AP Biology Study Guide[*]

UNIT I
CHEMISTRY/BIOCHEMISTRY

I. CHEMISTRY: THE BASIS FOR LIFE

A. ELEMENTS

Almost everything around us can be broken down into simpler substances. These substances can be further broken down into other simpler substances. There is a point where substances can no longer be broken down into other substances while keeping their characteristic properties. These substances are called elements. There are currently 106 named elements (92 naturally occurring), but this number is increasing because more man made elements are being created in laboratories.

From these 92 naturally occurring elements, only 20 are necessary for life. Of these 20 life elements, 6 make up 99% of all living matter: Sulfur, Phosphorous, Oxygen, Nitrogen, Carbon and Hydrogen (SPONCH, mnemonic device). Living organisms still need the other 14 elements, but in smaller amounts.

An atom is the smallest indivisible unit of an element that still has the characteristic of the element. Two or more atoms can combine chemically and form a molecule. A compound is any pure substance that contains two or more different atoms.

$$\text{Atom} = H \qquad \text{Molecule} = H_2 \qquad \text{Compound} = H_2O$$

B. FORMS OF MATTER

Atoms, elements, and compounds are forms of matter. Matter can come in one of three states on the earth:

1. **Solid**
    Has definite shape and has a definite volume
2. **Liquid**
    Has no definite shape but has a definite volume
3. **Gas**
    Has no definite shape and has no definite volume

C. SUBATOMIC PARTICLES

Atoms can be broken down into smaller components called subatomic particles: protons, neutrons, and electrons. Protons and neutrons make up the nucleus of an atom. They are roughly equal in mass, one atomic mass unit (*amu*) or Dalton. Protons are positively charged and neutrons are not changed. Electrons are negatively charged, have relatively small mass. An atom can be described as having a small, very dense nucleus with a very low-density electron cloud surrounding it. Therefore, most of the mass of the universe is made up of protons and neutrons.

Strong nuclear forces hold the protons and neutrons together, while the electrons are attracted to the positive charge of the protons. Protons and neutrons can be broken down into smaller particles called quarks. All atoms of the same element have the same number of protons. The number of protons is the atomic number (written in subscript to the left of the atomic symbol). Unless otherwise noted, the number of protons equals the number of electrons. An atom is usually neutral in charge since the positive and negative charges are equal.

We can determine the number of neutrons by using the mass number which is the sum of the protons and neutrons (written as a superscript to the left of the atomic symbol). The number of protons is fixed, but the number of neutrons can vary within the same element. Thus, the same element may have different atomic masses. Atoms of the same element that have different atomic masses are called isotopes:

Hydrogen: 1p, 1e-   Deuterium:1p, 1n, 1e-   Tritium: 1p, 2n, 1e-

1 amu   2 amu   3 amu

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Some combinations of protons and neutrons are stable, but other combinations are internally unstable and break down spontaneously. When this happens, the atom releases various subatomic particles and radiation. These isotopes are called radioactive isotopes.

D. ELECTRON ORBITALS

Electrons move in undefined paths in regions around the nucleus, called orbitals (orbitals are merely a volume in which the electron is probably moving). Only two electrons can occupy the same orbital. Electrons move to the orbital that is lowest in energy, usually closet to the nucleus. There are other regions called energy levels that contain orbitals. The energy level closet to the nucleus contains one orbital. The second energy level holds four orbitals and the third level also contains four orbitals.

- The first energy level can hold up to two electrons. (1s)
- The second energy level can hold up to eight electrons. (2s, 2p)
- The third energy level can hold up to eight electrons. (3s, 3p)

There are more than three energy levels, but biologists are concerned with 18 total electrons. Atoms are most stable when their outer energy level is filled with electrons. Of the three atomic particles, only the electrons are directly involved in the chemical reactions between atoms.

Not every electron has the same amount of energy (the ability to do work). There are two types of energy: Potential energy and Kinetic energy. Potential energy, the amount of energy that matter stores, is due to the position or location of the matter. Electrons have potential energy in relation to the nucleus. The potential energy that an electron has is determined by its distance from the nucleus. The more energy the electron contains, the further it will be from the nucleus; an electron with low energy will be closer to the nucleus.

Electrons can move to a higher energy level by having added to it (sunlight and light energy). Once the electron moves to the higher level, it contains that added energy. When this electron moves back to its original position, the same amount of energy that it took to move the electron is released.

E. HOW ATOMS FILL THEIR OUTER SHELL

An atom with its outer shell filled with electrons is a stable atom. Atoms react with other atoms chemically by filling their outer shells. Atoms can fill their outer shell in one of three ways.
1. **Ionic Bonds**
   a. Gain electrons from another atom.
   b. Lose electrons from its outer shell to another atom.
2. **Covalent Bond**
   a. Share one or more pairs of electrons with another atom.

F. BONDS

There are two types of bonds between atoms, and these correspond to how the atom attains a stable electron configuration.

1. **Ionic Bonds and Ions**
   Look at Sodium and Chlorine. Sodium has 11 electrons: $1s^2$, $2s^2$, $2p^6$, $3s^5$. Sodium needs to gain seven more electrons or lose one electron. Chlorine has 17 electrons: $1s^2$, $2s^2$, sp^6, $3p^5$. Chlorine has to lose seven electrons or gain one electron. Sodium donates one electron to Chlorine. These two atoms combine to form a compound, sodium chloride salt.

   An ion is any charged atom. Sodium donates an electron, which is negatively charged and becomes a positively charged ion. The Chlorine receives an electron and becomes a negatively charged ion. The two ions are Sodium$^+$ and Chlorine$^-$. When two atoms give and receive electrons, they form ions and ionic bonds. These bonds are approximately as strong as covalent bonds.

   Cation: Positively Charged Ion.   *Anion*: Negatively Charged Ion.

2. **Covalent Bonds**
   Covalent bonds form through the process of sharing of electrons. Two atoms can fill their outer shells by sharing electrons. In fact, atoms give up little by sharing. For example, 2 Hydrogen atoms share their electron to have two electrons in their shell. Oxygen ($1s^2$, $2s^2$, $2p^4$) shares two electrons to form O_2. Methane

is another example. Carbon has six electrons: $1s^2, 2s^2, 2p^2$. The carbon shares its four electrons of its outer shell with 4 Hydrogen atoms to get CH_4 = Methane.

If atoms share one pair of electrons, one electron from each atom, then they form one covalent bond (single bond). If two atoms share two pairs of atoms, two from each atom, they form two covalent bonds (double bond). If two atoms share three pairs of electrons, three from each atom, they form three covalent bonds (triple bond).

a. Nonpolar covalent bonds
The attraction of electrons to an atom is called electronegativity. The more electronegative an atom, the more a shared electron is pulled towards its nucleus. If there are two atoms of the same element or the same electronegativity, the pull of the electron is equal and the bond is a nonpolar covalent bond.

b. Polar covalent bonds
If one atom is more electronegative than another atom, the electron is pulled closer to the atom and the electron is not shared equally. The atom with the greater electronegativity will be slightly negative- due to the fact that a negative electron spends more time around its nucleus. The other atom has a slightly positive charge. This bond is called a polar covalent bond.

c. Hydrogen bond
Hydrogen bonds happen between molecules. The electrons between hydrogen and the other atoms are shared unequally. (Hydrogen forms a polar covalent bond with an atom with greater electronegativity.) This unequal sharing causes the hydrogen to have a partial positive charge. The hydrogen is attracted to another atom or molecule, (not the one that it is covalently bonded to) with a slightly negative charge.

G. Dissociation and pH scale
Many substances come apart (dissociate) in water. Some dissociate completely, while others dissociate only partly. In a solution, some molecules are intact while others are ionized (gain or lose electrons). Water dissociates into H^+ and OH- equally (hydrogen and hydroxide)(10^{-7} K_{eq}).

1. **Acids**
   Substances that yield H+ when they dissociate in water are called acids (by Arrherrius definition). Acids add H+ to the solution, increasing the H+ concentration.
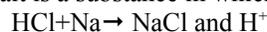 $$HCl \rightarrow H+ \text{ and } Cl-$$

2. **Bases**
   Substances that yield OH- when they dissociate in water are called bases (e.g. $NaOH \rightarrow Na^+$ and OH^-). Bases also accept H^+ (by Bronstead Lowry definition). Bases reduce the amount of H+ in a solution:

3. **Salts**
   A salt is a substance in which the H^+ of an acid is replaced by another positively charged ion.
   $$HCl+Na \rightarrow NaCl \text{ and } H^+$$

4. **pH**
   The acidity of alkalinity (base) is known as pH (from the term *pouvoir Hydrogene* meaning hydrogen power). pH formula:
   $$pH = -\log [H+] \text{ If pH=6 then the concentration of H+ per liter is } 10^{-6} \text{ in a solution.}$$

   The pH scale goes from 0-14. Acidic is <7, and the Basic is >7. Neutral=7. A pH of 5 is 10 times more acidic than a pH of 6. The more hydrogen ions present, the higher the hydrogen ion concentration, and the more acidic the solution.

   An acid not only adds H^+ to a solution but decreases the concentration of OH^-. Because $H^+ + OH^- \rightarrow$ H_2O. However, $[H^+][OH^-]+10^{-1}M^2$

5. **Buffers**
   Buffers are substances that take up or release H^+ or OH to prevent swings in pH. An important buffer is H_2CO_3. H_2CO_3 dissociates to H^+ and HCO_3^-. The H^+ is a base acceptor, and the HCO_3^- is an acid acceptor.

H. Chemistry of Water

H_2O is 2 H and 1 O. The H are covalently bonded to the O.

This is a polar molecule, because it has partial positive and partial negative ends. The hydrogen atoms of the water molecule can now form bonds with other slightly negative (polar) compounds. In this case, each hydrogen of this water molecule can form hydrogen bonds with oxygen atom of other water molecules. Hydrogen bonds are 20 times weaker than covalent bonds. But hydrogen bonding between molecules is very important with organic compounds.

1. **Water Properties**
   The unique structure of water gives water its seven important properties.

   a. **Water is a Powerful Solvent**
      Water is able to dissolve anything polar due to polarity. Water separates ionic substances. Many covalently bonded compounds have polar regions, the covalent compounds dissolve in water and are called hydrophilic (water loving) compounds. Nonpolar substances do not dissolve in water and are called hydrophobic (water fearing).

   b. **Water is Wet**
      Water adheres to a surface due to two properties.
      1) Adhesion: The attraction between water and other substances.
      2) Cohesion: The attraction of water molecules to other water molecules.
      These two properties allow capillary action. Water is attracted to the polar substances (adhesion) and climbs these substances, while pulling up the other water molecules due to cohesion. The meniscus, in a column of water, is formed because gravity pulls down on the water molecules in the center while water molecules at the sides of the container "climb."

      Inhibition occurs when water moves into a substance (due to capillary action) and that substance swells.

   c. **Water has High Surface Tension**
      Water is attracted to itself, and this attraction, due to hydrogen bonds, is stronger than the attraction to the air above it.

   d. **Water has a High Specific Heat**
      It takes a lot of heat to increases the temperature of water and a great deal of heat must be lost in order to decrease the temperature of the water. Water heats up as the hydrogen atoms vibrate (molecular kinetic energy- energy of molecular motion).

   e. **Water has a high boiling point**
      A great deal of energy must be present in order to break the hydrogen bonds to change water from a liqid to a gas.

   f. **Water is a good evaporative coolant**
      Because it takes a lot of energy to change water from a liquid to a gas, when the vapor leaves it takes a lot of energy with it. When humans sweat, water absorbs the heat from the body. When water turns into water vapor, it takes that energy (heat) with it.

   g. **Water has a high freezing point and lower density as a solid than a liquid.**
      Water's maximum density is 4°C, while freezing is 0°C. This is why ice floats, this fact also allows for aeration of still ponds in spring and fall and the reason ponds don't freeze from the bottom up.

II. BIOLOGICAL CHEMISTRY: ORGANIC MOLECULES

Organic compounds are molecules containing carbon that are found in living things.

A. DEFINITIONS
1. **Isomers**
   These are compounds that have the same molecular formula but different three dimensional structures and hence different physical and/or chemical properties. There are 3 types of isomers:
   a. **Structural Isomers**
      These differ in the arrangement of atoms. Fro example, glucose and fructose both have the formula $C_6H_{12}O_6$, but have different bonding arrangements.

b. Geometrical Isomers

These have the same covalent partnership but different special arrangements because of the orientation of groups around a double bond, which does not permit free rotation around it. The orientations of the constituent groups are spatially fixed around the double bond. Such arrangements around a double bond are called cis-isomers when the name constituents are oriented on the same side of the double bond, and trans-isomers when the constituents are oriented across from each other.

c. Stereoisomers

These are molecules that are mirror images of each other. A central (not terminal) carbon atom is covalently bonded to four different atoms or groups of atoms; the carbon is called an asymmetrical or chiral carbon. The result is a pair of compounds that are mirror images, right handed and left handed isomers.

2. Functional Groups

A combination of the SPONCH elements. These are the portions of an organic molecule that are usually involved in chemical reactions. Functional groups behave in a characteristic way regardless of what the rest of the molecule is like. These groups are attached to the carbon skeleton, replacing one or more of the hydrogens that would occur in a hydrocarbon. Here are the biologically important functional groups.

3. Energy Factor

Covalent bonds are strong, stable bonds. These bonds have different strengths depending on the configurations of the electrons in orbitals. The atoms of the molecules are always moving – vibrating, rotating and shuffling positions. If the motion becomes great enough, the bond will break, and the atoms will separate.

The bond strengths are expressed in terms of energy (kilocalories or kilojoules per mole) that must be supplied to break the bonds under standard conditions of temperature and pressure. The more energy required to break the covalent bond, the stronger that bond is. Weak bonds are easier, or, require less energy to break. Once the covalent bonds break, the atoms form new covalent bonds quickly. Depending on the temperature, pressure, and the nature of the other reactants, the same compounds or new compounds are formed.

B. CARBON BACKBONE

Carbon can form covalent bonds directly with one to four atoms since it as four valence electrons. In many biological molecules carbon atoms form long chains. Carbon is unique in that it can form single, double, and triple covalent bonds with itself and other atoms.

DIAGRAM

C. HYDROCARBONS

These compounds consist solely of H and C. they are not part of living systems except as the backbone to which functional groups are attached. Examples of hydrocarbons are methane (CH_4), butane (C_4H_{10}) and cyclohexane (6 carbons in a ring, C_6H_{12}).

D. OTHER ELEMENTS IN ORGANIC COMPOUNDS

Along with carbon and hydrogen, other elements are found in organic compounds. The most common of these elements are nitrogen, phosphorus, sulfur, and oxygen (the SPONCH elements).

1. Oxygen

Oxygen, as O_2, makes up 21% of the earth's atmosphere and is found in the great majority of organic compounds in living systems.

2. Nitrogen

Nitrogen is found in all proteins and nucleic acids. 79% of our atmosphere is N_2. The bond between the two nitrogen atoms is a triple bond and is a difficult bond to break. The only way for most organisms to get usable nitrogen is through nitrogen fixing bacteria.

3. Phosphorus and Phosphates

Phosphorus is found in living systems as phosphates in ions such as HPO_4^{-2} or $H_2PO_4^{-}$. Phosphorus is covalently bonded to four oxygen atoms. When the oxygen-phosphate bond is broken, energy is released. Phosphorus is an important element in nucleic acids.

4. Sulfur

Sulfur occurs in some proteins. The sulfur appears as part of sulfhydryl groups (-SH) in the amino acid cysteine. These groups allow parts of proteins to bond together covalently via disulfide bridges.

$$R–SH + HS–R \rightarrow R\text{-}S\text{-}S\text{-}R + H_2$$
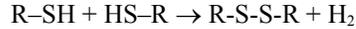
There are four main groups of biologically important organic molecules: carbohydrates, proteins, lipids, and nucleic acids.

