1 from each time around the cycle) - 4 CO2 produced (2 from each time around the cycle)

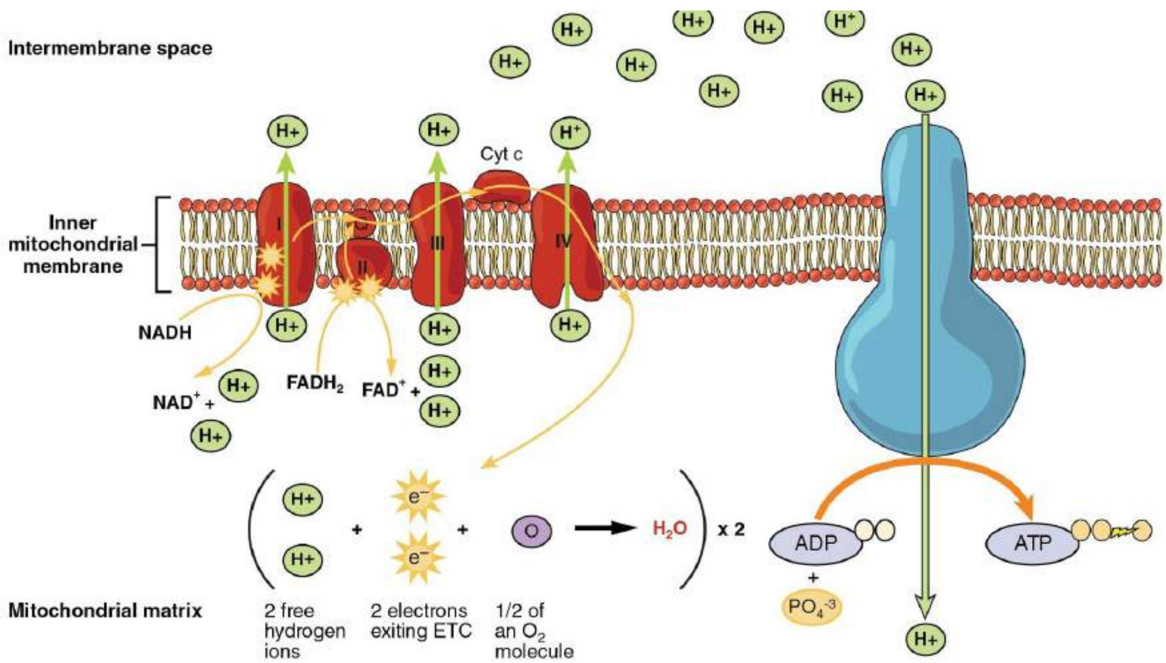


Electron Transport Chain (ETC)

Transfers electrons, then protons across inner membrane, to diffuse back through the ATP synthase to generate power to synthesize ATP from ADP and P

Location	'Ingredients'	Products
Inner membrane of the mitochondria	- 10 NADH - 2 FADH2 - ADP, P	- About 34 ATP molecules - (4H+) + (O2) -> (2 H2O)

NADH and FADH2 are created and sent to the ETC in order to provide energy to move electrons across inner membrane, which causes the protons (H+ ions) to move across, which then powers the ATP synthase to synthesize ATP from ADP and P



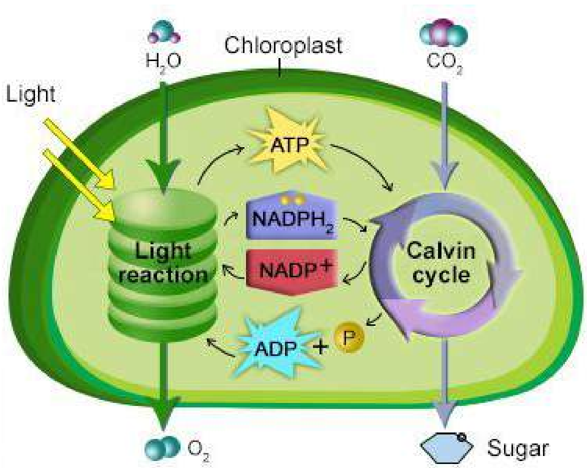
Unit 27: *Photosynthesis*

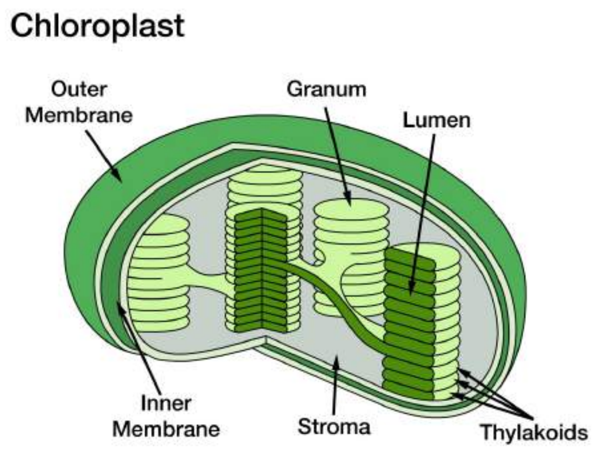
Overview of Photosynthesis

Converts light energy into sugar, specifically glucose in the form of G3P molecules

