Chapter 1: Introduction

Bio is the study of living organisms and their interactions with each other and their environments.

Unifying Elements

- Evolution (the core theme of bio)
- Emergent Properties: result from the arrangement and interaction of parts within a system
    - Atoms → molecules → cells → tissues → organs → organ systems → organisms

Structure and Function

- Prokaryotic (no nucleus) and eukaryotic (nucleus)
    - No organelles
    - Organelles
- Basic features of cells
    - Plasma membrane, DNA/chromosomes, Cytosol/cytoplasm, Ribosomes
- 4 types of eukaryotic cells
    - Protist, fungi, plant, and animal

DNA Structure and Function

- A DNA molecule holds hundreds or thousands of genes, each a stretch of DNA along the chromosome
- Gene expression is the process of converting info from gene to cellular product (protein or RNA)
- ***Genes*** are the units of inheritance that transmit info from parents to offspring
- As cells grow and divide, the genetic info encoded by DNA directs their development. Genes encode for proteins and some types of RNA.

Genomics: Large-Scale Analysis of DNA Sequences

- An organism's ***genome*** is its entire set of genetic instructions
- The human genome and the genomes of many other organisms have been sequenced using DNA-sequencing machines
- ***Genomics*** is the study of sets of genes within and between species

Genetic Code is Universal

- Genetic code relates nucleotide triplets (codons) to amino acids.

All living organisms require energy to perform metabolic functions

Chapter 2: Chemical Foundations of Life

Tues 3-3:50pm jpl SR#4 Thurs 12-12:50pm jpl SR#7 Office hour wed 10-11am

Weak Bonds = Non-covalent bonds

- Ionic bonds
- Hydrogen bonds
- Hydrophobic bonds
- Van der Waals interactions

Ionic Bonds

- Atoms sometimes strip electrons from their bonding partners
- These bonds usually form between a metal and non-metal
- After the transfer of an electron, both atoms have charges
- Both atoms also have complete valence shells
- A ***cation*** is a positively charged ion
- An ***anion*** is a negatively charged ion
- An ***ionic bond*** is an attraction between an anion and a cation
- Compounds formed by ionic bonds are called ***ionic compounds or salts***

Hydrogen Bonds

- Forms when a hydrogen atom covalently that's bonded to one electronegative atom is also attracted to another electronegative atom (usually oxygen or nitrogen)
- ***Water molecules are polar, with the oxygen region having a partial negative charge and the hydrogen region a slight positive charge.***

Van der Waals Interactions

- Attractions b/w molecules that are close together
- Electrons are distributed asymmetrically in molecules or atoms
- Can result in hot spots of pos or neg charge (dipole)

Hydrophobic Interactions

- The property that non-polar molecules tend to form aggregates of like molecules in water
- Form b/w hydrophobic groups

Chemical reactions make and break chemical bonds

- ***Chem reactions*** are the making and breaking of chemical bonds
- The starting molecules of a chemical reaction are called ***reactants***
- The final molecules of a chemical reaction are called ***products***
- $H_2 + O_2 \rightarrow H_2O$
  [reactant] [product]

4 Emergent Properties of Water Contribute to Earth's Suitability for Life

- Cohesive behavior
- Ability to moderate temp
- Expansion upon freezing
- Versatility as a solvent

Cohesion of Water Molecules

- Water molecules are linked by multiple hydrogen bonds
- Water molecules stay close together because of this; it is called ***cohesion***

- Cohesion due to hydrogen bonding contributes to the transport of water and nutrients against gravity in plants
- ***Adhesion,*** the clininging of one substance to another, also plays a role

High Heat Capacity of Water

- Water has a high specific heat capacity
- The ***heat capacity*** is the amount of heat required to raise the temp of an object or substance one degree
- Water's high specific heat capacity can be traced to hydrogen bonding
    - Heat is absorbed when hydrogen bonds break
    - Heat is released when hydrogen bonds form

Water as a Solvent

- Ions and polar molecules can readily dissolve in water because it is polar.
- Polar = Hydrophilic
- Non-polar = Hydrophobic

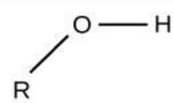
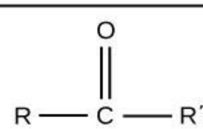
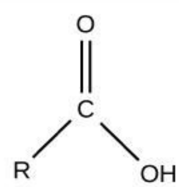
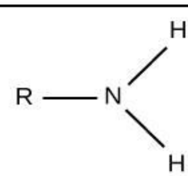
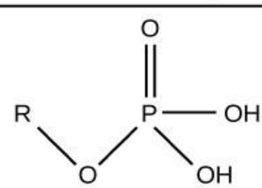
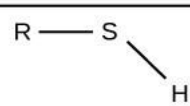
Acids and Bases

- Sometimes a ***hydrogen ion*** is transferred from one water molecule to another, leaving behind a ***hydroxide ion***
- The proton binds to the other water molecule, forming a ***hydronium ion***
- Solutes called acids and bases disrupt the balance between H+ and OH- in pure water
- ***Acids*** increase the H+ concentration in water, while ***bases*** reduce the concentration of H+
- An **acid** is any substance that increases the H+ concentration of a solution
- A **base** is any substance that reduces the H+ concentration of a solution (or increases the OH-)
- Acidic solutions have a pH less than 7
- Basic solutions have a pH greater than 7
- Most biological fluids have pH values in the range ***of 6-8***
    - Each pH unit represents 10 fold difference in H+ and OH- concentrations.
    - ***A solution with pH of is 10x more acidic than the one with pH of 6 and 1000x more acidic than pH of 8.***

Chapter 3: Biological Macromolecules

The chemical groups most important to life

- Functional groups are the components of organic molecules that are most commonly involved in chemical reactions
- The number and arrangement of functional groups give each molecule its unique properties
- The **7 functional groups** that are most important in the chemistry of life:
  - Hydroxyl group - OH
  - Carbonyl group - CO
  - Carboxyl group - COOH
  - Amino group - NH2
  - Sulfhydryl group - SH
  - Phosphate group - PO3
  - Methyl group - CH3

Functional Group	Structure	Properties
Hydroxyl		Polar
Methyl		Nonpolar
Carbonyl		Polar
Carboxyl		Charged, ionizes to release H^+. Since carboxyl groups can release H^+ ions into solution, they are considered acidic.
Amino		Charged, accepts H^+ to form NH_3^+. Since amino groups can remove H^+ from solution, they are considered basic.
Phosphate		Charged, ionizes to release H^+. Since phosphate groups can release H^+ ions into solution, they are considered acidic.
Sulfhydryl		Polar

Macromolecules are polymers, they are built from subunits called monomers
- A ***polymer*** is a long molecule consisting of many similar building blocks
- These small building block molecules are called ***monomers***
- Some molecules that serve as monomers also have functions of their own

The Synthesis and Breakdown of Polymers
- <u>Cells make and break down polymers by the same process</u>
- A ***dehydration reaction*** occurs when 2+ monomers bond together through the loss of a water molecule
- Polymers are disassembled to monomers by ***hydrolysis***, a reaction that is essentially the reverse of the dehydration reaction
- These processes are facilitated by ***enzymes***, which speed up chemical reactions

Carbs serve as fuel and building material
- ***Carbohydrates*** include sugars and the polymers of sugars
- The simplest carbohydrates are ***monosaccharides***, or simple sugars
- Carbohydrate macromolecules are polysaccharides, polymers composed of many sugar building blocks.