E. CARBOHYDRATES

Most carbohydrates have the empirical formula $C(H_2O)_n$. Carbohydrates are composed of covalently bonded atoms of carbon, hydrogen, and oxygen.
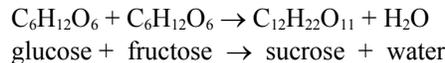
1. Monosaccharides

The basic unit of a carbohydrate is a monosaccharide or simple sugar. Monosaccharides can be burned (oxidized) to yield carbon dioxide, water, and energy. The principle source of energy for organisms is glucose. Structurally a sugar consists of a carbon backbone of three or more carbon atoms with either an aldehyde or carbonyl group on one carbon and hydroxyl groups on each of the other carbons.

The most common monosaccharide is glucose, $C_6H_{12}O_6$. Glucose is the form of sugar generally transported in the human body. A disaccharides formed by joining two monosaccharides together. The two monosaccharides are linked by a reaction called a dehydration or condensation reaction.

- A *monomer* is a relatively simple and small molecule; many of them can be linked together to form a polymer.
- A *polymer* is a large molecule composed of many similar or identical molecular subunits.
- A *polysaccharide* consists of many monosaccharides joined together by condensation reactions.
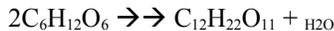
Condensation reaction: the joining of two smaller organic compounds resulting in the formation of a larger organic molecule and the release of a water molecule. The condensation reaction, a synthesis reaction, is important because it is the reaction that puts together polymers from monomer units. Synthesis reactions require energy to complete.

$$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$
$$\text{glucose} + \text{ fructose } \rightarrow \text{ sucrose } + \text{ water}$$

Hydrolytic cleavage (hydrolysis): With the addition of water, the splitting of a large organic molecule into two smaller organic molecules. Hydrolysis reactions liberate energy. Hydrolytic cleavage, or hydrolysis, is the opposite of a dehydration reaction. For example, in the human digestive system, sucrose (disaccharide) is split into glucose and fructose (two monosaccharides).

2. Disaccharides

Two monosaccharides that are joined by a glycosidic linkage, a covalent bond between two monosaccharides.

glucose + glucose = maltose   glucose + fructose = sucrose

$$2C_6H_{12}O_6 \rightarrow\rightarrow C_{12}H_{22}O_{11} + {}_{H2O}$$

3. Polysaccharides

Glycosidic linkages can be oriented in space. Two monomers can be joined either by an alpha or beta linkage. By a series of dehydration reactions, many monosaccharides can be put together to form a polysaccharide. Three examples of polysaccharides are starch, glycogen, and cellulose. In starch and glycogen the monomers are joined by alpha linkages; in cellulose the glucose monomers are joined by beta linkages.

a. Starch

Starch is the storage polysaccharide in plants and is an important reservoir for energy. There are two common types of starch.

1) *Amylose*: the simplest starch. Consisting of unbranched chains of hundreds of glucose molecules.
2) *Amylopectin*: large molecule consisting of short glucose chains with other glucose chains branching off the main chain.

b. Glycogen

Glycogen is the storage polysaccharide in animals. Glycogen is composed of branching glucose chains, with more branches then amylopectin. It is found in the liver and muscles and acts as a temporary storage form of glucose. The liver removes the excess glucose from the bloodstream, converts the glucose monomers to glycogen via condensation reactions, and stores it as glycogen.

When vertebrates need glucose for energy, glycogen is converted by hydrolytic cleavage back to glucose.

c. Cellulose

Cellulose is a structural polysaccharide and is the major building material made by plants. It is the most abundant organic material in earth. Cellulose is made up of long, straight glucose molecules. Cellulose is called a structural polysaccharide because it gives the plant cell its shape, is not soluble, and is very strong. Cellulose is flexible when the plant cell is young. As the cell grows, the cellulose becomes thicker and more rigid.

Cellulose is indigestible to animals because the linkages are 1-4 beta linkages, and our enzyme can only break down 1-4 alpha linkages because the shapes are different. Cellulose is the so-called fiber in our diets. Some bacteria, protests, fungi, and lichens can break down cellulose. For example, bacteria and protests found in the stomachs of termites and grazing animals break down the cellulose in the grass and wood to provide the animal with glucose.

d. Other structural polysaccharides

    1) *Pectin and andarrageenan*: these are extracted from algae. Pectin and carrageenan are put into food items such as jellies, jams, yogurt, ice cream, and milkshakes to give them a jelly-like or creamy consistency.

    2) *Chitin*: Chitin is principal component of the exoskeletons of insects and other arthropods, including lobsters. Chitin is very soft but is combined with $CaCO_3$ (calcium carbonate or limestone) to become hard. Most animals cannot digest chitin.

F.   PROTEINS

Proteins are large, complex organic molecules that are made of smaller monomer units, amino acids. Proteins are naturally occurring biological molecules that are composed of amino acids linked together through dehydration reactions.

1.   Amino Acids

Amino acids are the building blocks of proteins. There are 20 amino acids. All amino acids except one, glycine, are asymmetrical. When amino acids are prepared in the lab pairs of stereooisomers form. In living systems, only the left handed isomers are synthesized.

a.   Basic Structure of an Amino Acid

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                 R        O
                 |        ||
   N ——— H ——— C ——— C ——— OH
                 |        |
                 H        H
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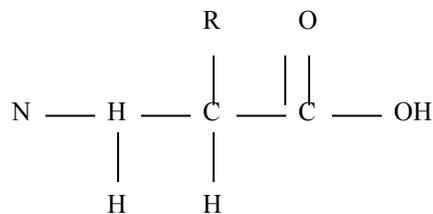
Each amino acid has a carbon with four different groups attached.

    1) Amine group, NH_2, 9basic, can accept H^+ and thus have a positiv charge).

    2) Carboxyl group, COOH, (acidic, can donate H^+ and thus have a negative charge).

    3) Hydrogen

    4) R group: the R group is the portion of the amino acids that is different in each amino acid. In the amino acid glycine, the r group is replaced with an H atom.

b.   R Groups

The r group of the amino acid determines the physical and chemical properties of the protein. R groups can be nonpolar, polar, acidic, or basic. They can also be the site of the addition of prosthetic groups, inorganic groups that are essential for the functioning of the protein. These prosthetic groups often determine the protein's function, as in hemoglobin. Minerals in our diets are often essential parts of prosthetic groups; for example, iron

(Fe^{2+}) in our diet is essential for the synthesis of the heme group the prosthetic group in hemoglobin. The activities of some proteins are dependent upon co-enzymes, which are small organic groups attached to the protein. Many of these co-enzymes cannot be made by animals and must be included I our diets in the form of vitamins.

To synthesize proteins, a dehydration reaction occurs. The amino end of one amino acid and the carboxyl end of a second amino acid are joined together. The covalent bond formed is called a peptide bond. The molecule that is formed by adding many amino acids together is called a polypeptide.

How do the cells in the body obtain amino acids? Any foods contain proteins; the proteins are broken down into small pieces called peptides. Peptides are about 30 amino acids long and are carried in the blood vessels. When a cell is actively making proteins, peptides are taken into the cell, broken down, and the constituent amino acids are reconfigured into a protein.

Proteins have a three dimensional configuration which is determined by the amino acid sequence. Proteins can be stringy or globular. The conformation of the protein is its three dimensional shape. The function of the protein is determined by its configuration. A protein may have four different levels of structure that determined its conformation.

c. **Levels of protein Structure**
The amino acid sequence is called the primary structure. The protein is defined by the amino acid sequence. Each protein has a different primary structure. Changing the amino acid sequence can change the protein shape and function.

d. **Secondary Structure**
The secondary structure of a protein refers to the way in which some segments of the polypeptide repeatedly coil or fold in patterns which contribute to the proteins overall shape. These folds and coils are the result of hydrogen bonding at regular intervals along the polypeptide backbone. The oxygen and nitrogen atoms of the polypeptide backbone have a partially negative charge. The partially positive hydrogen atoms attached to the nitrogen atom have an attraction to the oxygen atom of the nearby peptide bond.

Individually, the hydrogen bonds are weak, but since they are repeated many times, they can support a particular shape of the protein. And example of a secondary structure is the alpha helix. The helix is a coil held together by hydrogen bonds between every fourth peptide bond. If a protein is fibrous in appearance, it is made mostly of helices.

Another secondary structure is the beta-pleated sheet. When the polypeptide chain folds back and forth or when two regions of the chain lie parallel to each other, the amine groups and carboxyl group between the parallel regions form hydrogen bonds. These bonds will maintain the protein's secondary structure. A globular protein will have a beta sheet core.

Whether the secondary structure forms a helix or a pleated sheet depends on the size of the R groups. If the R groups are small and repeated many times, then the pleated sheet forms. If the R groups are too large, pleated sheets are unable to form and the alpha helix structure results.

e. Tertiary Structure
The tertiary structure is the actual three-dimensional shape of the polypeptide. There are two types of three-dimensional shapes: fibrous and globular. Some fibrous proteins are keratin and collagen. Globular proteins are more numerous. An example of a globular protein is hemoglobin.

The bends and loops of the amino acid chain are caused by the R groups of the amino acids reacting with R groups of other amino acids on the same polypeptide.

The non-polar (hydrophobic) R groups will tend to group together away from the surface of the polypeptide since water is the usual medium surrounding these molecules. Hydrogen bonds can form between polar R groups. Two sulfhydryl groups can form a

disulfide bridge. Charged R groups can repel or attract each other. These bends and twists cause the polypeptide to have a three dimensional shape.

f. Quaternary Structure

A protein consisting of two or more polypeptide chains has a quaternary structure. The quaternary structure is formed by polypeptide chains interacting with other polypeptide chains. These interactions are the same types that are responsible for tertiary structure, namely hydrogen bonds, disulfide bridges, electrostatic attractions and hydrophobic forces (London or dispersion forces).

g. Denaturation

Factors that determine conformation: A polypeptide will spontaneously arrange itself into a three dimensional structure. However, if the pH, salt concentration, temperature, or other environmental aspects are altered, the protein may unravel and lose its shape. This is called denaturation. A protein that denatures is biologically inactive.

Chemicals can disrupt hydrogen bonds, ionic bonds, or disulfide bridges, and change the structure of proteins. Excessive heat will also cause the protein to denature.

2. Types of Proteins

a. Binding Proteins

These have the unique ability to take specific shapes which enable to bind to other substances. For example, Hemoglobin, a globular protein, binds with oxygen.

b. Structural Proteins

These help with shapes and structures.
1. Collagen: Collagen consists of long fibrous molecules that clump together to make large fibers; these fibers are the principle component in connective tissues such as tendons, ligaments, and muscle coverings. Collagen can compose up to 25% of a person's body weight.
2. Elastin: Elastin has the ability to stretch and gives elasticity to connective tissues such as skin. Loss of elastic property over time causes bagginess in the face, neck and skin.
3. Keratin: Keratin is found in hair, nails, outer layer of skin, feathers, claws, horns, and scales. Cells fill up with keratin, then die and leave the keratin behind.

G.   ENZYMES: AN IMPORTANT CLASS OF PROTEINS

All chemical reactions need energy to get started; this energy is known as activation energy. The Rate of chemical reaction is related to the activation energy for that reaction. Generally, reactions with low activation energies are rapid while those with high activation energies are quite slow. The rate of a chemical reaction can be increased by the addition of a catalyst. A catalyst decreases the activation energy needed for the reaction to occur, thus increasing the rate at which the reaction proceeds. A catalyst participates in the reaction but is not consumed in that reaction. In living systems, enzymes are the catalysts. For each chemical reaction that occurs in an organism, a specific enzyme is required.

1. Enzyme Composition

All enzymes are proteins. Proteins make efficient catalysts because their shapes are very specific. Each enzyme has an active site. The active site is a groove or depression on the surface of an enzyme. The shape of the active site allows the enzyme to bind with a specific compound, called the substrate. When the substrate (s) binds to an enzyme, the complex is called the enzyme-substrate complex(ES).

"Induced Fit" model: The active site is not usually rigid. In fact, the active site can move around a bit, actually changing shape slightly to accommodate the shape of the substrate. When the substrate(s) is in the active site, then the enzyme catalyzes the reaction(s) of the substrate so that the product(s) form:

S	+	E	--->	ES	--->	P	+	E
Substrate		Enzyme		Enz-Sub Complex		Product		Enzyme

2. Rate of Enzyme reactions: Enzyme Kinetics

How do temperature and pH affect the rates of enzyme reactions? In what other ways can enzyme activity be regulated?

a. Temperature

When there is an increase in temperature up to 40 degrees C, the rate of reaction increases. Above this temperature, hydrogen bonds break. When the hydrogen bonds break, the enzyme loses its three dimensional shape, the active site cannot bind to the substrate, and no product can be formed. The enzyme has been denatured. Each enzyme has an optimal temperature, which is usually closest to the organism's ambient temperature.

b. pH

Different enzymes have different optimal conditions of pH. Pepsin (found in stomach, breaks down protein) works at pH of 2. Trypsin (found in the small intestine, also breaks down protein) works best at a pH of 8. If there is a decrease in pH because more acid is added, hydrogen bonds break down and the enzyme is denature and no longer effective.

c. Negative Feedback

This is a common method of regulation in living systems. As the product is formed, it hinders the mechanism that produced the product. If there is too much product being formed, then excess product remains in the active site. When this happens, the substrate can no longer enter the active site. When the level of product decreases, the product leaves the active site, and the reaction can resume.

d. Allosteric Control

Sometime an enzyme may have a second binding site, called an allosteric site. When a small molecule binds to the allosteric site. The enzyme's active site changes shape. When the active site changes, the enzyme can no longer bind to the substrates.

H. LIPIDS

Lipids are a diverse group of molecules defined by their solubility rather than by their structures. Lipids dissolve in nonpolar solvents such as chloroform, ether, and benzene. Lipids are hydrophobic and do not dissolve in water. There are 5 types of lipids: triglycerides, phospholipids, glycolipids, steroids and waxes.

1. Triglycerides: Fats and Oils

Fat: a lipid that is solid at room temperature.
Oil: a lipid that is a liquid at room temperature.

a. Triglyceride

A triglyceride is composed of one glycerol molecule and three fatty acid molecules.

The synthesis of a triglyceride occurs when a glycerol molecule joins with three (of the seventy different) fatty acids. Fatty acids usually have an even number of carbons, differ in the length of the carbon chain, and may contain double covalent bonds.

Triglycerides are a concentrated source of energy. When the fat is combined with oxygen, the fats release a large amount of energy, more than twice as much per gram as carbohydrates. Seeds store triglycerides, animals store energy as fat for lean seasons or migration or insulation, humans store fat under the skin and around internal organs. Fat serves for insulation and flotation. Storage fat serves as padding in your fingers and your bottom.

b. Saturated, Unsaturated and Polyunsaturated Fats

Some fatty acids have no double bonds. The have the most hydrogens possible. These are called saturated fats. Animal fats are usually saturated fats and solidify at room temperature. Some fatty acids have double bond between two adjacent carbons. This structure means that they have fewer hydrogens then the saturated fats; these are called unsaturated fats. Unsaturated fats tend to be oily liquids. They can be found in plants (olive oil, peanut oil and corn oil) more commonly than animals and are usually liquids at room temperature. We can't make unsaturated fats, so we need to eat small amounts of unsaturated fats. Polyunsaturated fats have more than one double bond.

2. Phospholipids

Phospholipids are closely related to triglycerides. Two fatty acids, one saturated and the other unsaturated are linked to a backbone of glycerol. In the place of the third fatty acid is a phosphate group. The phosphate group is hydrophilic while the hydrocarbon chains are nonpolar and hydrophobic. The cell membrane is made up of two layers of phospholipids and proteins.

3. Glycolipids

The third carbon in the glycerol molecule isn't bound to a phosphate group. Instead, it is bonded to a short carbohydrate chain (1-15 monosaccharides). The carbohydrate head is hydrophilic; thus glycolipids behave in the same way as phospholipids. They are also important components of the cell membrane.

4. **Steroids**

Steroids are not structurally similar to fatty acids or lipids. Since they are hydrophobic, however they are called lipids. All steroids have four linked carbon rings. Steroids have a tail and many have an –OH group.

    a. **Lanolin**

Commercially refined from sheep's wool. Humans have a small amount of lanolin in their hair and skin; lanolin helps give these structures flexibility.

    b. **Cholesterol**

A major constituent of the cell membrane. When bombarded with ultraviolet light, it rearranged into vitamin D. When modified slightly, it makes sex hormones.