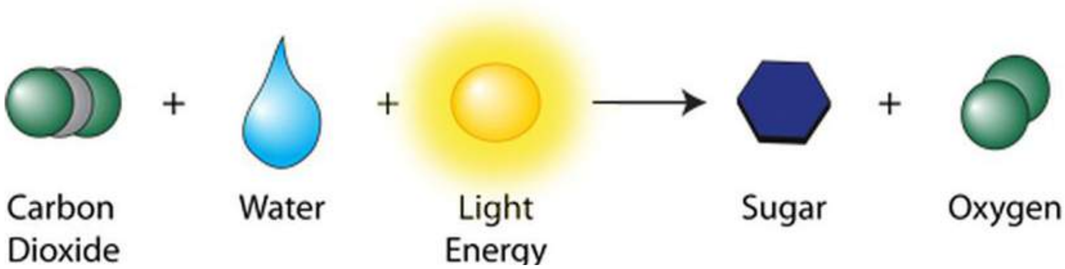
Stage 1: Light Reactions in the Thylakoid

Stage 2: Calvin Cycle in the Stroma





Overall Reaction for Photosynthesis

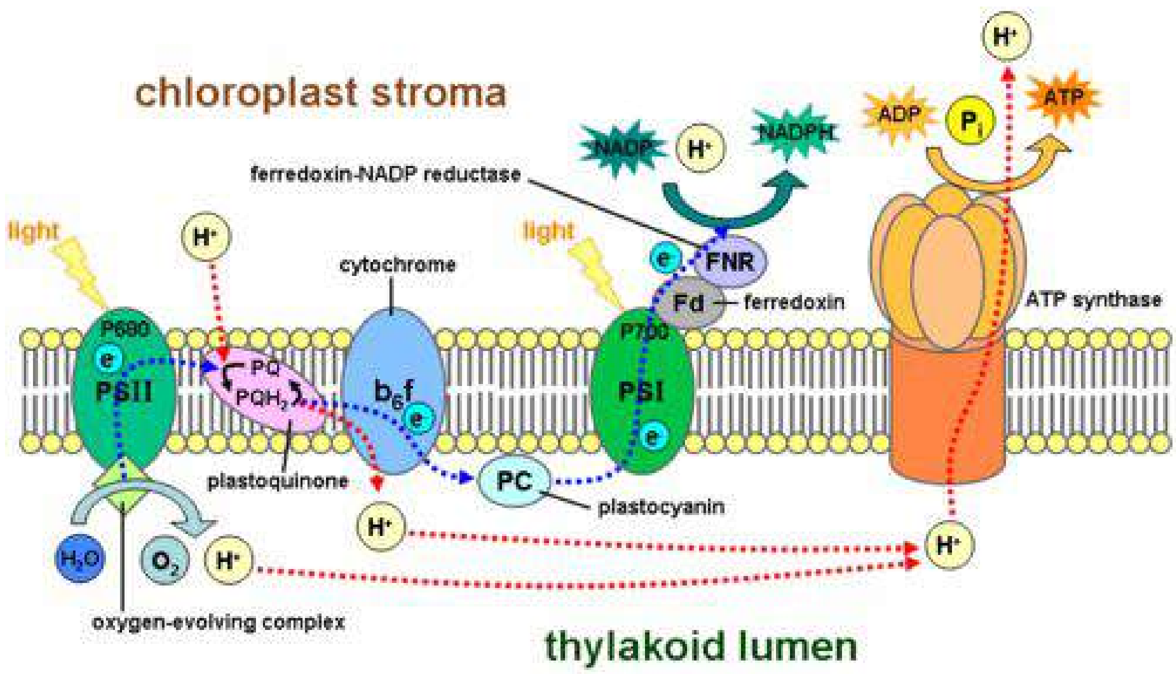


More about Photosynthesis

- Carbon dioxide, and oxygen can enter/exit through stomata, small holes on a leaf
- Water comes from the plants roots by the process of transpiration
  - Adhesion: water using its hydrogen bonds to pull up other surfaces
  - Cohesion: water using its hydrogen bonds to pull up by attaching to other water molecules