Sugars
- ***Monosaccharides*** have molecular formulas that are usually multiples of CH_2O
- ***Glucose*** is the most common monosaccharide
- Monosaccharides are classified by the number of carbons in the carbon skeleton and the placement of the carbonyl group

A ***disaccharide*** is formed when a dehydration reaction joins two monosaccharides. This covalent bond is called a ***glycosidic linkage***.
Sucrose is formed when a monomer of glucose and a monomer of fructose are joined in a dehydration reaction to form a glycosidic bond.

Polysaccharides
- ***Polysaccharides***, the polymers of sugars, have storage and structural roles
- The structure and function of a polysaccharide are determined by its sugar monomers and the positions of glycosidic linkages
- There are 2 types
    - ***Storage***
    - ***Structural***

Storage Polysaccharides
- ***Starch,*** a storage polysaccharide of plants, consists entirely of glucose monomers
- Plants store surplus starch as granules
- The simplest form of starch is ***amylose***
- ***Glycogen*** is a storage polysaccharide in animals
- Humans and other vertebrates store glycogen mainly in ***liver and muscle cells.***

Structural Polysaccharides
- ***Cellulose*** is a structural polysaccharide found in plant cell walls
- <u>Cellulose in human food passes through the digestive tract as insoluble fiber</u>

- Some microbes use enzymes to digest cellulose
- ***Chitin*** is found in the exoskeleton of arthopods and also provides support for fungi cell walls

Lipids are a Diverse Group of Hydrophobic Molecules

- **Lipids** do not form true polymers
- The unifying feature of lipids is having little or no affintiy for water (**hydrophobic and non polar**)
- The most biologically important lipids are ***fats, phospholipids, and steroids***

Fats

- ***Fats*** are constructed from 2 types of smaller molecules: ***glycerol and fatty acids***
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon
- A ***fatty acid*** consists of a carboxyl group attached to a long carbon skeleton

Hydrocarbons are organic molecules consisting of only carbon and hydrogen.
In a fat, 3 fatty acids join to glycerol by ester linkage to create a **triacylglycerol** (triglyceride)

Fatty acids vary in length and in number/locations of double bonds

- ***Saturated fatty acids*** have hydrocarbon chains connected by single bonds only. Solid at room temp.
- ***Unsaturated fatty acids*** have 1+ double bonds. Each bond may be in a cis or trans config. Liquid at room temp.
  - In cis, both hydrogens are on the same side of the chain. This causes a kink in the chain.
  - In trans, the hydrogens are on opposite sides of the chain.

Phospholipids

- In a ***phospholipid***, 2 fatty acids and a phosphate group are attached to glycerol.
- The 2 tails are hydrophobic, but the phosphate and its attachments form a hydrophilic head.
- ***Phospholipids are major constituents of cell membranes.***
- The phosphate may be changed by the addition of charged or polar chem groups.
- When phospholipids are ***added to water,*** they self assemble into a ***bilayer***, with the tails pointing inside.
- This feature of phospholipids results in the bilayer arrangement found in cell membranes

Steroids

- ***Steroids*** are lipids characterized by a ***carbon skeleton consisting of four fused rings***
- ***Cholesterol*** is a component in animal cell membranes
- Rings make the molecule very rigid

In membranes, the molecule is oriented parallel to the fatty acid chains of the phospholipids, and the hydroxyl group interacts with the nearby phospholipid head groups. Cholesterol is absent from the prokaryotes but is found to varying degrees in almost all animal membranes, making up almost 25% of the membrane lipids in certain nerve cells but is absent from some intracellular membranes.

Proteins

- ***Proteins*** account for more than 50% if the dry mass of most cells
- Protein functions include ***defense, storage, transport, cellular communication, movement, and structural support***
- **Slide 34 table**

Amino Acids are the monomers for proteins

- ***Amino acids*** are organic molecules with carboxyl and amino groups. They are <u>monomers.</u>
- Amino acids differ in properties due to differing side chains (***R groups***)
  - <u>4 classes: Non-polar, polar, + charge, and - charge</u>
- MEMORIZE SLIDE 36 - write names of amino acids and abbreviations, pay attention to Glycine (simplest amino acid) and Cysteine

Polypeptides

- Amino acids are linked by peptide bonds
- A polypeptide is a polymer of amino acids
- Polypeptides range in length from a few to 1k+ monomers
- Each polypeptide has a unique linear sequence of amino acids with a <u>carboxyl end (c-terminus) and an amino acid end (n-terminus)</u>
- Table to memorize
  - Large mol. | Monomers | Funct. Group | Covalent bond |
  - Protein a.a NH2 / COO- Peptide

Protein Structure and Function

- A functional protein consists of 1+ polypeptides precisely twisted, folded, and coiled into a unique shape
- The sequence of amino acids, determined genetically, leads to a protein's 3D structure
  - Aa1 aa2 aa3 aa4 aa5
  - ---|--------|-------|------|-----|----
  - Np p np p np
- A protein's structure determines its function
- <u>Proteins are initially built as a chain (synthesized) in the ribosomes then fold and become a protein</u>

4 Organizational Levels of Protein Structure

- The ***primary structure*** of a protein is its unique sequence of amino acids = Linear polypeptide chain
  - Stabilized by peptide bonds
- ***Secondary structure***, found in most proteins, consists of coils and folds in the polypeptide chain = local folding
  - <u>H-bonds form between the H- and O in the backbone between different amino acids not between R-chains</u>
  - Stabilized by H bonding b/w groups along peptide-bonded backbone
  - Can fold in 2 ways

        - Spiral (helix)
        - Pleats
    - If you have helix or pleat formation, than the amino acids will associate with each other via backbone components (functional groups of opposing/antagonistic amino acids)
    - <u>Positives attracting negatives are electrostatic bonds</u>
- ***Tertiary structure*** is determined by interactions among various a.a side chains (R groups)
    - Stabilized by bonds and interactions b/w R groups and peptide-bonded backbone
        - <u>Bond types are Hydrogen, Ionic, and Disulphide. Also, hydrophobic interactions.</u>
    - When your polypeptide chain achieves final 3D structure shape conformation
    - Possibility of activity
- ***Quaternary structure*** results from interactions between multiple polypeptide chains
    - The combination of 2+ tertiary units
    - Is stabilized by the same interactions found in tertiary structures
    - Quaternary structure of hemoglobin is made up of 2 alpha (yellow) and 2 beta (green) chains. The heme group in each subunit picks up O2 for transport in blood to the tissues