5. **Waxes**

Waxes are similar in structure to triglycerides, but instead of glycerol there is a long chain alcohol. Because of their hydrophobic quality, waxes are found in many living things that need to conserve water. Insects have waxy cuticles, plants have wax on their leaves, and fruit skins and petals have wax as an outer covering.

I. **NUCLEIC ACIDS**

Nucleic acids are the largest organic molecule made by organisms. There are two types: DNA (Deoxyribonucleic Acid) and RNA (Ribonucleic Acid). The pentose sugar in DNA, deoxyribose, has one fewer oxygen atom than ribose, the sugar in RNA.

DNA contains an organism's genetic information. Basically, DNA encodes the instructions for amino acid sequences of proteins. RNA carries the encoded information to the ribosomes, carries the amino acids to the ribosome, and is a major constituent of ribosomes.

1. **Structure**

Nucleotides are the basic units of both DNA and RNA and can exist as free molecules. A nucleotide is made up of three parts.

a. Pentose sugar: deoxyribose or ribose.
b. Phosphate: in free nucleotides, they occur as a group of phosphates bonded to a sugar.
c. Nitrogenous base: there are two types of nitrogenous bases. They are called bases because of the amine groups, which are basic.

    1) Pyrimidines: single ring compounds. The two pyrimidines in DNA are cytosine and thymine. In RNA, thymine is replaced by Uracil.
    2) Purines: double ring bases. The two purines are adenine and guanine.

2. **Importance of Nucleic Acids**

a. DNA is the hereditary material; RNA enables proteins to e synthesized from the DNA instructions.
b. A cell's energy source for chemical reactions is stored as ATP (adenosine triphosphate). Between the phosphate groups are bonds, which can be broken to yield usable energy, 7 kcal/mole.
c. CAMP (cyclic adenosine monophosphate) is used as a second messenger in many hormonal reactions.

<div align="center">

Unit II

Prokaryotes/Fermentation

</div>

I. **Introduction to cells and prokaryotes**
A. **Cell introduction**

    1. **cell theory**

in 1805 Lorenz Oken made several statements that together make up the cell theory. Here are four parts of the cell theory:

        a. all living things are mad of cells
        b. cells are alike in structure and function
        c. cells need information in order to survive

d.   new cells come from old cells
2. **Why are cells so small**

The cell theory never states that cells must be small. Two reasons may b3e given:

a.   **Efficiency**

By breaking down the cell up into smaller cells, the surface area is increased. Cells require nutrients and oxygen and must get rid of wastes. These nutrients/ wastes must move across the membrane and through the cell. If the cell were too big, the nutrients/ wastes would have to cover a large distance in order to get to the proper destinations.

b.   **Specialization**

Having numerous small cells permits specialization. I n multicellular organisms, different cells have different functions.

c.   **There are two types of cells**

1.   Prokaryotic: bacterial cells that make up the Monera kingdom
2.   Eukaryotic: all other cells

Eukaryotic

3. **animal cells**

all eukaryotic cells are very complicated. All animals are mad up from these cells. Animal cells contain structures, called organelles, that have specific functions. The organelles are found in a jelly-like medium called cytoplasm, and everything is held within the cell by a membrane called the cell membrane.

4. **Plant cells**

Plant cells have three more organelles than the animal cells. Plant cells have a cell wall, chloroplasts, and a large central vacuole.

Prokaryotic

5. **bacterial cells**

these are the simplest of all cells. Bacterial cells only have a cell wall and one organelle: ribosomes

6. **Prokaryotes: bacteria**

The first life forms were probably similar to the modern group of bacterial cells. This includes regular bacteria and cyanobacteria.

Early in the history of life, the prokaryotes split into two main groups: Archaebacteria and Eubacteria

All the organisms are primarily unicellular, although some form filaments made of many cells(cyanobacteria). Bacterial cells are prokaryotes. All prokaryotes have the following characteristics.

a.   **DNA loop**

Their DNA is in a naked loop in the cytoplasm. The DNA loop is a long, single fiber which contains almost all of the genetic material of the prokaryotes. The rest of the genetic material can be contained in the plasmids.

b.   **Ribosomes**

They have ribosomes floating freely in the cytoplasm. The ribosome is the site for protein synthesis. Interestingly, antibiotics, such as tetracycline bind to the prokaryotic ribosome and interfere with the ability of the prokaryote to produce protein.

c.   **Plasmids**

Prokaryotes can contain a small circular loop of extrachromosomal DNA, called plasmids

d.   **Cell Wall**

Most prokaryotes have a cell wall

All, except one of these classes of monerans have cell walls. The functions of the cell wall are to give the cell shape and protection from an unfavorable environment.

There are 2 types of cell walls. Bacteria are classified y the type of cell wall they have.

1.   Gram-positive cell wall: the gram positive bacteria have a thick peptidoglycan layer with no outer membrane layer.

2. Gram-negative cell wall: have a multilayered and complex cell wall. The outside layer is membrane mad up of lipopolysaccharide with a thin peptidoglycan layer inside.

The antibiotic penicillin inhibits the development of the cell wall. This prevents the reproduction of the prokaryote cell. An enzyme in tears, mucus and saliva dissolves the cell wall which rupturing the cell and killing the bacteria.

    e. Capsule
Some bacteria develop a capsule which is a jelly like coating that surrounds the cell wall. There are four functions of the capsule.
1. prevents the cell from drying out
2. helps the ells stick together or on other surfaces such as the tissues of other organisms
3. help prokaryotes slide on surfaces
4. keeps some bacteria from being destroyed by the host organism,

    f. Flagella
Some prokaryotes have a flagellum or many flagella that provide locomotion. Flagella: these are solid crystal proteins that stick out through the holes in the cell membrane and spin like propellers. Prokaryotic flagella are structurally different from plant and animal cell flagella

    g. Pili
Some bacteria have structures called pili. Pili are short bristle like appendages which have two functions.
1. attach bacteria to surfaces.
2. assist in the transfer of DNA from one bacterium to another.

    h. Eubacteria
1. coccus: sphere shaped
2. bacillus: rod shaped
3. spirillum: spiral shaped
4. spirochetes: spiral shaped with flagella

    i. Advantages of various shapes
1) Being round, cocci allows for less distortion in a dried out organism.
2) Rods have more surface are than the cocci. This allows the rod to take up more nutrients from the environment.
3) Spirochetes are very motile; they move by using a corkscrew motion.

D. Movement of Prokaryotes

Prokaryotes move by way of chemotaxis. Chemotaxis is the movement of an organism towards or away from a chemical. Chemicals that cause the organism to move toward them (positive chemotaxis) are called attractants. Chemicals that induce the organism to move away (negative chemotaxis) are called repellents.

This response has been studied extensively. Chemotaxis suggests some type of sensing and response. Bacterial behavior can be described as a combination of runs and twiddles (tumbles). Run is a steady swim. Twiddle occurs when an organism stops and jiggles in place. This causes a change in direction.

As bacteria experience higher concentrations of the attractant, the twiddling movement becomes less frequent and they run for longer periods of time.

Temporal sensing can explain the above phenomenon. Bacteria sense the environment. There are receptors on the cell which can transfer molecules into the cell. The bacteria swims towards a higher concentration of the attractant.

E. Prokaryote Survival

When environmental conditions are unfavorable, the bacterium becomes inactive. Some species of bacteria form endospores. An endospore is a thick wall that surrounds the genetic material while the rest of the cell disintegrates. The endospore is dormant and doesn't reproduce or show any signs of life, similar to a 'seed.' Endospores can withstand harsh environmental

conditions (boiling, freezing, drying out). When the conditions are favorable, the endosperm germinates to form an active cell.

F. Reproduction
    1. Asexual Reproduction
        a. Asexual fission / Binary fission
        The single loop of DNA is copied, and both loops attach to the cell membrane. The cell grows and divides by pinching between the two DNA loops

    2. Sexual Reproduction
        a. Conjugation
        A bridge is formed between two cells using the pili. Conjugation requires a plasmid called the F plasmid (F for fertility). The F plasmid contains approximately 25 genes and controls the formation of the F pilus. The F pilus is a long, rod shaped structure which will conned the tow different bacteria
        If a bacterium contains the F plasmid, it is known a F^+ cell. If a bacterium does not contain the F plasmid, it is known as an F^- cell. An F^+ cell attaches to an F^- cell with its F pilus. After connecting, the F^+ cell will give a copy of the F plasmid to the F^- cell, making the F^- cell an F^+ cell.

        The F factor can become integrated into the bacterial DNA. When this happens the cell is called an H_{fr} (high frequency recombination) cell. An H_{fr} cell, when attached to an F^- cell, will transport a copy of its DNA to the F^- cell. DNA recombination may then occur in the F^- cell after the H_{fr} DNA has entered it.

        R plasmid: the R plasmid contains genes that make a bacteria resistant to certain antibiotics. These genes can be transmitted, on a plasmid through conjugation, to other bacteria. Once the DNA molecule has been integrated into the main DNA of the cell, the cell is resistant.

        b. Transformation
        A living Bacteria absorbs the genetic material of a dead cell or 'naked' genetic material in the environment

        c. Transduction
        Transfer of DNA from a host to another cell by means of a virus. Viruses are pieces of DNA or RNA, enclosed by a protein coat that can infect bacteria. Their DNA is small and contains information for making proteins involved in infection

        During the lytic cycle of a virus life cycle, the virus makes use of the host cell's resources. All parts of the new viruses are made independently in the host cell and put together prior to lysis. The great number of viruses in a cell will cause the cell to lyse of break and release the newly formed viruses.

        The viral nucleic acid (DNA) is usually incorporated into the host cell's DNA strand as the virus is producing all of the viral parts. The viral nucleic acid is in a long sequence of repeating units. Each unit will be placed in the protein the protein capsid or coat prior to cell lysis. A viral enzyme will cut each viral DNA unit, and this sequence will be packaged into the capsid by another viral enzyme.

        Sometimes a host cell's DNA is cut by the viral enzyme, and this DNA can be incorporated into a capsid. The virus is released when the cell lyses. The virus recognizes and attaches to a new host cell. The virus will then inject the nucleic acid found in the capsid into the new host cell. This DNA (containing bacterial DNA) can integrate with the new DNA of the new host cell.

G. Metabolic diversity in Prokaryotes
    1. Heterotroph
    Organism that is dependant upon outside sources of organic molecules

        a. Photoheterotrophs

Organisms that can use light to produce ATP but they msut obtain carbon from another source. This type of metabolism is only found in prokaryotes

    b. Chemoheterotrophs

The majority of bacteria are chemoheterotrophs. There are three different types.

1) Saprobes: decomposers that absorb nutrients from dead organic material.
2) Parasites: absorb nutrients from the body fluids of living hosts
3) Phagotrophs: ingest food ad digest it enzymatically within cells or multicellular bodies

2. Autotroph

Organism that is able to synthesize organic molecules from inorganic substances

    a. Photosynthetic Autotrophs (Phototrophs)

Organisms that harness light energy to drive the synthesis of organic compounds from CO_2. These organisms use and internal membrane system with light harnessing pigments, (e.g. cyanobacteria, algae, and plants).

    b. Chemosynthetic Autotrophs (Chemotrophs)

Organisms that use energy from specific inorganic substances to produce organic molecules from carbon dioxide and provide life processes

    c. Chemoautotrophs

Organisms that need only carbon dioxide as their carbon source. They obtain energy by oxidizing inorganic substances like hydrogen sulfide, ammonia, ferrous or other ions. This group is unique to prokaryotes

The types of needed nutrients varies, depending on the species. For example, *E. coli*, can grow on a glucose medium. Lactobacillus can grow on a medium of 20 amino acids, several vitamins and other organic compounds. Some bacteria can use petroleum while others can use plastics as nutrients.

3. Oxygen requirements

Oxygen requirements can also be used in classifying prokaryotes.

    a. Obligate aerobes: use oxygen for cellular respiration and cannot survive without it.

    b. Facultative anaerobes: will use oxygen if present, but can grow by fermentation in an environment without oxygen.

    c. Obligate anaerobes: cannot use oxygen and are killed by it.

4. Nitrogen metabolism

Nitrogen is essential in the synthesis of proteins and nucleic acids. Prokaryotes can metabolize most nitrogenous compounds. Some bacteria can convert ammonia into nitrates. Other bacteria can convert atmospheric nitrogen to ammonia: this process is called nitrogen fixation. Cyanobacteria can fix nitrogen. In fact, cyanobacteria only require light carbon dioxide, atmospheric nitrogen, water and some minerals in order to survive. They are among the most self-sufficient of all organisms.

H. ARCAEBACTERIA

Archaebacteria have certain characteristics. Their cell walls lack peptidoglycan, the cell membrane has a unique lipid composition, most live in extreme environments, and they have different ribosomal RNA structure that eubacteria and eukaryotes.

There are three subgroups:

1. Methanogens

Use elemental hydrogen (H_2) to reduce carbon dioxide into methane. They are obligate anaerobes (cannot live in the presence of oxygen). Methanogens live in swamps, marshes and in the anaerobic environment of the guts of animals such as cows, sheep, and camels. They are important as decomposers in sewage treatment plants.

2. Extreme Halophiles (*halo*- salt, *phile*- lover)

These organisms lie in high salinity environments. Colonies of halophiles can color salt ponds pink. This color is due to their photosynthetic pigment called bacteriorhodopsin.

3. Thermoacidophiles

Need environment that is both hot (60-80ºC) and acidic (pH of 2-4). Examples are hot springs, water heaters, and coal piles. Thermoacidophiles have no cell wall and can grow aerobically and anaerobically.

II. FERMENTATION (ANEROBIC RESPIRATION)

A. INTRODUCTION

We know that early organisms looked like bacteria, but how did the first living cells make the energy they needed?

In a primitive environment, with no ozone layer- no barrier against ultraviolet light, organic molecules must have flourished. The first cells probably lived as heterotrophs.
Heterotrophs need to eat or ingest molecules to make energy. With the help of enzymes, these cells degrade complex organic compounds that are rich in potential energy into simpler waste products that have less energy. This process is a catabolic process.

The energy required came in the form of ATP (adenosine tri phosphate). In experiments designed to stimulate conditions of 2.6-3.9 billion years ago (early Achaean), researchers have readily obtained ATP from simple gas mixtures and phosphate. The first cells could have obtained their energy by ingesting ATP.

As the bacteria flourished and reproduced, the supply of ATP became depleted. Cells had to have another method for producing ATP for themselves. Since there was no oxygen, the process was anaerobic (without oxygen). The process that was used is called Anaerobic Respiration or Fermentation.

B. ENERGY

1. **First Law of Thermodynamics**
   Energy can be changed from one form into another, but cannot be created nor destroyed.

   Energy can be stored in various forms then changed into other forms. For example, energy in glucose is oxidized to change the energy stored in chemical bonds into mechanical energy. In all energy conversions some of the useful energy is converted to heat and so dissipates.

   Scientists have developed the notion of potential energy, which is "stored" energy. Molecules contain potential energy in bonds. When the bonds are broken, other bonds form, and some unusable heat is always produced.

2. **Second Law of Thermodynamics**
   In all energy exchanges and conversions, it is proven that if no energy leaves or enters the system under study, the potential energy of the final state will always be less than the potential energy of the initial state.

   a) Exergonic Reaction
      If the reaction releases energy, then the potential energy of the final state is less than the potential energy of the initial state. This type of reaction is called an exergonic reaction. These reactions occur without any energy being added.

   b) Endergonic Reaction
      These reactions need energy to complete the reaction. The energy added is greater than the difference between the reactants and the products.

3. **Entropy**
   Another factor besides the gain or loss of heat affects the change in potential energy- entropy. Entropy means the disorder of a system. The final state has more entropy and less potential energy that the initial state.