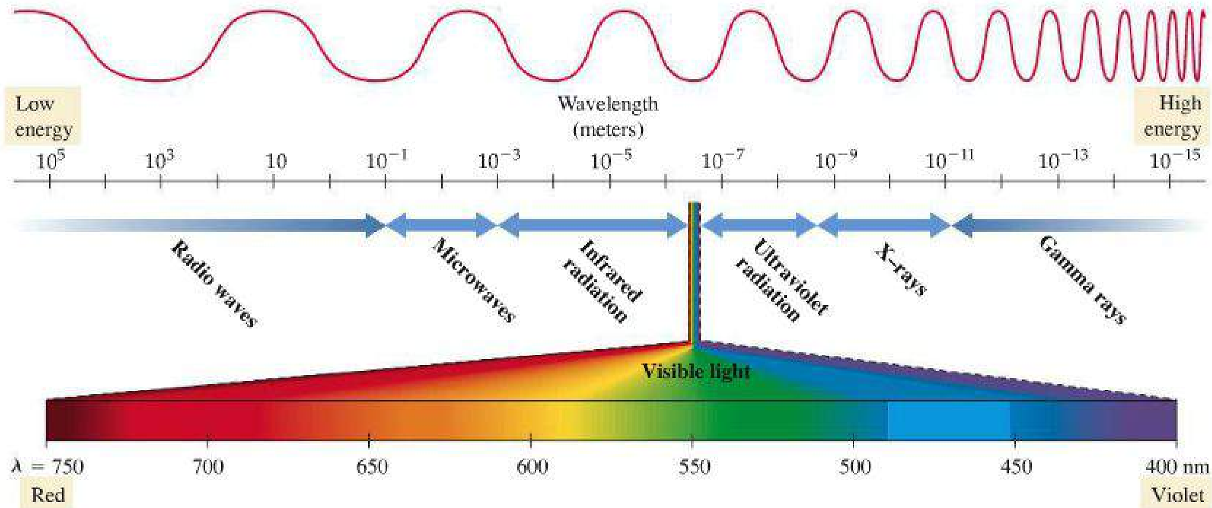
Stage 1: Light Dependent Reaction

- Located in the thylakoid and around the thylakoid membrane
- PSII breaks down water in oxygen gas, hydrogen ions, and electrons using light energy
- Electrons pump hydrogen ions from the stroma into the lumen
- Hydrogen gradient causes the hydrogen ions to go through the ATP Synthase
- Low energy electrons used in PSII get excited again in PSI from light energy
- Electrons reduce NADP+ to NADPH
- ATP and NADPH made are sent to the calvin cycle
- Oxygen is oxidized, carbon is reduced



Review of Light

- A form of electromagnetic radiation - can be waves or particles
- Wavelength: the distance between the crests in the light wave
- Photon: a particle of light that is a fixed quantity of energy
- Electromagnetic spectrum: all the wavelengths, with visible light relatively in the middle
- The color that something appears is the light it does not absorb and reflects back
- Plants appear green because they do not absorb green light for photosynthesis and therefore reflect it back into their surrounding environment



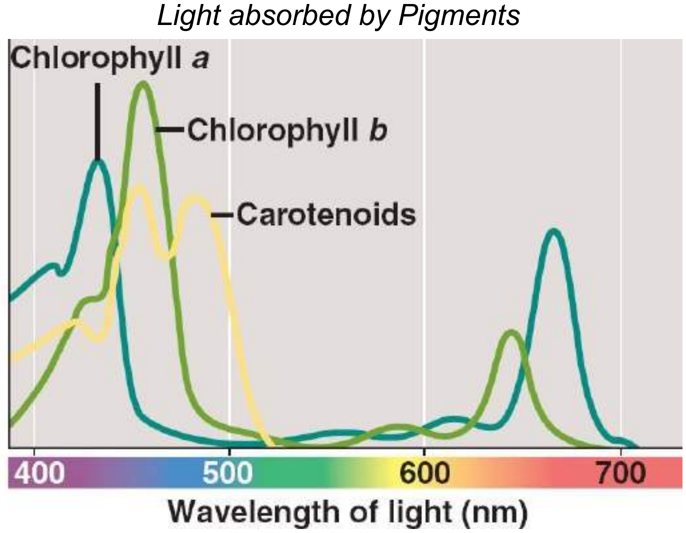
RED ORANGE YELLOW GREEN BLUE INDIGO VIOLET

(ROYGBIV)