Sickle-Cell Disease
- The 6th Glycine in the polypeptide chain is changed to Valine (or the T and A are swapped?)
- Tissues are deprived of oxygen
- Developed as a response to malaria

What Determines Protein Structure?
- ***Alterations in pH, salt, temp, etc can cause a protein to unravel***
- This loss of a protein's native structure is called ***denaturation***
- A denatured protein is biologically inactive. This is the reversal of folding

Nucleic acids store, transmit, and help express hereditary information
- The amino acid sequence of a polypeptide is programmed by a unit of inheritance called a ***gene***
- Genes are made of DNA, a ***nucleic acid*** made of monomers called **nucleotide**

The Roles of Nucleic Acids
- 2 types
    - Deoxyribonucleic acid (DNA) - always double stranded
    - Ribonucleic acid (RNA) - always single stranded
        - mRNA determines amino acid sequence in polypeptide chain
- DNA provides direction for its own replication
- DNA directs synthesis of mRNA and <u>controls protein synthesis through that</u>

The Components of Nucleic Acids
- Nucleic acids are polymers called ***polynucleotides***
- Each polynucleotide is made of monomers called ***nucleotides***

- <u>Each nucleotide consists of a nitrogenous base (ATCGU), a pentose sugar, and 1+ phosphate groups</u>
- The portion of a nucleotide w/o the phosphate group is called a nucleotide

A prime(') is used to identify the carbon atoms in the ribose such as the 2' carbon

- Know the structure of phosphate group + sugar + nitrogenous base
- If you have a hydrogen, it is a deoxyribonucleotide
- Slide 51 - ask someone to explain

Nitrogenous Bases

- Purines: Adenine (A) and guanine (G)
- Pyrimidines: Cytosine (C) Thymine (T in DNA) and Uracil (U in RNA)

The sugar in DNA is ***deoxyribose***, and in RNA it's ***ribose***

Nucleotide Polymers-Phosphodiester Bonds

- Adjacent nucleotides joined by covalent bonds are called ***phosphodiester bonds*** that form between the OH group and the Phosphate

The structures of DNA and RNA Molecules

- DNA molecules form a ***double helix in an antiparallel arrangement***
- RNA molecules form single chains

Complementary Base Pairing

- The nitrogenous bases in DNA pair up and form *hydrogen bonds: adenine (A) with thymine (T), and guanine (G) with cytosine (C)*
- A=T C=G → number of bonds
- This is called ***complementary base pairing***
- <u>This can also occur between 2 RNA molecules or between parts of the same molecule. There are x=several types of RNA (rRNA, tRNA, mRNA, etc.)</u>
- In RNA, ***thymine is replaced with uracil***, so A=U.

To study:

- Memorize slides
- Write down in notebook in own words
- Save for final
- 25min, 5-10 break
- Learning objectives
- If you can say it out loud, you know it
- Amino acids are: Polar, nonpolar, positively charged, negatively charged, acid?
- Don't need to know what amino acid belongs to which group or chemical structures of amino acids

Chapter 4: Cell Structure

Eukaryotic cells have membrane-bound organelles with specific functions

- The basic structural and functional unit of every organism is one of two types of cells: prokaryotic or eukaryotic
- Organisms of the ***domains Bacteria and Archaea consist of prokaryotic cells***
- Protists, fungi, animals, and plants all consist of ***eukaryotic*** cells

Comparing Prokaryotic and Eukaryotic Cells

- Basic features of all cells
    - Plasma membrane
    - Semifluid substance called cytosol / cytoplasm
    - DNA or chromosomes
    - RIbosomes

Prokaryotic Cells are characterized by having:

- ***No nucleus***
- DNA in an unbound region called the ***nucleoid***
- ***No membrane-bound organelles***
- ***Cytoplasm*** bound by the plasma membrane

Eukaryotic Cells are characterized by having:

- ***DNA in a nucleus*** that is bound by a membranous nuclear envelope
- ***Membrane-bound organelles***
- Cytoplasm in the region between the plasma membrane and nucleus
- Eukaryotic cells are generally much larger than prokaryotic cells

The ***plasma membrane*** is a selective barrier that allows sufficient passage of oxygen, nutrients, and waste to service the volume of every cell

The general structure of a biological membrane is a ***double layer of phospholipids*** with proteins and cholesterol embedded in it.

A panoramic view of the eukaryotic cell:

- ***A eukaryotic cell has internal membranes that divide the cell into compartments - organelles***
- The plasma membrane and organelle membranes participate directly in the cell's metabolism.

MEMORIZE SLIDES 10 and 11

The Nucleus: Information Central

- The ***nucleus*** contains most of the cell's genes and is usually the most conspicuous organelle
- The ***nuclear envelope*** encloses the nucleus, separating it from the cytoplasm
- The nuclear membrane is a ***double membrane***; each membrane consists of a lipid bilayer
- ***Pores*** regulate the entry and exit of molecules from the nucleus

- The shape of the nucleus is maintained by ***the nuclear lamina***, which is composed of protein (<u>**histones**</u>)
- In the nucleus, DNA is organized into discrete units called ***chromosomes***
- Each chromosome is one long DNA molecule associated with proteins
    - We have 23 pairs of chromosomes
- The DNA and proteins of chromosomes are together called ***chromatin***
- Chromatin <u>condenses to form discrete chromosomes</u> as a cell prepares to divide
- The ***nucleolus*** is located within the nucleus and is <u>the site of ribosomal RNA (rRNA) synthesis,</u> (2% of the genes, which are special and make RNA).
    - Usually the nucleolus is the site where mRNA goes through translation and spits out polypeptide chain
- The mRNA provides the code for the sequence (grey pearl, white pearl, etc).