C. OXIDATION/REDUCTION REACTIONS

The reactions that occur when an atom gains or loses one or more electrons are called oxidation/reduction reactions. The use of chemical energy in living organisms involves oxidation/reduction reactions.

Oxidation is the loss of an electron. In this example the Fe^{2+} ion has been oxidized; it lost an electron and a negative charge.

$$Fe^{2+} \rightarrow Fe^{3+} + 1e^-$$

Reduction is the gain of an electron. When the oxygen receives an electron, it gains a negative charge.

$$O + e^- \rightarrow O^-$$
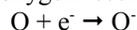
Electron carriers: Some compounds can accept and donate electrons readily, and these are called electron carriers in organisms. There are a number of molecules that serve as electron carriers. One molecule is NAD (Nicotinamide adenine dinucleotide) and is used in anaerobic respiration. NADP (Nicotinamide adenine dinucleotide phosphate) is another used in photosynthesis. These molecules readily give up 2 electrons (oxidized) and gain two electrons (reduced). Along with the electrons the molecules accept 2 hydrogens to offset the negative charge of the electrons.

When the electron moves to a lower energy level, energy is released.

D. ATP

1. ATP as Energy

Cells need energy to drive reactions. The molecule that supplies the energy is ATP (This reaction is called ATP hydrolysis). When the third phosphate is removed by hydrolytic cleavage, 7 kcal of energy is released per mole of ATP.

$$ATP + H_2O \rightarrow ADP + Phosphate + Energy (7 kcal)$$

When the second phosphate is removed, the same amount of energy is released.

$$ADP + H2O \text{-------------}> AMP + Phosphate + Energy (7 Kcal)$$

The bonds between the two phosphates are not strong bonds. In fact, these bonds are easily broken releasing 7Kcal of energy per mole. 7 Kcal of energy is enough to drive endergonic reactions in the cell.

All the energy does not come from the moving of electrons to a lower energy level. In fact, the rearrangement of electrons in other orbitals (i.e. ATP → ADP) result in a structure with less energy.

Enzymes catalyzing the hydrolysis of ATP are ATPases.

Sometimes the terminal phosphate group is transferred to another molecule. The addition of a phosphate group is called PHOSPHORYLATION. Enzymes that catalyze this reaction are called KINASES. In these phosphorylation reactions, energy is transferred from the phosphate group in ATP to the phosphorylated compound. This newly energized compound will participate in other reactions.

2. Production of ATP
ATP originates when anaerobic respiration (fermentation) takes place in the absence of oxygen. What happens is that sugar is broken down into smaller molecules and energy is released. The energy is used to generate ATP from ADP and P.

$$ADP + P \rightarrow ATP$$
$$Sugar \rightarrow Smaller molecules$$
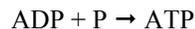
The breakdown of the sugar takes place through a series of chemical reactions. Living organisms have developed numerous and different fermenting pathways; however, most organisms use the following Embden-Meyerhoff pathway, named for the two discoverers.

The anaerobic respiration pathway takes glucose (C6 H12 O2) and breaks it down into two molecules of pyruvate (three carbon compound). This occurs in the cytoplasm of the cell. The pyruvate can take two pathways in anaerobic respiration:

a. Pyruvate will be converted to alcohol (ethanol) and carbon dioxide. This is called alcohol fermentation and is the basis of our wine, beer and liquor industry.
b. The pyruvate will be converted to lactic acid. This is called lactic acid fermentation. Lactic acid is what makes your muscles burn during prolonged exercise, this process is also used to make yogurt.

The overall reaction for alcohol fermentation looks like this:
$$C_6H_{12}O_6 \rightarrow 2 CH_3CH_2OH + 2 CO_2 + Energy$$

E. ANAEROBIC RESPIRATION
There are two phases in fermentation: the first five steps are the energy investment steps and the last 4-6 steps are the energy production steps.

Glucose enters the cell through facilitated diffusion.

1. Initially glucose is phosphorylated by ATP. This step keeps the glucose in the cell.
   Glucose → Glucose-6-P   Enzyme: Hexokinase
             ATP → ADP   Net use of 1 ATP
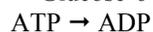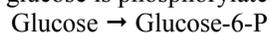
2. Fructose is an isomer of glucose

         Glucose-6-P -------> Fructose-6-P   Enzyme: Phosphoglusoisomerase

3. Another phosphorylization. This is an example of reaction coupling. Fructose-6-P will convert back to Glucose-6-P. However, if phosphorylated immediately, the anaerobic pathway will continue.

         Fructose-6-P -----------> Fructose-1,6-P   Enzyme: Phosphofructokinase

         ATP -------> ADP   Net use of 2 ATP

4. The enzyme Adolase splits the 6 carbon molecule into 2 three carbon molecules.

         Fructose-1,6-P ---------> 2 Glyderaldehyde-3-P   Enzyme: Adolase Pi

5. The electron carrier NAD accepts two electrons from glyceraldehyde (oxidizes the compound). Glyceraldehyde accepts a phosphate (inorganic source0; an exergonic reaction(_G=-10.3 kcal/mole).

         2 Glyceraldehyde-3-P ---------> 2 Diphosphoglycerate-1,3-P

            2NAD ----> 2 NADH   Enzyme; Triosephosphate dehydrogenase

6. A phosphate from Diphosphoglycerate is taken from the molecule and added to ADP to form ATP.

         2 Diphosphoglycerate -----------> 2 phosphoglycerate-3-P

            2ADP →→ 2ATP   Enzyme: Phosphoglycerate Kinase

                                          Net production: 0 ATP molecules

                                          (two used and two produced per

                                          molecule of glucose).

7. Phosphate is transferred to an adjacent carbon.

         2 Phosphoglycerate-3-P ---------> 2 Phosphoglycerate-2-P

                                          Enzyme: Phosphoglyceromutase

8. Water is removed from phosphoglyerate-2-P to form PEP.

         2. Phosphoglycerate-2-P ---------> 2 Phosphoenopyruvate

         Remove water   Enzyme; Enolase

9. The phosphate from phosphoenolpyruvate is removed and added to ADP to form ATP.

         2 Phosphoenolpyruvate -----------. 2 Pyruvate (pyruvic acid)   Enzyme: pyruvate kinase

            2ADP → 2ATP   Net ATP production: 2 ATP

10. A carbon and 2 oxygens are removed from pyruvate to form a two carbon compound called acetaldehyde.

         2 Pyruvate → 2 Acetaldehyde + 2 CO2

11. Acetaldehyde accepts 2 electrons from the NADH molecule. This addition causes acetaldehyde to be converted to ethanol.

         2 Acetaldehyde → 2 Ethanol

            2 NADH → 2 NAD

→12. NADH donated two electrons to pyruvate which is converted to lactic acid.

           NADH → NAD

        2 pyruvate → 2 Lactic Acid

→In anaerobic respiration, the organism invest 2 ATPs into the process and receives 4 ATPs back. The net gain is 2 ATPs.

→In anaerobic respiration, there is a molecule called NAD that received 2 electrons to become NADH. The cell has only a limited supply of NAD and if it is all converted to NADH, the breakdown of glucose would stop. The is over come by converting NADH back to NAD by giving the electrons to acetaldehyde to produce ethanol.

→Fermentation is an inefficient form of making energy. The end product, which are excretions into environment, can still be converted into simpler compounds, releasing more energy.

UNIT III
EUKARYOTIC CELLS / PHOTOSYNTHESIS

CELLS II: EUKARYOTIC CELLS
     →**A**.   **INTRODUCTION TO EUKARYOTIC CELLS**

        Most organisms, the kind usually studied in general biology rather than microbiology classes, are eukaryotic. As a rule, their cells are larger than bacteria and they contain not only a nucleus but also complex organelles and elaborate membrane systems; for example, mitochondria, plastids (in photosynthesizers), undulipodia, Golgi bodies, and the endoplasmic reticulum.

1. Organelles are microscopic structures found in cells; these organelles carry out specific functions. There are two classes of organelles.
    a. →Those that contain their own DNA and genes. Mitochondria and plastids are organelles that reproduce by dividing like independent cells.
    b. Those that do not contain their own DNA; For example, endoplasmic reticulum, ribosomes, Golgi bodies, undulipodia.
    →Unlike prokaryotes, most eukaryotes are capable of cell eating (phagocytosis) and cell drinking (pinocytosis). In times of scarcity, some of the cells can make thick walled, desiccation resistant cysts in which they reproduce and wait for a more favorable condition. Some single celled eukaryotes form poison darts (trichocysts or toxicysts) that they use to sting their prey.
2. *Origins:* What did the first eukaryotic cells look like? When did the first eukaryotes appear? How did they form?
    →We can not answer these questions with any certainty. The first eukaryotic cells were probably protests that were anaerobic, aquatic, unicellular organisms. Giardia trichomonads and microsporidia are all eukaryotic cells without mitochondria; they appear to be some of the oldest eukaryotes.
    →It is extremely difficult to trace the origin of eukaryotic cells through fossils. Most of the primitive eukaryotes live in the sea or in the pond water, formed no hard parts, and their soft bodies broke open when they died. Most of the studies of primitive eukaryotes come from studies of modern ones. This lack of fossil evidence makes it hard to date the appearance of he first eukaryotic cells. We know they must have evolved before the larger and more advanced eukaryotes. We estimate that the first eukaryote appeared one billion years ago.
    →This leaves the last question: how did eukaryotic cells first develop? There is a theory of eukaryotic cell development that involves symbiosis. Symbiosis is a relationship in which two organisms live in close physical proximity to one another for the most of their life cycle.
    →The symbiotic theory of eukaryotic cell evolution states that independent bacteria joined together, casually at first, then in a more stable association. As time passed, and as evolutionary pressures favored these symbiotic relationships, the partner microbes became permanently joined in a new cell composed of interdependent components. According to this theory three classes of organelles (plastids, mitochondria, and undulipodia) once lived as independent prokaryotes. For example, the mitochondrion was a small prokaryote that could use oxygen to produce energy. This prokaryote needed protection from predators and hid inside a larger prokaryote. The larger prokaryote received energy from the pre-mitochondria cell and could live in an oxygen rich environment, and the pre-mitochondria cells were protected by the larger prokaryote.

→→**B. NUCLEUS**

The nucleus is the most prominent and the most easily stained of organelles in the cell – averaging about 5 mm in diameter. The nucleus contains the chromosomes composed of nucleic acids or DNA. RNA, another nuclei acid, is also found in the nucleus. The DNA is associated with proteins (histone) and forms chromatin can be packaged into at least two chromosomes and some cells have up to 1,000 chromosomes.
→This is a distinct membrane that separates the nucleus from the cytoplasm; the nuclear membrane (envelope). The nuclear envelope is a double membrane. The two membranes are separated by a space of about 20 to 40 nm. Associated with the nuclear side of the envelope is a layer of proteins that help maintain the shape of the nucleus and which may also help maintain the organization of the genetic material. The envelope has a direct influence on the development of chromosomes. The phosphate groups of DNA strands are negatively charged and repel each other. However, the fluid of the nucleus contains a high concentration of sodium ions ($Na+$), higher that the rest of the cell. The sodium ions neutralize the repelling phosphate groups, and allow DNA to coil tightly.
→The nuclear membrane contains pore complexes that allow materials to move in and out of the nucleus.

→**C. NUCLEOLUS**

This is a dense, irregularly shaped body in the nucleus. The nucleolus makes and stores RNA. Each nucleolus will form new ribosomes. Sometimes there are two or more nucleoli.

→**D. MITOCHONDRIA**

1. →**Description**

These are small, distinct, oval shaped, double membrane bounded bodies, 1 to 10 m long, that float in the cytoplasm. Mitochondria are some of the largest organelles in the cell. They contain their own DNA that resembles bacterial DNA. If this DNA mutates, then the mitochondria usually become inactive, this maybe a cause of cell aging as less energy becomes available.

→Time-lapse films of living cells reveal mitochondria moving around, changing their shapes, and dividing into two.

→Eukaryotic cells contain many mitochondria. A higher concentration of mitochondria is found in cells such as muscle cells that produce more energy. They are potent generators of ATP. Mitochondria can produce 36-38 ATP molecules per molecule of glucose in anaerobic respiration.

→The mitochondrial matrix is the compartment enclosed by the inner membrane. Many of the metabolic steps of cellular respiration occur in the matrix, where various enzymes are located.

2. →**Origin**

As the oxygen concentration of the atmosphere increased, non-photosynthetic respiring microbes evolved and they were dependent upon oxygen to produce energy. It is believed that free living anaerobic bacteria that looked similar to the modern mitochondria at first established casual relationships with larger anaerobic bacteria. Maybe the first casual relationship was that of a predator and prey, the mitochondria being the predator which bored into the larger prokaryote.

Some anaerobes developed a tolerance for their predators, which resides for extended periods in the interior of the anaerobe host cell. This tolerance would have required the protection of the host cell's DNA from oxygen. The host cell would have had develop a nuclear membrane or other mechanism to shield the DNA from the poisonous gas. If this theory is correct, such a partnership would be favored as the oxygen concentration in the atmosphere increased. The host cell would use the products of the aerobes metabolism while the anaerobe lived in a rich soup, the waste products of the host fermentation, and the aerobes were sheltered. After some time, the host became dependent upon their former enemies and their guests gave up their individual lifestyle.

E. PLASTIDS

These organelles became integrated in the same manner as the mitochondria- some eukaryotic cells acquired other bacteria. These bacteria added photosynthetic powers to the host cell. Like the bacteria that became dependent upon mitochondria, the photosynthetic partners eventually grew dependent upon their host or became integrated into the host cells as plastids.

There are three types of plastids:

0 **Leucoplasts**
White in color-found in roots and tubers.
1 **Chromoplasts**
Many colors-contain accessory pigments.
2 **Chloroplasts**
Green in color-found in leaves and stems.

The chloroplasts has two membranes which are responsible for its photosynthetic functions. The inside of the double membrane are flattened, membranous discs known as thylakoids from stacks called grana and are surrounded by a matrix called the stroma. As with mitochondria, the chloroplasts move around the cell and occasionally pinch in two to divide.

F. RIBOSOMES

These are non-membrane bounded organelles that are the most numerous of the cell organelles. Ribosomes are sites where proteins are synthesized. They translate the mRNA code into proteins. Made of RNA and proteins, there are three classes of ribosomes named for their size.

0 **70S**
Found in prokaryotes. These ribosomes are smaller than eukaryotic ribosomes and have a slightly different molecular composition.
1 **70S (o)**
Associated with eukaryotes and their organelles (endoplasmic reticulum). These ribosomes generally make proteins that are destined either for inclusion into the membrane or for export from the cell.
2 **80S**
Found in the cytoplasm in eukaryotes.

70S (o) are similar to bacterial ribosomes. Chloroplast and mitochondrial ribosomes are similar to, and smaller than, prokaryotic 70S ribosomes.

The difference in ribosomes is medically significant. Certain drugs can paralyze prokaryotic ribosomes without inhibiting the ability of eukaryotic ribosomes to make proteins. These drugs, which include tetracycline and streptomycin, are used as antibodies to combat bacterial infections.

G. ENDOPLASMIC RETICULUM (ER)

The word 'endoplasmic' means "within" the cytoplasm, and 'reticulum' is derived from the Latin word meaning "network." It is complex membrane system that takes up a large part of the cytoplasm in eukaryotic cells. The endoplasmic reticulum is a network of interconnecting flattened sacs, tubes, and channels that, along with attached ribosomes, are engaged in protein synthesis, transport, and modification. The amount of ER can increase or decrease depending on the cell's activity.

The ER is a dynamic organelle that changes its structure. It is often continuous with the cell membrane and the outer membrane of the nucleus. This whole system of ER, golgi body, and nuclear membrane is sometimes called the *endomembrane* system.

The membranes of the endoplasmic reticulum have the same basic structure as the cell membrane. Sometimes the membrane can balloon out and pinch off to become closed sacs or vesicles.

0 **Two main types of Endoplasmic Reticulum**
0 **Rough ER (RER)**
This is associated with ribosomes and is the site of protein and glycoprotein synthesis. Most secretory proteins are glycoproteins (proteins that are covalently bonded to carbohydrates). In the cisternal space the carbohydrate is attached to the protein by enzymes built into ER membrane. The carbohydrate appendage of a glycoprotein is an oligosaccharide.