<u>Pigments in Light Dependent Reactions</u>

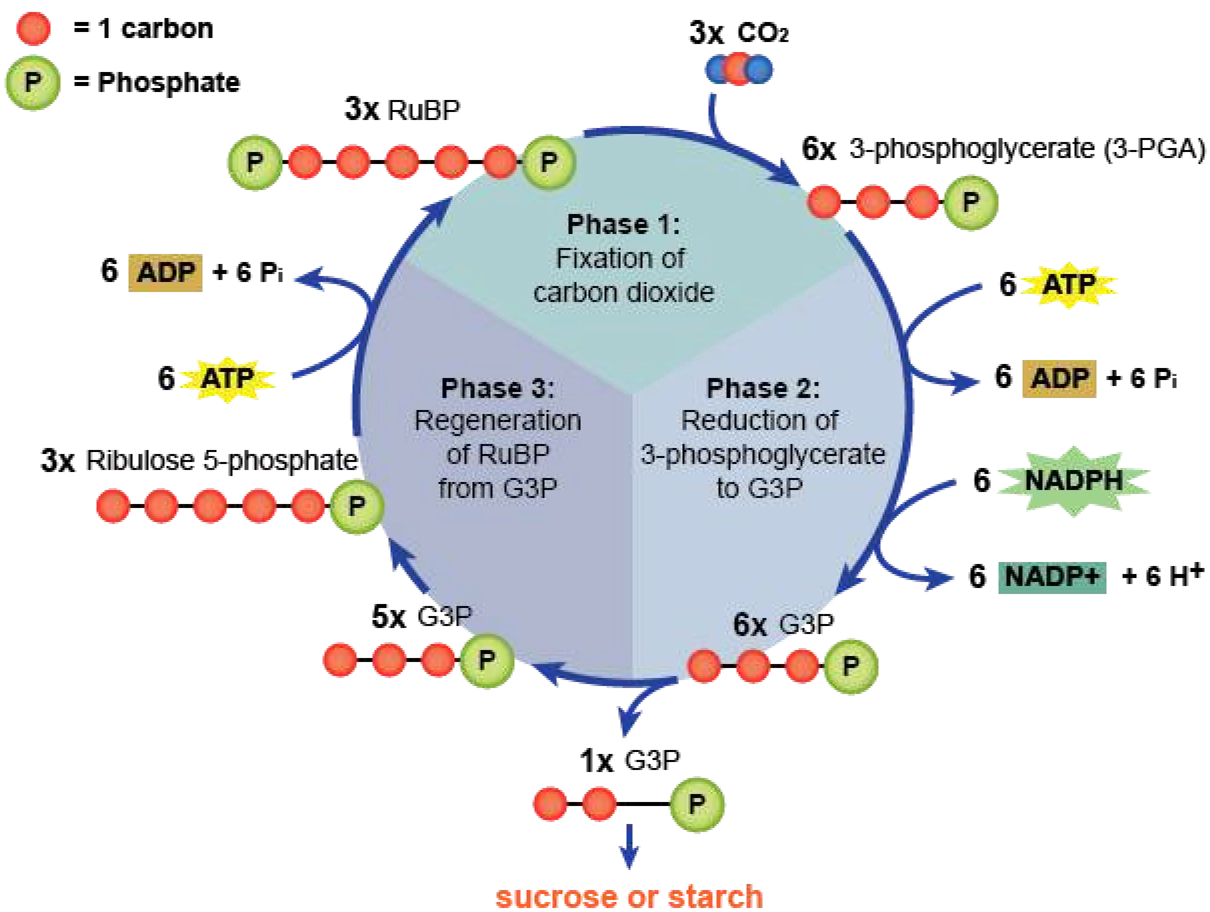
- Pigment: captures light energy
- Chlorophyll a: participates directly in light reactions, absorbs blue-violet and red light
- Chlorophyll b: does not directly participate in light reactions, but conveys the light it absorbs to chlorophyll a, absorbs blue and orange light
- Carotenoids: pass blue-green light energy to chlorophyll a, also dissipate excessive energy that would hurt chlorophyll
- Each photosystem contains a few hundred pigment molecules to absorb incoming light
- After collected by pigments, light goes to the reaction center (chlorophyll a molecules), and then to a primary electron acceptor