Ribosomes: Protein Factories

- Ribosomes are complexes of ribosomal RNA and protein
    - Ribosomal proteins are the brick, rRNA is the mortar
- There are 2 types
    - ***Free ribosomes*** found in cytosol
    - ***Attached or bound ribosomes*** found in the outside of the endoplasmic reticulum or the nuclear envelope (bound ribosomes)
- ***DNA polymerases are enzymes (proteins) that get synthesized in cytoplasm***

The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- Components of the system:
    - Nuclear envelope
    - ER
    - Golgi apparatus
    - Lysosomes
    - Vacuoles
    - Plasma Membrane
- These are either continuous or connected through transfer by ***vesicles***

ER: Biosynthetic Factor

- The ***ER*** accounts for more than half other total membrane in eukaryotic cells
- Continuous with the nuclear envelope
- 2 types of ER
- Smooth: no ribosomes
    - <u>Synthesizes lipids</u>
    - <u>Metabolizes carbohydrates</u>
    - <u>Detoxifies drugs and poisons (found in liver)</u>
    - <u>Stores calcium ions</u>
- Rough: ribosomes
    - <u>Polypeptide chains folded into proteins</u>
    - <u>Proteins modified</u>
    - Distributes ***transport vesicles***, protein encapsulated by membranes to the golgi

    - Is a <u>membrane factory</u> for the cell <u>(synthesizes phospholipids and incorporates these with proteins to its own membrane to be used later by other organelles)</u>

The Golgi apparatus: shipping and receiving center

- The ***Golgi apparatus*** consists of flattened membranous sacs called cisternae
- Functions of the Golgi apparatus
    - <u>Modifies products of ER</u>
    - <u>Manufactures macromolecules like polysaccharides</u>
    - <u>Sorts and packages materials (proteins into transport vesicles</u>

Lysosomes: Digestive Compartments

- Digest extracellular protein
- A ***lysosome*** is a membranous sac of hydrolytic enzymes that can digest macromolecules
- Lysosomal enzymes can ***hydrolyze*** proteins, fats, polysaccharides, and nucleic acids
- Lysosomal enzymes work best in the acidic environment inside the lysosome, with a ***pH of 5.***
- Some types of cell can engulf another cell using ***phagocytosis***, which forms a food vacuole
- <u>Plants don't have lysosomes, they do digestive work in central vacuole</u>
- A lysosome fuses with the food vacuole to digest the molecules
- <u>Lysosomes also use enzymes to recycle the cell's own organelles and macromolecules,</u> a process called ***autophagy***

Vacuoles: Diverse Maintenance Compartments

- ***Vacuoles*** are large vesicles derived from the endoplasmic reticulum and Golgi apparatus
- The ***plant central vacuole*** can occupy up to 80% of the cell's interior. It stores water and nutrients.

Mitochondria and Chloroplasts fuck with energy and it changes forms

- ***Mitochondria*** is the site of cellular respiration, a process that uses oxygen to generate ATP (powerhouse of the cell!)
    - <u>Mitochondrial DNA is only passed down from your mother</u>
- ***Chloroplasts*** (in plants and algae) are the sites of photosynthesis
    - Found in leaves and green organs of plants
    - Contain chlorophyll
    - ***Thylakoids, membranous sacs, stacked to form a granum. Stroma is the internal fluid.***
- Both are similar to bacteria (prokaryotic origins)
    - <u>Enveloped by double membrane</u>
    - <u>Contain free small sized ribosomes</u>
    - <u>Contain circular DNA</u>
    - <u>Grow and reproduce somewhat independently in cells</u>

- **Endosymbiotic Theory**
    - Early ancestor of eukaryotic cells engulfed a non-photosynthetic prokaryotic cell, forming an endosymbiotic relationship with host
    - Host cell and endosymbiont merged into single organism (eukaryotic cell with a mitochondrion)
    - One of these cells may have taken up a photosynthetic prokaryote, becoming the ancestor of cells that contain chloroplasts
    - Eukaryotes have linear DNA, and prokaryotes have circular DNA
    - **Cyanobacteria - photosynthetic. Engulfed by eukaryotic cell**

Mitochondria: Chemical Energy Production

- Mitochondria are in all eukaryotic cells
- **Cristae**: folded smooth outer/inner membrane
- The inner membrane creates 2 compartments
    - Intermembrane space
    - **Mitochondrial matrix**
- Some metabolic steps of cellular respiration are catalyzed in the mitochondrial matrix
- Cristae present a large surface area for enzymes that synthesize ATP

Peroxisomes: Oxidation

- ***Peroxisomes*** are specialized metabolic compartments bounded by a single membrane
- They produce H2O2 and convert it to water

Proteasomes

- Digest erroneous intracellular proteins

Cytoskeleton

- Network of fibers extending throughout the cytoplasm
- Organizes the cell's structures and activities, anchoring many organelles
- 3 main types of fibers
    - ***Microtubules*** - the thickest of the three
    - ***Microfilaments (or actin filaments)*** are the thinnest
    - I***ntermediate filaments*** are fibers with diameters in a middle range

Microtubules, Centrosomes, and Centrioles

- Microtubules - hollow rods constructed from globular protein dimers called tubulin
- Functions
    - ***Shape and support the cell***
    - ***Guide movement of organelles and vesicles***
    - ***Separate chromosomes during cell division (mitotic spindle)***
- In anime cells, microtubules grow from a **Centrosome**
    - A centrosome is 2 centrioles
- Microtubules control the beating of **cilia** and **flagella**
    - Flagella are limited to one or a few per cell
    - Cilia occur in large numbers
    - They differ in their beating patterns
    - A motor protein called ***dynein*** drives the bending movements
- Microfilaments

    - Thin, solid rods made of actin
    - Structural role - bear tension, resisting pulling forces
    - Interact with motor protein, myosin
    - Actin + Myosin cause muscle contraction, amoeboid movement of wbcs, and cytoplasmic streaming in cells
        - ***Myosin always means Muscle***
- Intermediate Filaments
    - Support cell shape / fix organelles

Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by ECM
- The ECM is made of ***glycoproteins such as <u>collagen</u>, proteoglycans, and <u>fibronectins</u>***
- ECM proteins bind to receptor proteins in the plasma membrane called ***integrins***

Cell Junctions

- There are several types of intercellular junctions that facilitate the adherence, interactions, and communication through in cells
    - **Plasmodesmata**
        - Channels that perforate plant cell walls
        - Water and small solutes (proteins, RNA) can pass through
    - **Tight**
        - **Desmosomes**
        - Made from proteins called cadherins
    - **Gap**
        - Made from proteins called connexins
- Tight, desmosomes, and gap
    - Found in animal cells
    - Common in epithelial tissues

Chapter 5: Membrane Transport and Cell Signaling

Fluid Mosaic Model

- Membrane structure contains proteins and cholesterol
- Amphipathic structures
    - Membrane phospholipids
    - Integral proteins
- Amphiphilic structures
    -
- ***Apoptosis:*** Cell death, serene group tied to amino acids on phospholipids
- ***Fluidity:*** Lipids and proteins can shift around laterally and rotate, but don't flip flop. The unsaturated phospholipids tail contributes to fluidity.
- <u>Cell membranes are asymmetrical because they face different directions and perform different functions.</u>
- Steroid cholesterol maintains fluidity
    - Warm temperatures: restrains phospholipid movement
    - Cool temperatures: prevents tight packing
- Fluidity of phospholipid bilayer is increased by double bonds between carbon atoms in the fatty acid tails

6 Major Functions of Membrane Proteins

- Transport
- Enzymatic activity
- Attachment to ECM/Cytoskeleton
- Cell to Cell recognition
- Intercellular joining
- Signal transduction

Peripheral Proteins

- Bound to surface of membrane loosely

Hydrophobic Amino Acids

- Line the exterior of the protein

Lipid Bilayer Permeability

- Hydrophobic molecules dissolve in lipid bilayer and cross over easily
- Polar molecules (sugar) can not cross over easily
- <u>Sex hormones, vitamin D, and thyroid hormones can cross over easily</u>
- Large, polar molecules and ions <u>can not cross</u> over at all.