In addition to making secretory proteins, the rough ER is a membrane factory that grows in place by adding proteins and phospholipids to itself.

1 **Smooth Endoplasmic Reticulum (SER)**
This is not associated with ribosomes. It is found in cells that synthesize, secrete, and/or store carbohydrates, steroids, hormones, lipids, or other non-protein products.

2. Functions of the Endoplasmic Reticulum
0 The ER provides some internal framework of the cell. It gives the cell some support.
1 The ER provides a means of transporting materials through the cell via a canal system rather than by diffusion.
2 The ER and ER vesicles provide a way of storing material.
3 Large proteins are synthesized in the ER and the proteins are either:
0 Secreted
1 Become part of the cell's biochemical processes
2 Integrated into the cell membrane
4 Membranes are synthesized in the ER.
5 Phospholipids are synthesized

The ER forms close associations with other organelles, such as mitochondria, chloroplasts, and lysosomes. These associations are probably related to intercellular transport.

The ER is an extension of the outer membrane of the nucleus. In the RER, each flattened sac is known as a cisterna. The inside is the lumen (center). Tubular SER can form vesicles that contain lipids, hormones, pigments, oils, and cholesterol.

H. GOLGI COMPLEX (BODIES0

These were discovered in 1980 by Camillo Golgi, an Italian cytologist. The Golgi complex is highly variable. A cell may produce a lot of Golgi structures; then they may disappear.

0 **Basic Structure**
The Golgi Complex consists of flattened membranous sacs that are stacked together. Each flattened sac is called a cisterna. The interior of each sac is the lumen.

The Golgi apparatus generally has a distinct polarity, with the membranes of cisterne at opposite ends of a sac differing in thichness, molecular composition, and function. The two poles of a Golgi stack are referred to as the CIS FACE (the forming face) and the TRANS FACE(the maturing face).

The cis face is usually located near the ER. Transport vesicles move material from the ER to the Golgi. A vesicle that buds from the ER will add its membrane and its contents to the cis face by fusing with the Golgi membrane. The trans face gives rise to vesicles, which pinch off from and travel to other sites. During the transit from the cis pole to the trans pole of the Golgi products of the ER are modified.

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Osmotic pressure is zero if the solute concentration on both sides of the selectively permeable membrane are equal. If there is a barrier that prevents the hypertonic solution in a cell from expanding, the solution in the cell will exert an increasingly greater outward pressure.

As the pressure increases, the flow of water molecules into the hypertonic solution decreases. The pressure required to stop the osmotic movement of water into a solution is called osmotic pressure. The lower the water potential, the more water that can move into the cell by osmosis; thus the greater the osmotic pressure that will develop.

Plant cells have a central vacuole filled with solutes and thus have a lower water potential than the surroundings. Therefore water enters the cells. In mature cells, the cell wall does not expand. Since the wall does not expand, it exerts an inward pressure, called cell wall pressure, on the solution. This pressure prevents the net movement of water molecules into the cell. However, the cells remain hyperosmotic to the environment and the tendency of water molecules to continue to move into the cells keeps the plant cells fully hydrated and turgid. This internal pressure outward is called turgor pressure and keeps the cell rigid. If water is not available, turgor pressure falls because water leaves the cells and the plant wilts.

d. Facilitated Diffusion

Since the lipid layer is amphipathic, most polar molecules cannot pass through the nonpolar region. Since most organic molecules are polar, they are unable to pass through the cell membrane by simple diffusion. For example, glucose enters cells by facilitated diffusion. This process does not require energy.

The transport of largely hydrophilic molecules across the cell membrane depends upon integral membrane proteins called transport proteins. The transport proteins are highly selective. The tertiary and even quaternary structures of the transport proteins determine which molecules are transported. These transport proteins are called permeases.

Types of transport proteins.
1)*Uniport:*carries a single molecule across the membrane.
2)*Symport:* moves two different molecules at the same time in the same direction. Both molecules must bind to the protein for transport.
3)*Antiport:* exchanges two molecules by moving them in opposite directions.

These proteins can be inhibited by molecules that resemble the molecule normally carried by the protein.

e. Active Transport

This type of transport requires energy and membrane proteins. Active transport occurs in situations where a substance is moved across the cell membrane and against its concentration gradient.

f. Vesicle Mediated Transport

Vesicles or vacuoles can fuse with the cell membrane. Vesicles formed inside the cell can move to the cell membrane, fuse with the outer cell membrane, and expel their contents outside the cell into the surroundings. This process is called exocytosis. In exocytosis, vesicles formed at the surface of the cell can capture substances outside the cell, and deposit their contents into the cell. There are three types of endocytosis.

1)*Phagocytosis* (cell eating): When the substance taken into the cell is a solid, the process is called phagocytosis. A vesicle forms around the object taken into the cell. Once the solid is in the cell, a lysosome joing with the vesicle and enzymes digest the solid.
2) *Pinocytosis* (cell drinking): When the substance taken into the cell is a fluid, the process is called pinocytosis.
3)*Receptor mediated Endocytosis:* The molecule attaches to a specific receptor on the cell surface before a vesicle forms around the molecule.

g. Cell-Cell junction

In multicellular organisms, cells are organized into tissues. Cells need to communicate with each other directly. Some communications are accomplished by chemical signals produced by the cell. They are thenexported through exocytosis, moved into the target cell or activate a second messenger within the target cell which will complete the message.

M. CYTOSKELETON

1. Background
   a. All cells have a distinct shape that varies with time and function. The cytoskeleton may enable a cell to change its shape.
   b. Cells have a high degree of internal organization. Organelles have patterns and form relationships that often change. Organelles and even cytoplasmic enzymes may be held in place by anchoring them to the cytoskeleton. Organelles can also be transported along the cytoskeleton which acts like a 'railroad track'.
   c. Some cells have the ability to move. Movement of organisms like ourselves depends on the same mechanisms used by the cells.

2. Three Characteristics Of the Cytoskeleton
   a. Cytoskeleton elements are non-membrane bounded organelles.
   b. Most cytoskeleton organelles have the ability for self-assembly
   c. The cytoskeleton organelles have no specific lengths.

3. Functions and Characteristics of the Cytoskeleton
   a. They are involved with the transport of organelles and cytoplasmic streaming.
   b. The organelles transport soluble products.
   c. They are altered when the cell comes into contact with a substrate; this may allow for cell to cell communication.
   d. These organelles are not dependent on the nucleus for assembly.
   e. The organelles for the cytoskeleton are inherited maternally.

4. Three Organelles that make up the Cytoskeleton
   a. Microtubules
   b. Actin fibrils
   c. Intermediate fibrils

5. Microtubules
   a. These are about 25nm in diameter.
   b. Microtubules are 200nm to 25mm in length.
   c. The microtubules are hollow tubes that are constructed from globular proteins called tubulins. A microtubule may elongate by the addition of tubulin proteins to one end of the tubule. Microtubules may be disassembled and their tubulin used to build microtubules elsewhere in the cell.
   d. These may exist in singles, groups, or complex arrangement.
   e. They are composed of alpha and beta tubulin dimers.

Microtubules extend outwards from an organizing center (centrosome) that is near the nucleus to near the cell surface. Plants do not have centrioles.

6. Functions of Microtubules
   a. Microtubules play an important role in cell division. They move things within the cell; for example, chromosomes during mitosis. Mitochondria, plastids and vesicles can move along microtubule tracks.
   b. They help maintain the structure of the cell. It is believed that microtubules act as a temporary scaffolding for the construction of other cell structures.
   c. Microtubules probably guide secretory vesicles from the Golgi complex to the plasma membrane.
   d. Cilia and flagella are formed through a specialized arrangement of microtubules. Microtubules are associated with motor proteins called dynein and kinesin.

7. Microfilaments- Characteristics and Functions
   a. They are 6-7nm in diameter
   b. Microfilaments are composed of the protein actin in helical chains (globular protein subunits).
   c. They are involved with cytoplasmic streaming and pseudopodia movement.
   d. They help arrange organelles
   e. Microfilaments such as actin, and myosin are the main component of muscle cells. Microfilaments are best known for their role in muscle contraction. 10% of all the protein in a cell is actin. Actin filaments are associated with motor proteins called myosin.

8. Intermediate Fibrils- Characteristics and Function
   a. They are 8-12nm in diameter.

b. Intermediate filaments comprise a diverse class of cytoskeletal elements, differing in protein composition from one type of cell to another.
c. Intermediate fibrils are permanent and very stable.
d. There are 5 classes of intermediate fibrils.
e. They radiate from the nuclear envelope and associate with microtubules- forming a cage in which the nucleus sits.
f. Experiments suggest that intermediate filaments are important in reinforcing the shape of a cell and fixing the position of certain organelles.

N. HOW CELLS MOVE

All cells show some type of movement. Cytoplasmic streaming, movement or chromosomes, and changes in shape are examples of movement that occur within the cell.

Some cells move in their environment. Two different mechanisms are responsible for assembly.
1) Assemblies of cilia and flagella (undulipodia).
2) Assemblies of micro filaments (actin proteins).

1. Undulipodi: Cilia and Flagella

Undulipodi move the eukaryotic cell by undulating. There is no structural difference between eukaryotic flagella and cilia. If a protist has a flagellum, it is classified with the flagellates. If a protist has cilia, it is a ciliate. Flagella are longer and few per cell. Cilia are shorter, beat differently and are usually abundant.

Undulipodia seen in a cross section are about 0.25 mm in diameter and how a circle of pairs of microtubules (minute cylinders). There are nine fused microtubules that form a ring surrounding two additional fused microtubules (in the center). Microtubules are composed of tubulins.

Traces of RNA have been found inside the base of the undulipodium. It is hypothesized that unduliodia were once free living spirochetes. These spirochetes formed association with heterotrophic protists. The spirochete began to propel the host through the environment. There is a weakness in this theory; no genetic material has been found in the undulipodia. The genes that determine the amino acid sequence of the tubulin proteins that make up the undulopodia are found in the nucleus of the cell.

2. Basal Bodies and Centriole

a. Basal Body

These structures have the same diameter as cilia (about 0.2mm). They are composed of microtubules arranged in nine triplets instead of pairs. Cilia and flagella are formed from basal bodies.

b. Centriole

These are small cylinders (about 0.2mm) which contain nine microtubule triplets (identical to the basal bodies). Distribution in the cell is different. Within the centrosome of an animal cell are a pair of centrioles. When a cell divides, the centrioles replicate.

In a nondividing animal cell, centrioles lie in pairs at right angles to each other near the nuclear envelope, where the microtubules radiate. During cell division, centrioles organize the spindle. The spindle appears at the time of cell division and is involved with chromosome movement during mitosis. The spindle is composed of numerous microtubules.

Centrioles are not required for spindle formation. Plant cells, which lack centrioles, form spindles.

3. Actin and other Proteins

In cells that exhibit movement, actin is associated with a motor protein called myosin. These proteins are found in organisms that exhibit cytoplasmic streaming. Actin has been found in concentration bundles near the moving edge of the cell. Actin also helps pinch a dividing cell into daughter cells during animal cell division.

Actin and myosin are the contractile proteins found in vertebrate muscle cells.

O. CELL SURFACE

1.Cell Walls

One of the features that distinguishes plant cells from animal cells is the cell wall. The cell wall protects the plant cell, maintains its shape, and prevents excessive uptake of water.

Plant cell walls are much thicker than the plasma membrane and range from 0.1 to several um. Although the exact chemical composition of the wall varies from species to species and from one cell type to another in the same plant, the basic design of the wall is consistent. Fibers made of the polysaccharide cellulose are embedded in a matrix of other polysaccharides and protein.

A young plant cell first secretes a relatively thin and flexible cell wall called the primary cell wall. Between the primary walls of adjacent cells in the middle lamella, a thin layer rich in sticky polysaccharides is called pectins. The middle lamella glues the cells together. When the cell matures and stops growing, it strengthens its wall. Some cells do this by secreting hardening substances into the primary wall. Other plants cells add a secondary wall between the cell membrane and the primary wall. The secondary wall, made of several layers, has a strong and durable matrix that affords the cell protection and support. Wood consists of mainly secondary walls.

2. Glycocalyx

Animal cells lack structured walls, but many have a fuzzy coat called the glycocalyx. The glycocalyx is made of sticky oligosaccharides. The glycocalyx strengthens the cell surface and helps glue the cells together. The olgisaccharides also contribute to cell cell recognition by serving as unique identification tags for specific types of cells.

3. Intracellular Junctions

The many cells of an animal of plant are integrated into one functional organism. Neighboring cells often adhere, interact, and communicate through special patches of direct physical contact. The walls of plants are perforated with channels called plasmodesmata through which strands of cytoplasm connect the living contents of adjacent cells. In animals there are three main types of intracellular junctions: tight junctions, desmosomes and gap junctions.

AEROBIC RESPIRATION

Aerobic Respiration, the production of energy in the presence of oxygen, occurs in the mitochondria. Aerobic respiration produces 12-36 ATP molecules per molecules of glucose. Compare this to the 2 ATP molecules which are produce in anaerobic repiration.

A.   **INTRODUCTION TO AEROBIC RESPIRATION**
1.   **Glucose**

Although carbohydrates, fats and proteins can ll be processed and consumed as fuel, we usually track glucose in the production of energy. The breakdown of glucose is exergonic, having free energy change of -686 kilocalories per mole of glucose (recall that negative_G indicates that the products of the chemical reaction store less energy that the reactants).

2.   **Energy**

This energy is stored as ATP. ATP is the chemical equivalent of a loaded spring; the close packaging of the three negatively charged phosphate groups ia an unstable, energy-storing arrangement (like charges repel). The chemical "spring" tends to "relax" from the loss of terminal phosphate. The cell taps this energy source by using enzymes (kinases) to transfer phosphate groups from ATP to other compounds, which are then said to be phosphorylated. Adding the phosphate primes a molecule to undergo some kind of change that performs work, and the molecule loses its phosphate group in the process.

In order to understand the process of making energy, we must briefly review redox reactions.

a. Reduction

Gaining electrons,hydrogen or losing oxygen.

b. Oxydation

Losing electrons, hydrongen or the gaining ofoxygen. An electron loses potential energy when it shifts from a less eletronegative atom towards a more electronegative one. A redox reaction that relocates electrons closer to oxygen realeases chemical energy which can be put to work.

In the combination of glucose, sugar is oxidized and oxygen is reduced. Meanwhile, electrons lose potential energy along the way.

c. Changing in Covalent Status

Usually, organic moelcules that have and abundance of hydrogen are excellent fuels because their bonds are a source of electrons with high potential energy. They also have the potential to drop the energy when they move closer to oxygen. The important point in aerobic respiration is the change in covalent status of electrons as hydrogen is transfered to oxygen.This is what liberates the energy.

At key steps in aerobic respiration, hydrogen atoms are stripped from glucose, but they are not directly tranferred to oxygen. They are passed to a coenzyme called NAD+ (nicotinamide adenine dinucleotide) which functions as the oxidizing agent.

Enzymes called dehydrogenases remove a pair of hydrogen atoms from the substrate. These enzymes deliver two electrons along with one proton to NAD+, forming NADH. The other proton is released as a hydrogen ion into the surrounding solution.

Electrons lose very little potential energy when they are transferred by dehydrogenases from glucose (organic molecules) to NAD+. Thus, each NADH molecules formed during respiration represents stored energy that can be used to make ATP when the elctrons complete their journey from NADH to oxygen.

3. Mitochodria Review

The mitochondria is surrounded by two membranes. The outer is smooth and the inner folds inwards. The inner folds are called cristae. Within the inner compartment of the mitochondrion, surrounding the critae, there is a dense solution known as the matrix. The matrix contains enzymes, co-enzymes, water, phosphates, and other molecules needed in respiration.

The outer membrane is permeable to most small molecules, but the inner one permits the passage of only certain molecules, such as pyruvic acid and ATP.