Light absorbed by Pigments

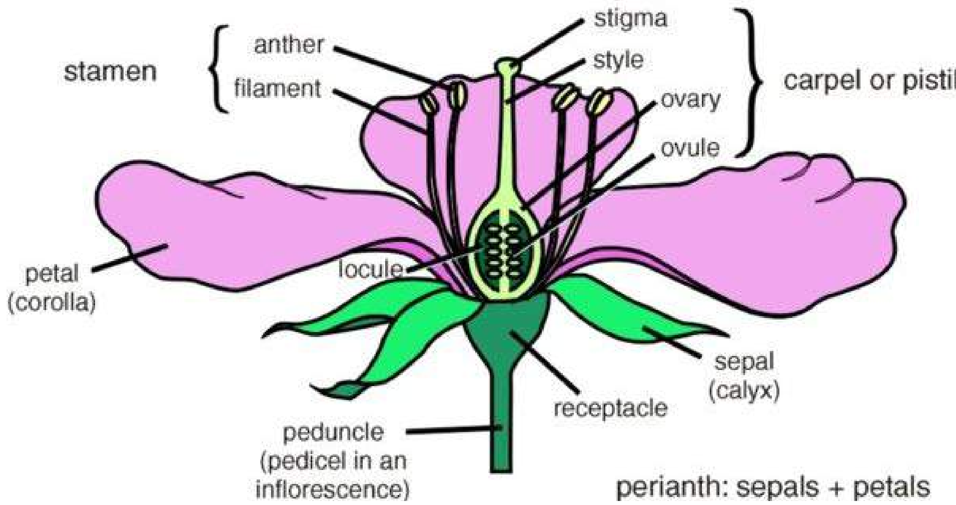


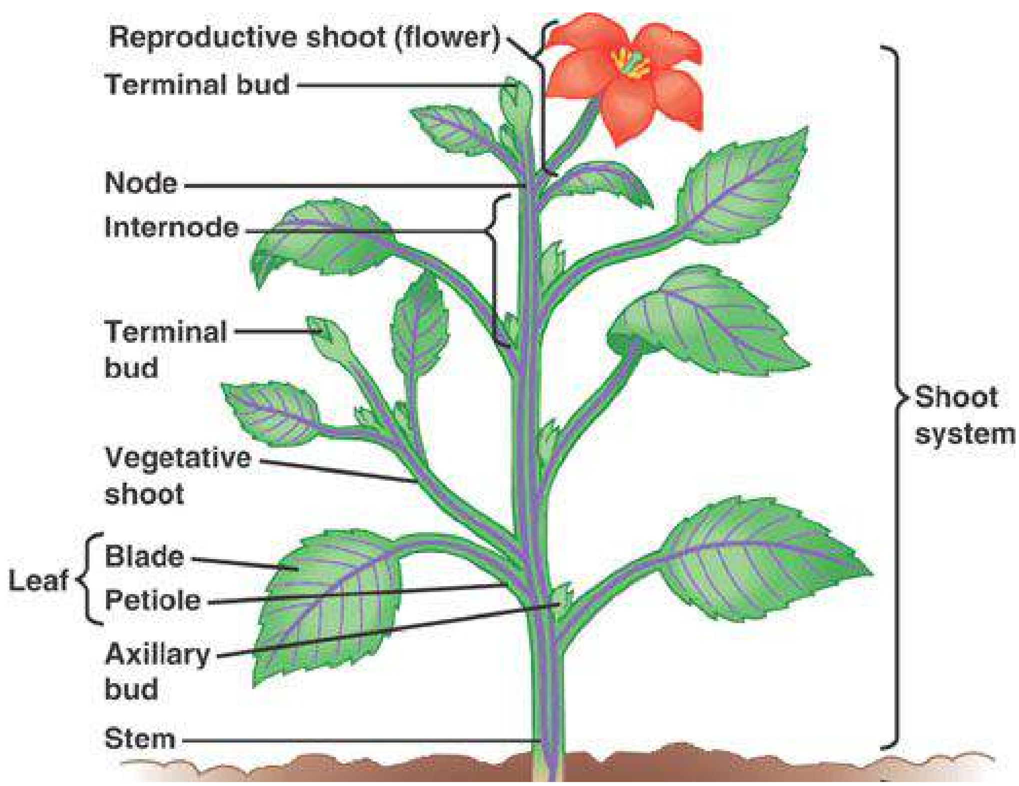
Stage 2: Light Independent Reactions - The Calvin Cycle

- Takes place in the Stroma
- Phase 1 - Fixation of Carbon Dioxide: 3 RbPG sugars (5C molecule) combine with 3 carbon dioxide molecules to form 6 3-PGA molecules (3C molecule), excess oxygen from the carbon dioxide is released into the air, RuBisCo (enzyme) helps in the process
- Phase 2 - Reduction of 3-PGA: 6 ATP and 6 NADPH are added to turn the 6-PGA molecules into 6 G3P (or PGAL) molecules, one is emitted and can be turned into glucose, sucrose, starch...
- Phase 3 - Regeneration of RuBP: 5 G3P continue on in the cycle and transform to 3x a 5C molecule, 6 ATP is added and 3x RuBP sugars are recreated to start again