Diffusion: movement of a solute and solvent from higher to lower concentration

- Tonicity
    - Hypo, hyper, isotonic
- Osmosis
    - Diffusion of water

Facilitated Diffusion

- ***In facilitated diffusion:*** transport proteins speed the passive movement of molecules across plasma membrane to allow the passage of hydrophilic substances across the membrane and also play a role in determining the selective permeability of the plasma membrane in addition to the hydrophobic core.

- ***Carrier proteins:*** undergo subtle change in shape to translocate the solute-binding site across the membrane
- ***Channel proteins:*** allow specific molecule/ion to cross membrane
    - Include *aquaporins* for facilitated diffusion of water
    - Include *Ion Channels* to facilitate the diffusion of ions and open/close in response to a stimulus (*gated channels*)

Active Transport

- Uses energy to move solutes against their gradients
    - <u>Some transport proteins (called pumps) can move solutes against their gradients</u>
- ***Primary active transport*** uses ATP energy to transport molecules across the membrane against their gradient. All ATP-powered pumps contain 1+ binding sites for ATP.
    - In the cytosol, the sodium is intracellularly low and the potassium is high, and reversed extracellularly.

Electrochemical Gradient

- Due to the ion gradient, there are less positive ions inside the cell.
- The inside is negative compared to outside, so there is a movement of positive ions into the cell.
- There are 2 forces that drive the ionic diffusion: chemical (concentration gradient) and electrical. Together these forces are the electrochemical gradient.

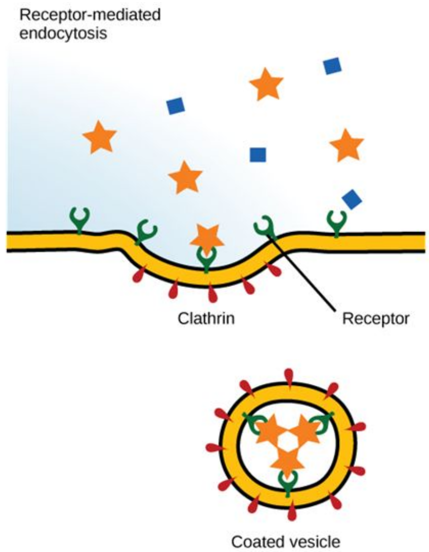
Secondary Active Transport

- <u>The electrochemical gradient can move other substances against their concentration gradients</u> (glucose).
- Co-transport ***(secondary active transport)*** occurs when active transport indirectly drives transports of other solutes.
- <u>***Does not require direct energy from ATP molecule***</u>
- Pump Types
    - ***Symport protein***: Pumps 2 different molecules in the same direction
    - ***Antiport protein***: Carries 2 different molecules in different directions
    - ***Uniport protein***: Carries 1 molecule in 1 direction

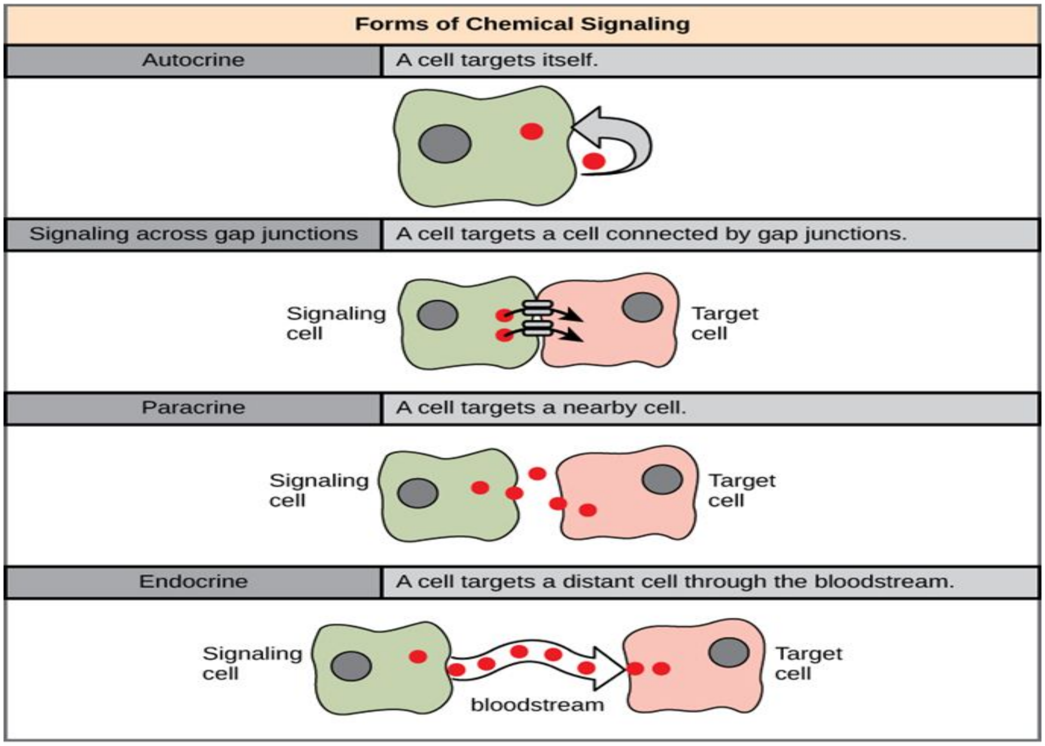
Bulk transport

- Requires energy
- Large molecules cross membrane in bulk through vesicles
- Exocytosis (export)
    - Transport vesicles migrate to the membrane, fuse, and then release their contents
    - Use secretory to export products
- Endocytosis (import)
    - Cell takes in molecules by forming vesicles from plasma membrane
    - Three types

- ***Phagocytosis*** (cell eating)
- ***Pinocytosis*** (cell drinking)
- **Receptor-mediated endocytosis**



Chapter 9: Cell Signaling



Paracrine Signaling

- Messenger molecules are secreted by a signaling cell. The signals elicit quick responses that last a short time. A class of these - ***growth factors*** - stimulates nearby cells to grow and divide (cell division).
- <u>Secreted molecules diffuse locally and trigger a response in neighboring cells</u>