Proteins are built into the membrane of the cristae. These proteins are involved with the Elctron Transport Chain. The inner membrane is about 80% protein and 20% lipids. 95% of the ATP generated by the heterotrophic cell is produced by the mitochondrion.

B. GLYCOLYSIS

. The first step in aerobic respiration is called Glycolysis closely resembles anaerobic respiration

1. Overall Reaction

Glucose ----------------------------------> 2 pyruvate + 2 ATP

2. Steps

ATP ----> ADP

1) Glucose ------------------------------> Glucose-6-P

2) Glucose-6-P ------------------------> Fructose-6-P

                    ATP-----> ADP

3) Fructose-6-P ------------------------> Fructose-1,6-P

                    Enz: Aldolase

4) Fructose-1,6-P -----------------------> 2 3-Phosphoglyceraldehyde

                    P1--------->

5) 2 3-Phosphoglyceraldehyde ---------> 2 1,3-Diphosphoglycerate

                    NAD+ -----------> NADH

                    2ADP------------> 2 ATP

6) 2 1,3- Diphosphoglyceraldehyde ----> 2 3-Phosphoglycerate

7) 2 3-Phosphoglycerate ------------------> 2 2-Phosphoglycerate

8) 2 2-Phosphoglycerate ------------------> 2 2-Phosphoenolpyruvate + H2O

   2 ADP ----------> 2 ATP
9) 2 2-Phosphoenolpyruvate -------------> 2 Pyruvate

The products NADH and Pyruvate are formed in the cytoplasm of the cell. The remainder of the aerobic respiration takes place in the mitochondria.

Note: NADH cannot enter the innner chamber of the mitochondrion, but it can ass its electrons to a shuttle carrier on the surface o the inner membrane and build up a supply of interior electrons. The pyruvate can enter the mitochondrion. Here the pyruvate is altered so that it can take part in the rest of the process.

C. PRODUCTION OF ACETYL COA

Pyruate can be further oxidized. The carbon and oxygen atoms of the carboxyl group are removed and two acetyl groups are left. These react with NAD+, give two electrons to NAD+ (tgis is converted to NADH), and CoA adds on to form Acetyl CoA, a large complex molecule from pantothenic acid (vitamin B)

2 pyruvate + 2 NAD + 2 Co-enz A ---> 2 Acetyl CoA + 2 NADH + 2 CO2
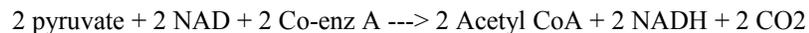
From here the Acetyl CoA can enter the Krebs (TCA , Citric Acid) Cycle (discovered in 1930 by Hans Krebs). Acetyl CoA moves into the mitochondria and is completely dismantled by the enzymes in the mitochondria.

D. KREBS CYCLE

As he Krebs Cycle dismantles pyruvate, CO2 is produced. The carbon and oxygen come from the pyruvate, which is being torn apart. The electrons are what's important.

The Krebs Cycle only gives us two molecules of ATP. Added withe the two molecules of ATP made in Glycolysis, the total is now a meager four molecules of ATP. The remainder of the ATPs come from the Electron Transport System, which takes the elctrons produced in the Krebs Cycle and makes ATP.

There are nine steps in the Krebs Cycle and the aim is to totally dismantle the Acetyl CoA using only its electrons. Here are the steps:

1) 2 Acetyl CoA + 2 Oxaloacetate + 2 H2O ----> 22 Citrate + 2 CoA

2) 2 Citrate ----. 2 cis-Aconitate + 2 H2O

3) 2 cis-Aconitate + 2 H2O -----------> 2 Isocitrate

4) 2 Isocitrate + 2 NAD+ ------------> 2 Oxalosuccinate + 2 NADH

5) 2 A-Ketoglutrate + 2 CoA + 2 NAD+ ---> 2 Succinyl CoA + 2 CO2 + 2 NADH
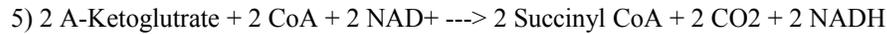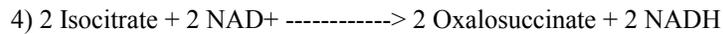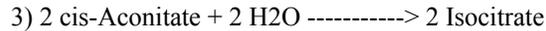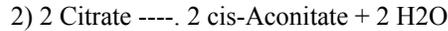
In the next reaction, the high energy bond is formed. GDP is changed to GTP (Guanine instead of Adenine) as the CoA is released. We don't know why the cell uses GDP instead of ADP , but the terminal phosphate in the GTP is tranferred to ADP in order to form ATP.

6) 2 Succinyl CoA + 2 P + 2 GDP ----> 2 Succinate + 2 CoA + 2 GTP
2 GTP + 2 ADP ----------> 2 GDP + 2 ATP

7) 2 Succinate + 2 FAD ------. 2 Fumarate + 2 FADH2

8) 2 Fumarate + H2O ------> 2 Malate

9) 2 Malate + 2 Nad+ ----------> 2 Oxaloacetate + 2 NADH
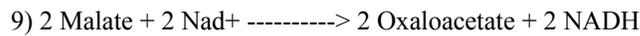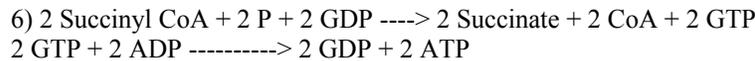
We have totally taken apart the glucose molecule. Only four ATPs have resulted, 2 from glycolysis and 2 from the GTPs. But we still have a lot of hydrogens in the form of NADH and FADH2 and a lot of electrons.
Total electrons carriers:

Glycolysis (fermentation)	2 NADH
Pyruvate to Acetyl CoA	2 NADH
Citric Acid Cycle	
Step 4	2 NADH
Step 5	2 NADH
Step 7	2 FADH2
Step 9	2 NADH
Total	24 Electrons

The electtrons will go through the elctron transport chain to produce energy, and the hydrogen ions will pass into the outer compartment of the mitochondria.

E. ELECTRON TRANSPORT CHAIN

As stated before , the mitochondria has two sets of membranse. The outer membrane is simple in the sturacture and highly permeable. The inner membrane is highly convoluted and forms extensive folds / shelves call critae that reach into the center of the organelle. The folding of the inner membrane allows for thousands of protein chain copies in each mitochondrion.

The proteins contain prothetic gouprs(Nonprotein components essential for catalytic functions of enzymes). These groups are oxydized and reduced.

The inner membrane is impermeable to H+ and many other substances. The membrane is mostly a protein membrane that is bound together by phospholipids. The enzyme carrier of the electron transport system are tightly packes within the inner membrane.

The ETC begins with th electron flow from NADH to FMN (flavin mononucleotide0. MN passes the 2 electrons to an iron-sulfur (Fe-S) protein. Fe-S passes the two electrons to a small carrier co_enzyme ubiquinone (Q). Q takes the two electrons from Fe-S and two hyrogens from the inner compartment and becomes QH2. Qh2 diffuses across the membrane to release two H+ and passes the two electrons to Cytochrome b(cyt b) . Cyt b passes the two electrons to another Fe-S group which, in turn, passes the electrons to cytochrome C1. C1 passes the elctrons to cytochrome c (cyt c). Cyt c passes the electrons to

cytochrome a (cyt a) which passes the electrons to cytochrome a3 (cyt a3). Finally the two electrons are accepted by oxygen and by removine 2 H+ from the interior compartment, are converted to H2O.

If FADH2 is the electron carrier, FADH2 passes its electrons to Fe-S ----> Q

F. OXYDATIVE PHOSPHORYLATION; CHEMIOSMOTIC COUPLING

Production of ATP from ADP and P is powered by a proton gradient. This mechanism is known as chemiosmotic coupling. Chemiosmotic refers to the fact that the production of ATP molecules is a chemical process and a transport process across a semipermeable membrane.

Two events take place in chemiosmotic coupling:
1) The proton gradient is established across the inner mitochondiral membrane
2) Potential energy stored in the gradient is released and captured to form ATP   from ADP and Phosphate.

The proton gradient is established as electrons as electrons move down the ETC. At three different times in the ETC, there is a significant drop in potential energy held by electrons. These are the three reactions: Fe-S->Q CytC1-> Cytc ,and Cyt a3-> O2. As a result relatively large amount of energy is released. This energy powers the pumping of H+ from the mitochondrial matrix through the inner membrane to the space that separates the inner and outer membrane. One in that space, the protons are free to leave the mitochondrion.

The electron carriers in the chain are positioned so that the electrons travel in a zig zag manner-- from the inner to the outer surface of the inner membrane. Each time the electrons travel to the inside surface, the electrons pick up two H+. When the electrons travel to the outer surface, they release two H+. The actual number of protons moved is not known. It is known, however, that at least six protons are moved.
The difference in the proton gradient on the outside of the inner membrane represents the potential energy. The potential energy results from a difference in pH and electric charge. H+ flow through the channels, ATP is formed from ADP and phosphate. It is not known how many flowing H+ it takes to form an ATP molecule (3 ATPs from 1 NADH and 2 ATPs from FADH2).

Oxygen acts as the final electron acceptor. Once the oxygen accepts the electrons, it is converted into water. That is why you need to breathe oxygen. If oxygen were not there to accept the electrons, the electron transport system would get backed up, no energy would be produced, and without energy there would be no life. Cyanide is a powerful poison because it blocks the transfer of electrons from cyt a3 to oxygen.

The elctron transport syustem produces 17 to 32 molecules of ATP. Add this to the previous total of four ATP molecules produce in Glycolysis and the Krebs Cycle, and we now have a total of 21 to 36 molecules of ATP from each molecule of glucose oxidized.

Oxygen is used as the final electron acceptor. Carbon dioxide is produced during the Krebs Cycle and most of the energy is produced from the ETC and H+ concentration / gradient.

G. OTHER CATABOLIC PATHWAYS

Starch is broken down into monosaccharides. The monosaccharides are phosphorylated to glucose-6-P and enter glycolysis.

Fats are split into glycerol and fatty acids. The fatty acids are cut up into two carbon fragments and slipped into the Krebs Cycle as Acetyl CoA. Glycerol slips in as Glyceraldehyde-3-P.

Proteins are broken Down into Amino Acids. Amino acids have the amino group removed. The carbon skeleton is either converted into acetyl group or a larger compound that can enter glycolysis. If the amino group is not used, it is excreted as urea.

H. HOW ELSE CAN THIS AFFECT YOU?
In the muscle tissue, there are a lot of mitochondria. During heavy exertion a great deal of ATPs can be used. Muscle systems usually work aerobically; but, in larger animals, it is impossible for the circulatory system to bring enough oxygen tot eh tissues during heavy exertion. Therefore, we have two back up systems.

1) Creatine Phosphate
This transfers a phosphate to ADP in order to form ATP. Creatine Phosphate + ADP ----> Creatine + ATP. As the Creatine phosphate is used up, there is another quick source of energy.

2) Anaerobic Glycolysis
NADH combines with pyruvate to form lactic acid (lactate0. Lactic acid accumulates quickly during intensive use of muscles. This is the burn that is felt when excercising. Animals can remove lactic acid in two ways.

a. Lactic acid combines with oxygen to form the circulatory system. The oxygen reverses the lactic acid to pyruvate which proceeds in the aerobic pathway.
b. lactic acid can be washed away by the circulatory system and carried to the liver. In the liver, the lactic acid can be metabolized back into glucose with oxygen.

After periods of heavy exertion, the muscle tissue will be depleted of creatine phosphate and the liver and muscles will be loaded with lactate. This causes pain. When the activity stops, it takes a long time, and lots of oxygen and ATP, for the lactic acid to be metabolized and for the creatine to regenerate into creatine phosphate.

During this time, a person will breathe hard and try to take in as much oxygen as possible. This is called oxygen debt. How long it takes to recuperate depends on physical condition. The better condition people are, the more oxygen they can take in and the heart can pump more blood with the oxygen to their tissues. Runners enlarge their lung capacity, increasing their capillary beds. The heart becomes stronger and can pump more blood with each stroke, which increasing the ability for runners to utilize oxygen.

Remember that starch and glycogen are polymers of glucose. These polymers are broken down into single glucose molecules during a process called phosphorolysis. During this process the bond is split by an enzyme that places a phosphate on the #1 carbon of the glucose molecule. This makes Glucose-1-P which changed to Glucose-6-P

Runners in the marathon who have hit 'the wall' have used up all of the glucose in their bodies. All that is left are fat and proteins which will be broken down for energy. This is very dangerous since the heart is a muscle that is made up of protein. This is why runners try to load up with carbohydrates before a big race.

III. PHOTOSYNTHESIS
This process of making glucose from inorganic substances is called photosynthesis. Certain types of bacteria, called cyanobacteria, Contain thylakoids that carry on the processes of photosynthesis.

A. REQUIREMENTS OF PHOTOSYNTHESIS
Photosynthesis requires carbon dioxide, water, and sunlight. The carbon dioxide and water provide the necessary elements to make glucose, while light is the energy source for the process.

In all photosynthetic organisms, two separate sets of chemical reactions make up the whole photosynthetic process. The first step is called light independent reaction (light reaction). The second step is called the light independent reaction (dark reaction).

B. LIGHT REACTION
1.   Chlorophyll and other Pigments
Light must be absorbed to be used by living organism. Pigments absorb light. Different pigments absorb different wavelengths. White pigments absorbs no light; black pigment absorbs all light; chlorophyll, a green pigment , absorbs red, blue and violet light. The green color is not absorbed, but is reflected back to our eyes.

Different organisms use different pigments in photosynthesis.

a. Chlorophyll a
The main pigment involved in the conversion of light energy to chemical energy in photosynthesis.

b. Chlorophyll b
Similar to chlorophyll a.

c. Carotenoids
Accessory pigments; carotenoids are yellow, red and orange. Beta-carotene is a carotenoid.

The green chlorophyll in plants masks the color of the carotenoids. Thus, we can only see the carotenoids when the leaf stops producing chlorophyll in the fall. Carotenoids absorb light energy of different wavelengths that chlorophyll. These pigments can pass the enrgy from the light to chlorophyll a.

When the pigments absorb light, the electrons within the pigment molecue are boosted to a higher energy level with three alternative consequences.
1) The energy is lost as heat.
2) The energy is re-emitted immediately as light energy of longer wavelengths-called fluorescence.
3) The energy may trigger other reaction.

Whether or not a chemical reaction occurs depends on the pigment and its relationship with neighboring molecules.

2. Thykaloids
Chlorophyll appears in association with sheet-like membrane structures called thylakoids. A thylakoids is a flattened sac or vesicle that makes up part of the organelles called chloroplasts in eukaryotic plant cells. Within the thylakoid membrane there are approximately 200 – 300 chlorophyll molecules. In the thylakoid membrane there are two types of chlorophyll molecules.

a. Light Antennas
Light Antennas gather light energy. When the light strikes the molecules, it vibrates. Because the molecules are tightly packed together, the excitation of the molecules spreads rapidly from molecule to molecule until it reaches the reaction center. The reaction center releases electrons into the electron transport chain.

b. Reaction center
When any molecule absorbs light, its electrons become excited and are boosted to a higher energy state. In Photosynthetic cells, and excited molecule will pass its energy to an adjacent molecule. The passing of energy to the adjacent molecule continues until the energy reaches the reaction center.

Because the chlorophyll molecules are neatly lined up the high energy electrons pass easily from the excited reaction centers to the electron transport chains.

Electron transport chains are chains of molecule that pass electrons from molecule to molecule. There are two types of electron transport chains in the light reaction. In one electron transport chain, the electrons are used to make ATP and returned to the reaction center. In this way, no chlorophyll electrons are lost. In the second type of electron transport chain, the electrons are passed to the molecule NADP+ that carries the electrons to the dark reaction. Chlorophyll electrons are lost in this electron transport chain.

3. Light dependent Reaction/ Light Reaction
The photosynthetic unit contains two different photosystem. Each photosynthetic unit contains a slightly different type of antenna and reaction center. One photosystem , p680 or photosystem II, absorbs light rays with a wavelength of 680 nm. The other photosystem, p700, or photosystem I absorbs light rays that have a 700 nm wavelength. Both photosystems are needed to complete the light reaction.