Unit 28: *Plant Anatomy*



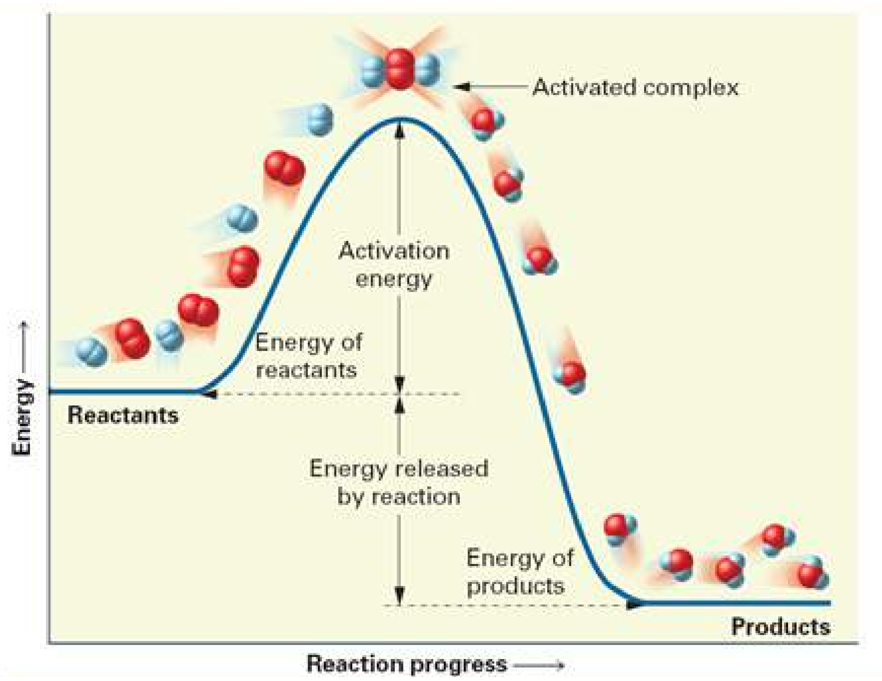


Unit 29: *Energy of Reactions*

Collision Theory

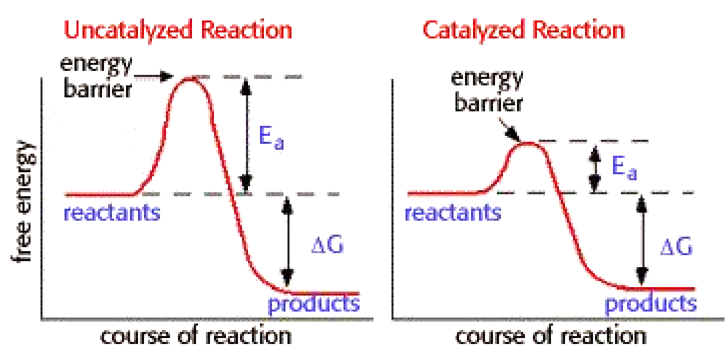
- Reacting molecules have to hit each other with enough energy and in the correct orientation to react and form products
- This is represented by an activation complex, a graph of the amount of energy consumed over the course of the reaction
- Activation energy: the minimum amount of energy needed to react
- Heat acts a product or reactants based on activation energy and endo/exo-thermic
- Endothermic: when heat is absorbed from the surroundings
- Exothermic: when heat is released into the surroundings

Activation Complex



Ways to Speed Up a Reaction

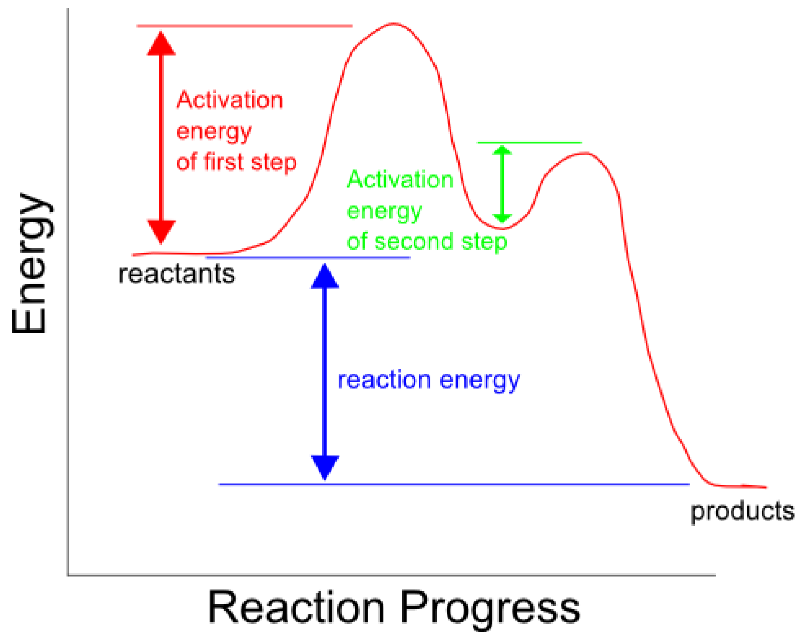
- Add energy (temperature, heat)
- Add a catalyst (lowers the activation energy)
- Increase the concentration (more reactants = higher chance of correct orientation)
- Decrease particle size (increase surface area that hits the other reactants)