Three Stages of Cell Signaling

- Hear knock on door, relay information “mom get the door”, someone answers the door
- Reception
  - Signaling molecule attaches to receptor on ligand (generally causes a shape change)
  - If the receptors are on the cytosol, it’s called a cytosolic receptor
  - If the receptor are intracellular, the molecule will cross membrane and then bind
    - The molecules should be small and hydrophobic (like sex hormones and thyroid)
  - 2 types of receptors
    - Cell surface
    - Intracellular
- Transduction
  - Relay molecules

    - Message is passed through the relay molecules, starting with one and spreading to more (***amplification***).
- Response
    - Activation

Intracellular Receptors

- Found in cytosol of nucelus or target cells
- Small/hydrophobic chemical messengers can cross membrane and activate receptors
- Examples of hydrophobic messengers are steroid/thyroid hormones of animals and nitric oxide in plants and animals

Protein Kinases transfer phosphates from ATP to protein, a process called phosphorylation

- Dephosphorylation enzyme is Phosphatase

Chapter 6: Metabolism

Metabolism
- The totality of an organism's chemical reactions
- Involves reactions that create energy and ones that use energy

Metabolic Pathways
- Begin with specific molecule and end with a product
- Each step catalyzed by specific enzyme

Catabolic Pathways
- Release energy by breaking down complex molecules into simple compounds
- IE Cellular respiration and ATP synthesis

Anabolic Pathways (anabolism = biosynthesis)
- Consume energy by building complex molecules from simple compounds
- IE protein synthesis from amino acids

Gibbs Free Energy
- The portion of a system's energy that can perform work
- Change in free energy is calculated with Change G = G(final) - G(initial)
- Scientists use this concept to determine which reactions occur spontaneously and which require input of energy

Exergonic Reaction - energy is released
- Proceeds with a net release of free energy and is spontaneous; change of G is negative.
- Magnitude of change represents max amount of work that the reaction can perform.

Endergonic Reaction - energy is added
- Absorbs free energy from surroundings and is nonspontaneous; change of G is positive.
- Magnitude of change represents energy required to drive reaction.

Activation Energy (EA)
- The amount of energy required to initiate a reaction
- During chemical reactions, bonds get rearranged and the molecule gets contorted during breakage. Energy input is required to achieve the contorted state.
- ***Transition state:*** contorted state, high energy, unstable. Only exists at a higher energy state than the reactants, so EA is always positive.

ATP powers cellular work by coupling exergonic to endergonic
- A cell does three types of work
  - Chemical
  - Transport
  - Mechanical
- To do work, cells manage energy resources by energy coupling
- ***Energy coupling:*** The use of an exergonic process to drive an endergonic one
- ***Most energy coupling in cells is mediated by ATP***

Structure/Hydrolysis of ATP
- ATP is the cell's energy shuttle
  - Composed of
    - Ribose

        - Adenine
        - 3 phosphate groups
- The bonds between phosphate groups of the tail can be broken by hydrolysis
- Energy is released from ATP when the terminal phosphate bond is broken
- The release of energy comes from the chemical change to a state of lower free energy
- ATP drives endergonic reactions via phosphorylation, transferring a phosphate group to some other molecule like a reactant
- The recipient molecule is called a ***phosphorylated intermediate***
- The phosphorylated molecule has increased chemical potential energy and is primed to do cellular work

ATP Regeneration

- ATP is renewable and regenerated by addition of phosphate group to ADP
- The energy to phosphorylate ADP comes from catabolic reactions in the cell
- ATP cycle is a revolving door that the energy passes through during the transfer from catabolic to anabolic pathways.
- Cells replace the energy-rich ATP that gets destroyed in energy-coupled reactions by mitochondrial synthesizing of ATP using energy that's released by oxidizing sugars and fats

Catalysts

- The chemical agent that speeds up a reaction without being consumed by the reaction
- An enzyme is a catalytic molecule that is mostly protein
    - Enzymes catalyze reactions *by lowering the EA barrier (activation energy)*, but they don't affect the Free Energy change.

Substrate Specificity of Enzymes

- The reactant that an enzyme acts on is the enzyme's ***substrate***
- The enzyme binds at the active (Catalytic) site, forming the ***enzyme-substrate complex***, which allows the stretching of bonds in the substrates.
- Enzymes change shape due to the chemical reactions with substrate
- The induced fit brings chemical groups of the active site into positions that enhance their ability to catalyze the reaction.
- The site opposite of the active site is the ***allosteric*** (Regulatory) site.

Enzyme Activity Affected By:

- Temperature
- pH
- Chemicals that specifically influence that enzyme (like urea)
- ***These things affect the enzyme activity by changing the shape, disrupting hydrogen/ionic bonds, and disrupting the hydrophobic interactions.***

Coenzyme

- ***Cofactors*** are non-protein enzyme helpers
- Cofactors can be inorganic or organic
- An organic cofactor is called a ***coenzyme*** (like NAD+ or FAD+)
- Coenzymes include vitamins

Enzyme Inhibitors

- ***Competitive inhibitors***: bind to active site of an enzyme, competing with the substrate (reversible)
- ***Noncompetitive inhibitors***: bind to another part of enzyme, change enzyme shape, make the active site less effective (irreversible)
- IE toxins, poisons, pesticides, and antibiotics

Allosteric Regulation of Enzymes

- May either inhibit or stimulate an enzyme's activity
- <u>Allosteric regulation occurs when a regulatory molecule binds to a protein at one site and affects the protein's function at another site</u>
- Most allosterically regulated enzymes are made from polypeptide subunits (quaternary structures)
- When the activator binds to the regulatory site, it stabilizes the active form of the enzyme
- The inhibitory binding stabilizes the inactive enzyme form
- ***Cooperativity*** is a form of allosteric regulation that can amplify enzyme activity
  - Allosteric because binding of a substrate to the active site increases binding of other substrates to other active sites

Feedback Regulation

- In ***negative feedback regulation***, the metabolic end product shuts down the pathway and prevents a cell from wasting chem resources by synthesizing more product than needed
  - Reaction A produces products that start Reaction B and so on
- In ***positive feedback regulation***, the product stimulates its own formation
  - The products act as allosteric activators and push the reaction forward

Specific locations of enzymes within the cell

- Some enzymes act as structural components of membranes
- In Eukaryotic cells, some enzymes reside in organelles
  - <u>Enzymes for cellular respiration are located in mitochondria</u>

Chapter 7: Cellular Respiration and Fermentation

Energy
- Flows into an ecosystem as sunlight and leaves as heat
- Photosynthesis generates O2 and organic molecules, which are used as fuel for cellular respiration