Photosystem I probably evolved first since this reaction can operate independently.

When light hits the chlorophyll, the electrons of the chlorophyll molecule absorb the light energy. Since the light antenna vibrates, the energy excitation is passed from molecule with out actual passing of electrons. The excitation is passed on to the reaction center. When the reaction center receives this excitation energy, two electrons are boosted to a higher level of energy. The electrons leave the reaction center and are accepted by ferredoxin, the first molecule in the electron transport chain.

C.   Z DIAGRAM
1.   **Steps the electrons that the reaction center loses must be replaced**. The elecron are replaced by a process known as the Z diagran of the Z scheme. There are five steps in the Z diagran involving water and a protein called the Z protein. At the end of the Z diagram, the products will be H+, electrons , and 2 2H2O molecules.

    a.   H20 + Z protein ----------------> Z-OH + H+ + e-
    b.   H20 + Z-OH --------------------> Z-2OH + H+ + e-
    c.   H20 + Z-2OH ------------------> Z-3OH + H+ + e-
    d.   H20 + Z-3OH -----------------> Z-3OH + H+ + e-
    e.   Z-4OH --------------------------> Z protein + 2 H2O + O2

Water is found in the thylakoid space. The H+ from water is pumped into the medium inside the thylakoid membrane and are used in making ATP. The 4 electrons are pushed into the reaction center, the O2 is released as free oxygen, and the water is placed back into the Z diagram.

2. The Electron transport Chain of the Light Reaction
Ferredoxin receives the electrons from the reaction center and passes these electrons to plastoquinone. Plastoquinone picks up two electrons from ferredoxin and 2H+ from the medium outside the thylakoid. Plastoquinone (PQ) is changed to PQH2 passes the electrons to Cytochrome f (cyt f) and the 2 H+ to the place inside the thylakoid. Cyt f passes the two electrons to Plastocyanin passes the two electrons to the photosystem 700 reaction center.

In the p700 system, the electrons are accepted. When light rays measuring 700 nm hit the photosystem, the light antenna gets excited and passes this energy tot eh reaction center. The reaction center boosts the 2 electrons from p680 to a higher energy level. Another molecule accepts the electron and begins to pass these electrons down and electron transport chain.

At the end of the p700 electron transport chain, a molecule called NADP+ accepts the two electrons and an H+ from the medium outside the thylakoid to become NADPH. NADPH carries these two electrons to the light independent or dark reaction.

3. Cyclic Electron Flow
There is evidence that photosystem I (p700) can work independently. In this reaction (called the cyclic electron flow), no NADPH is formed. Instead the electrons are boosted from p700 to the primary electron acceptor. These electrons go down the electron transport chain that connects p680 to p700. ATP is produced in the course of electrons being passed from molecule to molecule.

Some photosynthetic bacteria carry out photosynthesis in this manner. However, this is an alternative path in eukaryotes.

D. Photosynthetis Phosphorylation
The phosphorylation of ADP to ATP (as the electrons are passed down from the p680 to the p700) is a chemiosmotic process. The two electron transport chains contain cytochromes. The electron carriers and the enzymes are embedded in the membrane of the thylakoids, or chloroplasts, which is impermeable to H+ ions.

In this energy producing mechanism (chemiosmotic coupling) two events occur; a proton gradient is established, and potential stored in the gradient is releaed and captured in the formation of ATP from ADP and a phosphate.

There is an electrochemical gradient of potential energy established as protons are pumped through the thylakoid membrane. They use energy released as electrons passed down the chain. ADP is phosphoroylated to ATP as protons flow down their gradient through ATP synthetase complexes.

The H+ are pumped out of the stroma and into the thylakoid space. When the H+ flow down the gradient, they move from the thylakoid space back into the stroma where ATP is synthetized.

The potential energy come from a different of pH and the difference of electricl charge across the membrane. In fact the pH on the inside of the thylakoid membrane is around 5, while the pH on the outside of the thylakoid memebrane is about 8. The protons flow through a channel and neutralize negative charges on the other side of the membrane, releasing energy. The channel I provided by a large enezyme called ATP synthetase. This complex , composed of two factors known as F0 and F1, are embedded in the membrane. ATP synthetase has sites for ADP and ATP and catalyzes the formation of ATP from ADP and phosphate. It is not known whether it takes two, three or four H+ ions passing through the ATP synthetase complex to form an ATP molecule.

E. Dark Reaction

This reaction occurs otside the thylakoid membrane. In this part of the photosynthetic process, the carbohydrates are actually made. There are two different ways in thich the carbohydrates can be made. The Calvin Cycle, C3 cycle, forms a three carbon compound called 3-phosphoglycerate. The second way to produce glucose is called the four carbon pathway. This C4 pathway uses phosphophenolpyruvate (PEP) to join with carbon dioxide to initially form a four carbon compund.

1. Calvin Cycle (C3 cycle)
    The first step of this reaction starts with ATP and a 5 carbon phosphorolyzed sugar called ribulose-5-P (RuP). RuP reacts with ATP to form Ribulose-1,5-biphosphate.

$$ATP \text{ -------> } ADP$$
$$Ribulose \text{ ----------------------------> } RuBP$$
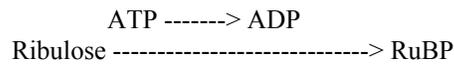
The ATP that was produced in the light reaction by chemiosis is now used to synthesize carbohydrates.

RuBP is the compound that is added to carbon dioxide. CO2 is added to RuBP to form an unstable 6 carbon compound. The compound is so unstable that is immediately breaks down into two molecules of 3-phosphoglycerate.

$$RuBP + CO2 \text{ ----------> } Unstable \text{ 6 carbon compound } \text{ ---------> } 2 \text{ 3-PG}$$
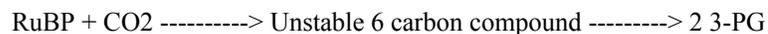
The enzyme is RuBP carboxylase.

In the Next step, a phosphate from ATP is added to 3-PG from ATP. 1,3-diphosphoglycerate (DPGA) is formed.

$$2 \text{ 3-PG} + 2ATP \text{ ----------------------------------> } 1 \text{ 1,3-DPGA} + 2ADP$$

NADPH gives its electrons to the DPGA molecule. When this happens, a three carbon molecule called phosphoglyceraldehyde (PGAL) or glycerldehyde phosphate and a phosphate are released.

$$2 \text{ DPGA} + 2 \text{ NADPH} \text{ ------------------> } 2 \text{ PGAL} + 2 \text{ NADP} + 2 \text{ P}$$

The PGAL can be combined to form the following products: Glucose, cellulose, maltose, starch, fatty acids, amino acids, and other molecules. RuP is also reformed through a series of complicated reactions.

Here's a reaction overview:
$$10 \text{ PGAL} \text{ ----------> } 6 \text{ RuP} + 4P \quad 10 \text{ out of every 12 molecules of PGAL form RuP.}$$
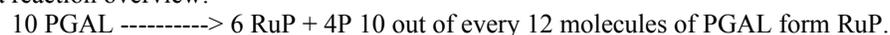
This is not an efficient process. Less that 1% of he light energy that reaches the chloroplasts is found in the carbohydratesproduced.

2. **C₄ Pathway**
   a. Carbon dioxide binds o phosphoenolpyruvate (PEP) to form a four carbon compound called oxaloacetic acid (the enzyme is PEP caboxylase).
   b. Oxaloacetic acid is reduced by electrons from NADPH to malic acid.
   c. Malic acid in decarboxylated to yield carbon dioxide and pyruvic acid. The carbon dioxide enters the Calvin cycle (C3 Path).
   d. Pyruvic acid is phosphorylated (ATP0 to reform phosphoenolpyruvate.

Carbon dioxide enters the plant via the epidermis through holes called stomata. The carbon dioxide enters the mesophyll cells and combines with PEP. The resulting malic acid is transported to the bundle sheath (a layer of cells surrounding the vascular tissue of plants). In the bundle sheath, malic acid is decarboxylated. Carbon dioxide enters the Calvin Cycle and pyruvate moves back to the mesophyll.

If the air is till and there are a lot of plants in an area, carbon dioxide may not be readily available. The air closest to the leaves will have a low concentration of carbon dioxide.

PEP carboxylase (enzyme in the C4 path) has a higher affinity for carbon dioxide that RuBP carboxylase, the enzyme in the C3 Pathway. Since PEP carboxylase takes up carbon dioxidefaster, the carbon dioxide concentration is lower inside the leaf than it is outside the leaf. This is because the carbon dioxide binds to PEP immediately and is subsequently transported away from the mesophyll cells. This process maximizes the carbon dioxide gradient between the cells and the environment. When the stomata are open, carbon dioxide diffuses more readily into the C4 leaf than the C3 leaf.
The RuBP carboxylase binds to oxygen as readily as it does to carbon dioxide. The subsequent reactions produce glycolic acid, a substance for photorespiration. Photorespiration is the oxidation of carbohydrates in the presence of oxygen and light. Up to 50% of the glucose made by the C3 plant may be reoxidized back to carbon dioxide due to photorespiration. Photorespiration reduces the efficiency of C3 plants.

High carbon dioxide to oxygen concentrations help limit photorespiration. In C4 plants the carbon dioxide is brought to the RuBP carboxylase in a concentrated form, thus reducing photorespiration. Any carbon dioxide realeases due to photorespiration is bound by PEP carboxylase and brought back to RuBP carboxylase.

C44 Plants evolved in the tropics and are adapted to high intensities of light, high temperatures, and dry conditions, the optimal temperature for C4 plants is higher than C3 Plants. C4 plantsmay flourish in temperatures that may kill C3 plants.

IV. Cell Cycle

a. Introduction
A typical eukaryotic cell contains DNA that forms a number of distinct chromosomes. Human somatic (body) cells have 46 chromosomes. When human cells divide, a copy of each of the 6 chromosomes is inherited by each cell. The organelles must also be apportioned in the appropriate numbers. This process occurs in the cell cycle. Traditionally, the cell cycle has been divided into stages: G1 phase, S phase, G2 Phase, and M Phase.

M = Mitosis, S = Synthesis of DNA and histones, G1 and G2 = gap 1 and gap 2

Let's review the following terms: chromosome, chromatid, and centromere (kinetochore).

1. **Chromosome**
A gene is made up of DNA which codes for one or more polypeptides. A chromosome is made up of many genes. The DNA in the chromosome is wrapped around histone and non-histone proteins. Before DNA synthesis, there is only one double stranded helix of DNA in each chromosome.

2. Chromatid
After DNA synthesis , there are two identical DNA helices connected by a structure called the centromere. Each DNA helix is called a chromatid.

3. Centromere (Kinetochore)
After DNA synthesis, the chromosome is made up of two identical chromatids connected by a centromere (Kinetochore). These chromatids are called sister chromatids.

The Cell cycle is an endless is an repetition of mitosis, cytokinesis, growth, and chromosomal replication. Some cells, such as fingernail cells, break out of the cycle and die, thus performing their function.

b. Interphase
2. **G1 Phase or the Gap 1 Phase**
   The chromosomes decondense as they enter the G1 Phase; this is a physiologically active for the cell. The cell sysnthesizes the necessary enzymes and proteins needed for cell growth. DNA consists of a single unreplicated helix (with histone and non-histone proteins. In the G1, the cell may be growing, active, and performing many intense biochemical activities.
3. **S Phase or he Synthesis Phase**
   DNA and chromosomal proteins are replicated. This phase lasts a few hours.
4. **G2 phase of the Gap2 Phase**
   Between synthesis and mitosis. The mitotic spindle proteins are synthesized. The mitotic spindle is structure that is involved with the movement of chromosomes during mitosis.

C. REGULATION OF THE CELL CYCLE
Different types of cells take different amounts of time to complete the cell cycle. For example, bean cells take 19 hours to complete the cycle: 7 hours in the S Phase, 5 hours in the G1 and G2 phase, and 2 hours in mitosis.

Some cells, for example, nerve cells, do not go through the cell cycle and no longer divide.

If cells divide too rapidly, they invade specialized tissues. This disrupts the function of the tissue and is referred to as cancer.

It is important that cells divide only upon reaching a certain size. Cells need to be large enough to ensure that the daughter cells will contain the necessary machinery to suvive.

A number of environmental factors such as depletion of nutrients, changes in temperature, and pH can stop a cell from growing and dividing. Growth factors are required by cells at various stages of the cell cycle.

The density of cells can control cell division. Cells need space to divide as crowding inhibits cell division. This is called density-dependent inhibition. Related to density-dependent inhibition is a requirement for the adhesion of cells to a substructure. Cells will stop dividing if they lose anchorage. Cancer cells do not exhibit density-dependent inhibition.

When normal cells stop growing due to changes in the environment or when touching other cells, they stop growing during the G1 phase of the cell cycle. This point is known as the R (restriction) point. Once a cell passes through the R point, the cell is committed to the M phase. If the cell doesn't divide, it enters the G0 phase or the non-dividing state.

For most dividing cells passing through the R point, cell sizes seems to be the crucial factor. A cell must grow to a certain size in the G1 phase for the DNA synthesis to occur.

There is an MPF complex (M phase Promoting Factor) that moves the cell from late G2 (interphase) to mitosis. The level of MPF increases and decreases – MPF appears in late interphase and reaches the highest concentration during mitosis. MPF disappears after mitosis.

MPF acts as a protein kinase and leads to the phosphorylation of certain chromatin proteins that cause the chromosomes to condense during prophase.

D. THE CONDENSED CHROMOSOMES

The chromosomes begin to condense after the S phase of the cell cycle. These chromosomes can be seen under the light microscpe. Each chromosome consists of two copies of the same chromatid. Each chromatid is joined together by a constricted area common to both chromatids. This region of attachment is known as the centromere. Within the constricted region is a disc shaped protein containing structure – kinetochore. This is where the microtubules of the spindle are attached.

E. MITOSIS AND CELL DIVISION

Duplication and division of the nucleus and the chromosomes contain therein. The Gap 1, synthesis, and Gap 2 stages have been described as Interphase. The M stage (Mitosis) has five phases; Prophase, Prometaphase, Metaphase, Anaphase, and telophase. The letters IPPMAT describe the cell cycle. Gap 1, synthesis and Gap 2 Phases are all parts of Interphase.

Interphase occurs first and prepares the cell for mitosis. During interphase, the cells grows, replicates the DNA and chromosomal proteins, and grows.

F. PROPHASE

1. Chromosomes condense; histone I and RNA molecules play an important role in the supercoiling of the chromosomes. The chromosomes get more compact and become visible. What we draw as chromoses are the chromosomes after they condense.
2. Nucleoli disappear.
3. Each chromosome is made up of two sister chromotids and these two chromatids are held together by a kinetochore. The kinetochore is the actual site of the insertion of the spindle threads. The kinetochore is made up of proteins and is a permanent part of the chromosome.

G. PROMETAPHASE

1. Nuclear envelope Fragments.

2. Microtubules
The spindle can now invade the nucleus and interacts with the chromosomes.

3. Spindle fibers
Spindle fibers extend from the poles to the equator.

The spindle apparatus which moves the chromosomes consists of two proteins: actin and tubulin. At the beginning of mitosis, the two centrioles that were fairly close together move the the opposite poles of the nucleus. As the nuclear memebrane disappears, the spindle forms between the two centrioles.

The spindle apparatus is composed of two different types of spindle fibers:
a. Kinetochore Spindle Fibers: These attach from the kinetochore of the chromosome to the centriole.
b. Polar Spindle Fibers: These attach one centriole to the other centriol of animal cells.

When spindle microtubules are formed, the microtubules of the cytoskeleton are partially disassembled. The microtubules are formed from tubulin (protein) dimmers which are borrowed from the cytoskeleton. After cell division the spindle is taken apart, and the cytoskeleton network is put back together.

The spindle microtubules elongate by incorporating more subunits of the protein tubulin. Several parallel microtubules form spindle fibers. The assembly of spindle microtubules is started in the centrosome, microtubule organization center. Microtubules are polar with distinct ends – a positive and negative end. The positive ends move away from the centrosome. The microtubules changes length by the addition or removal of proteins at the positive end.