Reaction Mechanisms

- Explains the steps of some multi-step reactions
- An intermediate molecule is created and then goes away
- The slowest step is the rate determining step which sets the speed of the reaction (activation energy)

Activation Complex for a Reaction with Two Steps



Reaction Rate

- Enthalpy (ΔH): change in heat (exothermic and endothermic)
- Entropy (ΔS): change in disorder (gas has more than liquid, which has more than solid)
- Enthalpy and entropy determine whether or not a reaction will occur by itself

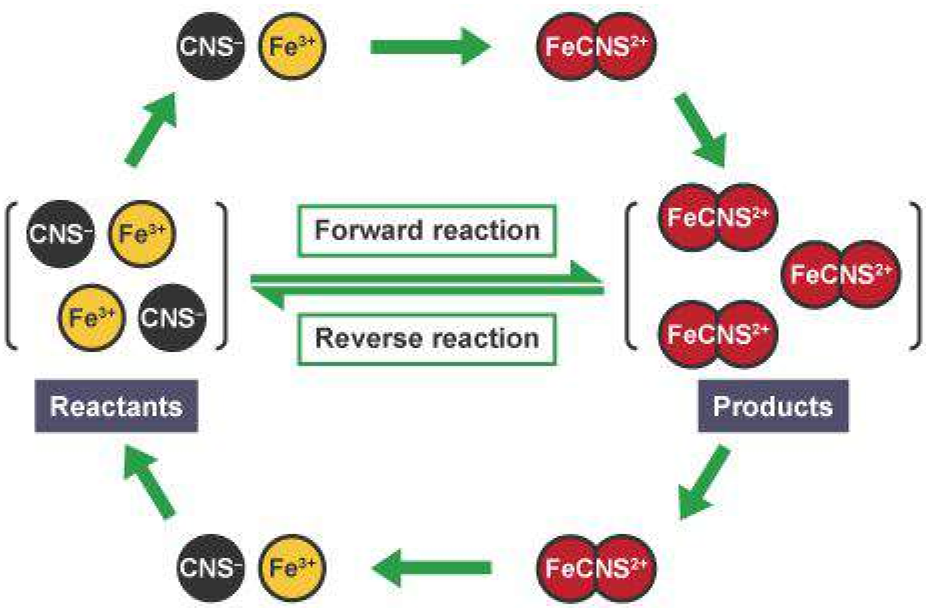
Determining the Reaction Rate

- 0th order: when a change in concentration of a reactant does not affect the reaction rate
- 1st order: when a change in concentration of a reactant is proportional to the change of the reaction rate
- 2nd order: when a change in concentration of a reactant is proportional to the change of the reaction rate squared (i.e. [A] increases by x3, the reaction rate increases/decreases by the concentration's increase squared, 9)
- 3rd order: when a change in concentration of a reactant is proportional to the change of the reaction rate cubed (i.e. [A] increases by x3, the reaction rate increases/decreases by the concentration's increase cubed, 27)

Unit 30: *Equilibrium*

Overview

- Reversible reaction: when the reactants and products can react to form the other
- Equilibrium: when the amounts of reactants and products do not change
  - This does not mean there is 50% reactants and 50% products
  - They have not stopped reacting, they just occur at the same rate and so there is no visible change in amounts of each substance



Le Chatelier's Principle

When a chemical system at equilibrium is disturbed, the system shifts in the direction that minimizes the disturbance, a new equilibrium is formed when stress is applied

Changes and Results

- Reaction shifts away from a side whose concentration increases, towards a decrease
- For gases, a decrease in volume (or increase in pressure) causes the reaction to shift to the side with fewer moles, an increase goes to the side with more moles
- Temperature changes:

Reaction	Exothermic	Endothermic
Temp increase	Left	Right
Temp decrease	Right	Left