Catabolic Pathways and Production of ATP Cellular Respiration
- ***Cellular respiration transforms the chemical bond energy of organic molecules to the chemical bond energy of ATP***
- Key biochemical pathways of cellular respiration has
    - ***Glycolysis***
    - ***Pyruvate oxidation***
    - ***Citric Acid Cycle***
    - ***Oxidative phosphorylation***
- These three biochemical pathways are a series of oxidation-reduction reactions

Redox Reactions: Oxidation and Reduction
- <u>The transfer of electrons during chemical reactions releases energy stored in organic molecules</u>
- This released energy is ultimately used to ***synthesize ATP***
- Chemical reactions that transfer electrons between reactants are called oxidation-reduction reactions

Oxidation of Organic Fuel Molecules During Cellular Respiration
- <u>Organic molecules with an abundance of hydrogen, like carbohydrates and fats, are excellent fuels</u>
- <u>As hydrogen is transferred to oxygen, energy is released that can be used in ATP synthesis</u>
- During cellular respiration, ***the fuel is oxidized and O2 is reduced***
- Redox reactions that move electrons closer to electronegative atoms like oxygen release chemical energy that can be put to work

Electron Carriers
- Electrons from organic compounds are usually first transferred to NAD+ (coenzyme)
- <u>NAD+ and FAD+ are derived from Vitamin B</u>
- NADH represents stored energy that is tapped to synthesize ATP
- NADH passes electrons to electron transport chain
- O2 pulls electrons down the chain
- The energy that is yielded is used to regenerate ATP
- <u>NADP plays important role in anabolic reactions and photosynthesis</u>

Oxidative Phosphorylation
- <u>Accounts for almost 90% of the ATP generated by cellular respiration</u>
- A smaller amount of ATP is formed in glycolysis and citric acid cycle by ***substrate level phosphorylation***
- ***For each mol of glucose degraded to CO2 and water by respiration, the cell makes up to 32 mol of ATP***

Glycolysis

- Harvests chemical energy by oxidizing glucose to pyruvate (in cytosol)
- In order to start glycolysis, must input 2 ATP molecules
- Breaks down glucose into 2 molecules of pyruvate
- Glycolysis occurs in cytoplasm and has 2 major phases
    - Energy investment phase
    - Energy payoff phase
- Occurs whether or not O_2 is present

Pyruvate Oxidation + Citric Acid Cycle

- Completes breakdown of pyruvate to CO_2
- Pyruvate oxidation generates 2 NADH and 2 CO_2 per Glucose (or 2 pyruvate)

It is a chain of reactions that are happening, each step is enzyme catalyzed, eventually you will get waste products and main products. Pay attention to the fact that we start with a 6 carbon molecule and by the fourth step it splits into 2 3-carbon molecules.
What is happening is the breaking of the bonds in the glucose molecule.
The electrons make the bonds energetic and allow them to form.

How many electron carriers can you make?

Krebs Cycle

- At the end of the cycle, 4CO_2, 2 ATP, 6 NADH, and 2 $FADH_2$ per glucose are produced
- Has nothing to do with electron transport

10 electron carriers for glycolysis

- Become loaded with electrons (from hydrogen in carbohydrates)

ATP < -- > ADP + Pi

During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis

- After glycolysis and kreb's cycle, NADH and $FADH_2$ account for most of the energy that's been extracted from food
- They donate electrons to the electron transport chain (powers ATP synthesis with oxidative phosphorylation)

Pathway of Electron Transport

- ETC is in the inner membrane (cristae) of the mitochondrion
- Mostly made of proteins that exist in multiprotein complexes
- Electrons drop in free energy as they go down the chain, the final electron acceptor is O_2, which forms H_2O
- NADH donates electrons to first complex, FADH donates to the second.

Oxidative Phosphorylation (recorded on blackboard)

- Electron is donated to first complex
- Complex captures electron, and transport from one complex to another

- By complex 4, they lose all the energy that the electrons had because when the NADH and FADH donated the electrons, they lost their protons to the matrix. The protons are pumped into the intermembrane space.
- The electrons supply the energy for the complexes, which are pumps.
- In the matrix, the O2 molecule (THE FINAL E- ACCEPTOR) is very electronegative, so it hogs the electrons that are being transported down the chain.
    - Receives electrons and protons and water is produced
- H+ are released into the matrix along the way.
- The H+ ions in the intermembrane space create a electrochemical gradient and a pH gradient.
- In order to move back over, they find a channel (ATP Synthase)
    - ATP synthase is a turbine, involves rotation
- Facilitated diffusion happens as the protons flow through ATP synthase
- ATP synthase uses the exergonic flow of H+ to drive phosphorylation of ATP
    - This is ***chemiosmosis***: the use of energy in a H+ gradient to drive cellular work
    - Chemiosmosis is the energy provider for ATP synthase
- H+ gradient is referred to as a proton-motive force because of its capacity to do work
- ADP gets phosphorylized
- ADP and phosphate are already in the matrix

About 34% of the energy in a glucose molecule is transferred to ATP during cellular respiration (makes 32 ATP)

Fermentation and Anaerobic respiration

- Enable cells to produce ATP without use of oxygen
- Glycolysis couples with fermentation or anaerobic respiration to produce ATP without the electron transport chain
- ***Anaerobic respiration*** uses ETC with a final electron acceptor other than O2 (like sulfate)
- ***Fermentation*** uses substrate-level phosphorylation instead of ETC to generate ATP
    - Goal is to recycle NAD+

2 Types of Fermentation

- Alcohol
    - Performed by bacteria (and sometimes fungi like yeast)
    - Used if you are making beer or yoghurt
- Lactic acid
    - Accumulates in muscles
    - Pyruvate is reduced by NADH, forming lactate
    - Fermented by some fungi and bacteria
- The basic function of fermentation is the regeneration of NAD+, which allows continued ATP production by glycolysis

Glycolysis and the Citric Acid Cycle

- ***Connect to many other metabolic pathways***
- Are major intersections to various catabolic/anabolic pathways
- Glycolysis accepts a wide range of carbohydrates

- Proteins must be digested into amino acids
- Fats are digested to glycerol and fatty acids
- Fatty acids are broken down by beta oxidation and yield acetyl CoA
- Oxidized gram of fat produces 2x as much ATP as oxidized gram of carb

Chapter 8: Photosynthesis

Photosynthesis

- ***Autotrophs***
  - Don't eat anything derived from other organisms
  - ***Producers*** of the biosphere, produce organic molecules from CO_2
- ***Heterotrophs***
  - Obtain organic material from other organisms
  - ***Consumers*** of biosphere
  - Depend on photoautotrophs for food / O_2
- Converts light energy to chemical energy of food

Chloroplasts

- Leaves are major site of photosynthesis
- Found mainly in cells of the ***mesophyll*** (interior tissue of the leaf)
  - Mesophyll contains 30-40 chloroplasts
- Found in membranes of ***thylakoids***
- Contain ***stroma***, a dense interior

Photosynthesis Equation

- $6CO_2 + H_2O \rightarrow C_6H_{12}O_6$(sugar) + $6O_2$
- Chloroplasts split H_2O into hydrogen and oxygen

Photosynthesis Redox Reaction

- Photosynthesis reverses electron flow direction
- Is a redox process where H_2O is oxidized and CO_2 is reduced
- Endergonic process, energy boost is provided by light

2 Stages of Photosynthesis

- Light Reactions (photo part)
  - Split H_2O
  - Release H_2O
  - Reduce electron acceptor ($NADP^+$ to NADPH)
  - Generate ATP to ADP (***photophosphorylation***)
- Calvin Cycle (synthesis part)
  - Forms sugar from CO_2 using ATP and NADPH
  - Begins with ***carbon fixation***, incorporating CO_2 into organic molecules

Sunlight

- Light is a form of electromagnetic energy, called electromagnetic radiation
- Light that is visible to humans occupies the small portion in the middle of the electromagnetic spectrum

Light Receptors

- Pigments are substances that absorb visible light
- <u>Different pigments absorb different wavelengths</u>
- <u>Wavelengths that aren't absorbed are reflected / transmitted</u>
- <u>Leaves appear green, for chlorophyll reflects/transmits green light</u>

1882 Engelmann Experiment
- Action spectrum of light for photosynthesis.
- Demonstrated that ***red and blue light*** are far more effective in stimulating plant chloroplasts during photosynthesis
- Glass prism breaks up beam of light

Photon Energy
- When light photons strike a chlorophyll molecule, electrons of the chlorophyll molecule are elevated from one energy state to a higher energy state.

Excitation of Chlorophyll by Light
- When a pigment absorbs light, it jumps to an excited state and becomes unstable
- When it falls back to ground state, photons are given off and create an afterglow called fluorescence
- If illuminated, an isolated solution of chlorophyll will fluoresce, giving off light/heat

Light Reactions
- Overall function of light-dependent reactions is to convert solar energy to chemical energy (in form of NADPH and ATP)

Photosystems
- Called pigments
- Light harvesting complexes transfer energy of photons to reaction center of photosystems
- PS II
    - Functions first
    - Absorbs wavelengths of 680nm
    - Reaction center is called P680
- PS I
    - Absorbs wavelengths of 700 nm
    - Reaction center is called P700
- Absorption of photon excites chlorophyll, energy is transferred between chlorophyll molecules, when it reaches p68p it yields an excited e-
- ***NADP is the final electron acceptor***
- Water acts as an electron donor to the chlorophyll molecules
    - The water splits, and it's e- go to photosystem II
- Chemiosmosis is the result of the gradient between the two sides of the membrane. There's a chemical gradient due to lots of protons, there's a electrical gradient, and there's a pH gradient.
- Know final electron acceptors, know what chemiosmosis is and where it happens, know protein complexes

Light Reactions
- Generate ATP
- Increase PE of electrons by moving them from H2O to NADPH
- ATP and NADPH are produced on the side facing the stroma where the Calvin Cycle takes place

Mitochondria

- Generate ATP by chemiosmosis
- Transfer chemical energy from food to ATP
- Protons are pumped to the intermembrane space and drive ATP synthesis as they diffuse back into the mitochondrial matrix

Chloroplasts

- Generate ATP by chemiosmosis
- Transform light energy into the chemical energy of ATP
- Protons are pumped into the thylakoid space and drive ATP synthesis as they diffuse back into the stroma

Calvin Cycle

- Regenerates its starting material after molecules enter and leave the cycle
- <u>Builds sugars from smaller molecules by using ATP and the reducing power of electrons carried by NADPH</u>
- Carbon enters as CO2 and leaves as a sugar named ***glyceraldehyde 3-phosphate (G3P)***
    - Precursor to glucose
    - Must run cycle 2x to obtain
    - G3P is made up of carb, a.a, fatty acids
- 3 phases
    - ***Carbon fixation***
        - ***Rubisco*** = 3 CO2 + 3 Ribulosebis Phosphate (5c)
    - ***Reduction***
    - ***Regeneration of the CO2 acceptor (RuBP (5c))***

Plant Cells

- Can photosynthesize and respire at the same time because these processes occur in separate organelles
- Need large amounts of ATP because they grow

Photosynthesis uses solar energy to convert inorganics to energy-rich organics; respiration breaks down energy rich organics to synthesize ATP

Chapter 10: Cell Reproduction

Key Roles of Cell Division

- ***Binary Fission***: in unicellular organisms, division of one cell reproduces the entire organism
- In animals, Cell Division is necessary for
  - ***Tissue repair - mitosis***
  - ***Growth - mitosis***
  - ***Embryonic - mitosis***
  - ***Development - mitosis***
  - ***Tissue Turnover - renewal and mitosis***
  - ***Reproduction - meiosis***
- Most cell division results in identical daughter cells
- ***dsDNA*** is passed from one cell generation to the next
  - Exception is meiosis, which produces sperm and egg cells, and non-identical daughter cells that only have one set of chromosomes (half as many as parent)
- Diploid is 2n and has 2 sets on same circle
  - 46 chromosomes
- Haploid is n and has two circles with one set each
  - 23 chromosomes

Cellular Organization of Genetic Material

- All cellular DNA constitutes the cell's genome
  - A genome can consist of a single DNA molecule or a number of DNA molecules
- ***Somatic cells*** (non reproductive cells)
  - Have 2 sets of chromosomes
  - Maternal and paternal
- ***Gametes*** (reproductive: sperm and eggs)
  - Have half as many chromosomes as somatic cells
  - Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus

Chromosomes

- Eukaryotic chromosomes consist of ***chromatin***, a complex of DNA and protein that condenses during cell division, which are visible as ***chromosomes***
- <u>Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus</u>

Chapter 11: Meiosis

Prophase I

- Typically occupies more than 90% of the time required
- Chromosomes begin to condense
- **Synapsis**
  - Homologous chromosomes loosely pair up, aligned gene by gene
- **Crossing Over**
  - Non-sister chromatids exchange DNA segments
- Each pair form a tetrad
- Each has one+ Chiasmata (synapsis)
  - X-shaped regions where crossing over occurred

Metaphase I

- Tetrads line up at metaphase plate, with one chromosome facing each pole
- Microtubules
  - From one pole are attached to the kinetochore of one chromosome of each tetrad
  - From the other pole are attached to the kinetochore of the other chromosome.

Anaphase I

- Pairs of homologous chromosomes separate
- One chromosome moves toward each pole, guided by the spindle apparatus
- Sister chromatids remain attached at the centromere and move as one unit toward the pole.