In other words: an increase shifts away from the heat, decrease shifts towards it (assuming the heat as a reactant or product in the endo/exo reaction)

Equilibrium Constant (Keq)
Compares the concentration of products to the concentration of reactants

Finding Keq
Products over reactants, to the power of the coefficient
Liquids and solids are left out when finding Keq because their concentrations do not change
[x] = the concentration of element x, which is molarity (moles/liter)

$$aA + bB \rightleftharpoons cC + dD \qquad K_{eq} = \frac{\overbrace{[C]^c\,[D]^d}^{\text{Products}}}{\underbrace{[A]^a\,[B]^b}_{\text{Reactants}}}$$

Example:

$$\boxed{2}\,N_2O_5(g) \rightleftharpoons \boxed{4}\,NO_2(g) + \boxed{\ }\,O_2(g)$$

$$K_{eq} = \frac{[NO_2]^{\boxed{4}}\,[O_2]^{\overset{\text{Implied 1}}{\boxed{\ }}}}{[N_2O_5]^{\boxed{2}}}$$

What can be Determined from Keq
- If Keq << 1, there is much more reactants than products, reverse reaction is favored
- If Keq ≈ 1, there is a similar amount of reactants as products, no direction is favored
- If Keq >> 1, there is much more products than reactants, forward reaction is favored

53. Consider the reaction.

$$2\,H_2S(g) \rightleftharpoons 2\,H_2(g) + S_2(g)$$

An equilibrium mixture of this reaction at a certain temperature has $[H_2S] = 0.562$ M, $[H_2] = 2.74 \times 10^{-2}$ M, and $[S_2] = 7.54 \times 10^{-3}$ M. What is the value of the equilibrium constant at this temperature?

$$K_{eq} = \frac{[H_2]^2\,[S_2]}{[H_2S]^2} = \frac{[2.74\times10^{-2}]^2 \cdot [7.54\times10^{-3}]}{[0.562]^2}$$

$$= 1.8\times10^{-5}$$

Solubility Product Constant (Ksp)
Concentration of the products at equilibrium (Keq without the reactants)

Example:

$$Ca_3(PO_4)_{2(s)} \rightleftharpoons 3\,Ca^{2+}_{(aq)} + 2\,PO^{3-}_{4(aq)} \qquad K_{sp} = [Ca^{2+}_{(aq)}]^3[PO^{3-}_{4(aq)}]^2$$

Solving Ksp Problems

Calculate the molar solubility of $BaSO_4$.	
SOLUTION Begin by writing the reaction by which solid $BaSO_4$ dissolves into its constituent aqueous ions.	$BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$
Next, write the expression for K_{sp}.	$K_{sp} = [Ba^{2+}][SO_4^{2-}]$
Define the molar solubility (S) as $[Ba^{2+}]$ or $[SO_4^{2-}]$ at equilibrium.	$S = [Ba^{2+}] = [SO_4^{2-}]$
Substitute S into the equilibrium expression and solve for it.	$K_{sp} = [Ba^{2+}][SO_4^{2-}] = S \times S = S^2$ Therefore $S = \sqrt{K_{sp}}$
Finally, look up the value of K_{sp} in Table 15.2 and calculate S. The molar solubility of $BaSO_4$ is 1.03×10^{-5} mol/L.	$S = \sqrt{K_{sp}} = \sqrt{1.07 \times 10^{-10}} = 1.03 \times 10^{-5}$ M

Non-Equilibrium Concentration Comparison

Use Q, instead of Keq, when doing the same equation as Keq, but not at equilibrium

- If Q > Ksp, precipitate will (should) form
- If Q = Ksp, solution is saturated
- If Q < Ksp, precipitate cannot form

Example Problem:

100. If 50.0 mg of Na_2CO_3 are added to 150.0 mL of a solution that is 1.5×10^{-3} M in Mg^{2+}, will any $MgCO_3$ precipitate from the solution?

$$Mg^{2+} + Na_2CO_3 \rightarrow MgCO_3(s) + 2Na^+$$

Mg^{2+}: 1.5×10^{-3} M, 150 ml; Na_2CO_3: 0.05 g

$$\frac{0.05\,g}{105.988\,g} = 0.000472\ mol = 4.72 \times 10^{-4}\ mol$$

$$0.000472\ mol \cdot 2 = \frac{0.000944\ mol\ Na^+}{0.15\ L} = 0.00629\ M$$

$$Q = \frac{4.72 \times 10^{-4} \cdot 1.5 \times 10^{-3}}{0.00629} = 0.000113$$

$K_{sp} = 6.82 \times 10^{-6}$

$K_{sp} < Q$

No precipitate