If the cells contain centrioles, each pole is marked by a pair of newly formed centrioles. The cells with centrioles have a third set of spindle fibers called the ASTER. These may brace the poles against the cell membrane during the movements of mitosis. The rigid cellwall of plants cells may perform a similar function.

4. Centrioles and the Microtubules Organization center
It was once thought that the centriole had a large part in the formation of the cell's spindle. However, cells that do not have the centrioles form the spindle. Cells without centrioles, when stained, show a dark region where the microtubules originate (centrosome). This region seems to be where the microtubules originate. It has been suggested that the spindle separates the centrioles and basal bodies to ensure that the cells can construct flagella and cilia.

During interphase, the single centrosome replicates to form two centrosomess outside the nucleus. The two centrosomes move to the opposite poles of the nucleus, elongating their + ends. At the end of Prometaphase, the two centrosomes are at opposites poles of the cell, and some of the spindle microtubules are attached to the chromosome at the knietochore. The microtubule from one pole may attach to the knietochore first, and the chromosome and the chromosome begins to move toward the other pole aligning the chromosomes at the equatorial plane. Microtubules can only remain attached to a kinetochore where there is a force exerted on the chromosome from the opposite end of the cell.

H. METAPHASE.
The chromosomes line up on a plane called the metaphase plate. This lies in the middle of the spindle apparatus and is perpendicular to its axis. In actuality, the centromere/kinetochore is the only thing that lines up on the plate, the chromatids on the chromosomes can be pointing in any direction.
At metaphase, the chromosomes are aligned on the cell's midline. Approximately 15-35 mircotubules are attached to the kinetochore (by kinetochore microtubules). There are two types of nonkinetochore microtubules.

1. Some microtubules radiate from the centrosome toward the metaphaseplate without attaching to chromosomes. Others are too short to reach the metaphase plate.
2. Still others extened across the plate and overlap with nonkinetochore microtubules from the opposite pole of the cell.

1. ANAPHASE
Anaphase begins when the centromeres divide and the spindle apparatus starts pulling the kinetochores to the opposite poles (kinetochore microtubules shorten as chromosomes approach the poles). The daughter kinetochores move apart dragging the chromosomes (each now a single strand) to the poles. Two cells begin to form.

In anaphse the centromeres divide. Sister chromatids separate and move to the opposite ends of the cell. Microtubules pull a chromosome towards a pole by losing protein subunits are their centrosome and at the + end (attached to the kinetochore). How this works is unknown. The nonkintetochore microtubules are responsible for elongating the whole sell along the polar axis during anaphase.

J. TELOPHASE
Telophase is the reverse of Prophase , but there are now two nuclei instead of one.
1. Chromosomes decondense
2. Nuclear membrane reappears.
3. Spindle Fibers become disorganized.
4. The cell pinches in the middle, beginning the formation of the two cells.

K. CYTOKINESIS; DIVISION OF THE CYTOPLASM
1. Animal cells
Cytokinesis usually begins with an cleavage furrow at the metaphase plate by an indentation in the surface of the cell. It looks as though the cell membrane were being pulled toward the middle, as if a thread were being wrapped around the cell and being tightened.

On the cytoplasmic side of the furrow is a contractile ring of actin microfilaments. As the dividing cell's ring of microfilaments contracts the diameter of the cell diminished. The furrow is created by actin microfibrills that are found in the cytoplasm just beneath the cell emebrane. The furrow deepens until the cell is pinched in two.

2. Plant cells

At the time of telophase, small membraneous vesicles filled with polysaccharides, formed in the golgi complex, form on the metaphaste plate. The vesicles continue to form to form until they are more or less continuous and forms a double membrane, which is called the cell plate. The cell plate becomes impregnated with pectin and forms a cell wall. The cell plate forms across the midline of the plant cell where the old metaphase plate was located.

L. Function of mitosis
Cell division consists of mitosis (nuclear and chromosomal events) and cytokinesis (cell membrane and cytoplasm events). Mitotic cell division serves organisms in 2 ways.

1. **Single cell organisms**
Mitosis allow for and increase in the population. This is a form of asexual reproduction. There is no exchange of genes between individuals. The colony will be made up of individuals with genes what are identical to the founder, called clones.

2. **Multicellular Organisms**
   a. Mitosis and cytokinesis allow for an organism to grow in size while maintaining the surface area volume ratio of its cells.
   b. Mitosis and cytokinesis allow for specialization of cell types hrough cell differentiation.
   c. Mitosis and cytokinesis that are dead or damages allow cells to be replaced.

3. **Abnormal Cell Division**

   a. **Cancer cells**
   Cancer cells do not respond to normal cell division controls. They divide excessively and ignore density-dependent inhibition.

   Cancer cells, if they stop growing, also seem to stop at random points in the cell cycle and not at the restriction point. Cancer cells can go on dividing indefinitely. Most mammalian cells will divide about 20-50 times before many stop, age and die. However, there is a line of laboratory maintained cancer cells called heLa cells that have been dividing since 1951.

   The first step in cancer cell formation is transformation, which is the conversion of a normal cell to a cancer cell. Usually the immune system destroys such cells. However, sometimes the c ell can evade destruction. It will divide to form a tumor (a mass of cells in normal tissue). If the cells remain at the original site, it is a benign tumor. Malignant tumors spread. There is usually an abnormal chromosome number in tumor cells. The metabolism may be different and the cells cease to be constructive. The surface of the cells change, and they lose their ability to form attachments to neighboring cells and extracellular substructure. This process allows cancer to spread.

   b. **Metastasis**
   If cancer cells enter the circulatory system (blood and lymph), then the cancer can spread to all parts of the body. This spread is called metastasis.

Unit IV: Meiosis/Genetics

I.   Meiosis and sex cells: sexual reproduction

A. **INTRODUCTION**
In higher organisms, plants and animals, each individual is diploid. A diploid organism has a complete set of chromosomes in ever cell and is 2n (diploid means 'double set'). The organism gets one set from the mother and the other set from the father. The two partners produce gametes which are joined to produce an offspring. However, two problems must be solved in sexual reproduction

1)   If fertilization occurs and the gametes join, why isn't the genetic material doubled?
2)   How is it possible for each parent to give half of the genetic material?

The answer is meiosis, a process in which a diploid or double set of chromosomes is reduced to a haploid (n), or a single, set of chromosomes. It is a process that guarantees that the number of chromosomes remains stable from generation to generation. In humans he diploid number = 46 (2n=46), the haploid number = 23 (n=23); in fruit flies: 2n=8, n=4.

HOMOLOGOUS CHROMOSOMES

Chromosomes

In humans there are 46 chromosomes. Each chromosome consists of a double helix molecule of DNA. The DNA is folded with proteins to make up a chromosome. One chromosome represented hundreds of thousands of genes, and each gene is a specific region of the DNA molecule. A gene's specific location on the chromosome is called the its locus. The 46 chromosomes are actually 23 pair of chromosomes. The members of each pair are called homologous chromosomes (homologues). The two homologues are functionally equivalent and contain the same kinds of genes arranged in the same order.

Autosomes

one set of chromosomes that does not occur as homologues occurs in males. The X chromosome and the Y chromosome are not homologues, but pair up in meiosis. In females, then are two X chromosomes that are homologues. These chromosomes are the sex chromosomes and the other 22 pairs of chromosomes are called autosomes.

Homologues

During meiosis, three things happen to the homologues.
The homologues pair up.
The homologues exchange genetic information. This is called crossing over
The newly scrambled chromosomes separate and go into different daughter cells in such a way that each daughter cell contains only one of each pair of homologues. These cells are called gametes or sex cells.

MEIOSIS AND LIFE CYCLES

Meiosis occurs at different times during the life cycle of different organisms. In protests and fungi, meiosis occurs right after the fusion of the two mating cells. The mating cells are usually haploid and the fusion produces a diploid cell. Immediate meiosis restores the haploid lifestyle.

In all plans, a multicellular haploid phase alternates with a multicellular diploid phase. The typical fern id diploid and is called a sporophyte. The diploid sporophyte produces haploid spores through meiosis. A spore will grow into a small haploid plant called a gametophyte. These produce male and female sex cells (gametes) via mitosis. The gametes will join to form a diploid cell that will grow into the fern that you se.. This alternation between diploid and haploid is called alternation of generations.

Animals, including humans, are diploid organisms that produce haploid gametes. Two haploid gametes will join to produce a diploid zygote. Most of the lifecycle in animals is the diploid sate.

1.	Mitosis vs. Meiosis

    a.	**Mitosis**
    Occurs in haploid, diploid, and popyploid cells.
    b.	**Meiosis**
    Occurs only in diploid cells and popyploid cells. The nucleus divides twice producing four nuclei. The chromosomes replicate only once, so each nucleus contains half of the number of chromosomes
    c.	**Haploid Chromosome**
    Each haploid chromosome is a new combination of old chromosomes because of crossing over.

MEIOSIS I

There are two stages of Meiosis: Meiosis I and Meiosis II. Meiosis I is the replication of chromosomes, crossing over of the chromosomes, and reduction in the chromosome number from diploid to haploid. Meiosis I is often called the reduction division.

Premeiotic Interphase

G_1,S (replication of the chromosomes), and G_2.
Meiotic Prophase I: The first stage.
This is long and complex compared with mitotic prophase.

Nuclear membrane disappears.
Spindle fibers form.
The chromosomes condense.
The homologous chromosomes pair p by touching each other in the appropriate places. First there is a lot of random movement of chromosomes until the homologous chromosomes find each other. It is important, for example, that chromosome #13 find homologous chromosome #13. When the two homologous touch each other in the same place, a specialized structure called the synaptonemal complex holds the homologues together.

The meiotic cell of a human now has 23 genetic entities called tetrads, each packet containing four chromatids and two centromeres. This is the point when crossing over occurs. A special enzyme causes the chromatids to unwind, revealing the strands of DNA. A complex series of events happen and the genetic material is exchanged between homologues

Crossing over may occur at the introns.

Several Thousand base pairs of one strand pairs with the chromatid on another homologues. These are breakages and the chomatids untangle themselves. Meanwhile other enzymes are repairing the breaks in the DNA. This process makes new chromatids and is a source of genetic variation within a population.

After crossing over, the homologues begin to pull away from each other, except at the crossing over points called the ciasmata (chiasma – singular)

Metaphase I

In the first metaphase, the tetrads are brought to the metaphase plate. The synaptonemal complex is lined up on the metaphase plate.

Anaphase I

There is no separation of the centromeres, but the synaptonemal complex separates. This means that the homologues separate and move to opposite poles. The first meiotic division reduces the chromosome number by half.

Telophase I

In this phase, the nucleus reorganizes and the nuclear membrane reforms. The chromosomes decondense.

Cytokinesis I

In this phase, the cytoplasmic division occurs.

MEIOSIS II

Division of the chromosomes, analogous to mitosis

Meiotic Interphase

This involves G_1 and G_2 phases only. There is no S phase in this Interphase. This phase may be brief or last a long time.

Prophase II

As in mitotic prophase, there are two sister chromatids attached to a centromeres. The chromosomes condense, the nucleus disappears, ad the spindle apparatus forms.

Metaphase II

Centromeres move to the metaphase plate during metaphase II.

Anaphase Ii

During anaphase II, centromeres divide, and sister chromatids separate and move to the opposite poles.

Telophase II

During Telophase II, the nuclear membrane reforms and chromosomes decondense.

Cytokinesis II

The cytoplasm divides.

SUMMARY OF MEIOSIS

From one pair of homologues, there are four, unique chromatids from prophase I, if crossing over has occurred. Each unique chromatid ends up in one of the four cells that are the products of meiosis.

The amount of genetic material was reduced by one half in meiosis I and divided in meiosis II. Each resulting cell (gamete) is haploid.

1. **Meiosis in Males**

    In the male each of these haploid cells is called a spermatid. These spermatid will undergo cellular differentiation to become gametes (sperm).

2. **Meiosis in Females**

    Meiosis is begun but is only partly completed in human females shortly before birth. All oocyes remain in the last stage of meiotic prophase I. In humans, meiotic prophase I can last up to 50 years.

    In spite of not continuing to metaphase I, the paired meiotic chromosomes are very active, making large amounts of ribosomes and mRNA.

    By the time that oocyte is ready to be released. It is a large cell filled with yolk, mRNA, ribosomes, etc. The oocyte will not resume meiosis until released from the ovary. Even then meiosis will not be completed unless the oocyte meets a sperm and is fertilized. When this happens, many changes occur in the oocyte including the completion of meiosis.

    In females, the cell constituents are not divided evenly and most of the cytoplasm ends up in one cell. Only one cell will develop into the egg. Bout the time of ovulation, the oocyte's mitotic spindle forms off to one side of the oocyte. The normal reduction division occurs, but on e of the two daughter cells has most of the cytoplasm. The other daughter cell is very small and becomes the first polar body. The other bigger cell is known as the secondary oocyte.

    At fertilization, the head of the sperm enters the egg. A second meiotic division occurs after fertilization. As the cell divides there is the formation of another polar body and the fertilized cell retains all of the cytoplasmic material.

3. **Importance of Meiosis**

    a. Sexual reproduction is reshuffling of the genes of all the successful individuals of the population. There are virtually infinite possibility combinations of genes.

b.   The reduction and division of the chromosomes in the egg and sperm makes fertilization possible and enables the maintenance of a constant chromosome number within a species.

II.   INTRODUCTION TO GENETICS

D.   A.   MENDEL

1.   Early Life
Abbot Gregor Johann Mendel (1822-1884, Johann Mendel) was a monk of the Augustinian order n Brunn, Austria.

Early in his life, Mendel began training as a naturalist. After failing to qualify as a high school biology teacher, he joined the monastic order. In 1851, his superiors sent him to the University of Vienna for 2 years.

2.   Work
When Mendel returned to the monastery, he began his pklant breeding experiments. Mendel began experiments on the effects of crossing differestrains of the common garden pea. He used mathematics to examine his results. Mendel chose seven different pairs of contrasting pea traits with which to work. Note: D=dominant trait and R=recessive trait.
a.   Seed form: round (D) or wrinkled (R).
b.   Color of seed: yellow (D) or green(R).
c.   Color of flower: Purple (D) or white (R).
d.   Color of unripe seed pods: green (D) or yellow (R).
e.   Shape of ripe seed pods: inflated (D) or constricted between seeds (R).
f.   Length of stem: short (9-18 inches) (R) or tall (6-7 feet) (D).
g.   Position of flower: axial (in axial of leaves) (D) or terminal (at the ned of the stem) (R).

3.   Combinations
Each pea in a pod is a different individual with its own genes and traits. Each pea will mature and produce its own pods.

a.   Genotype
Combination of an organisms genes.

b.   Phenotype
Combination of visible traits. Mendel crossed two true breeding strains that differed in a single trait such as seed color. He had one problem: peas ordinarily self fertilize. His solution was to transfer the pollen by hand. He called his parent generation P_1. The first generation of offspring was designated F_1. The offspring of the F_1 generation would be called F_2.

c.   Allele
Alleles are different forms of a gene that code for a particular trait. For example, W is a gene that codes for a widows peak and w codes for a straight hairline. Although they both code for the hairline they are two different alleles, alternative forms of the gene that code for the same trait.

After extensive experimentation, Mendel proposed several principles of inheritence.

B.   PRINCIPLE OF DOMINANCE
When Mendel crossed the P_1 plants with contrasting traits, he found that the characteristics didn't blend. He found that when the plants that grew from round seeds were crossed with plants that grew from wrinkled pea seeds, all the F_1 plants produced round pea seeds.

Mendel termed the trait that appeared in the F_1 generation the dominant trait, and the trait that failed to appear in the F_1 generation the recessive trait.

What happened to the recessive trait? To answer this question, Mendel le the F_1 round seeded plants self-pollinate. In the F_2 generation, Mendel found that about 1/4 of the peas were wrinkled and that 3/4 were round. He repeated the experiment many times with the same results. He crossed a yellow pea strain with a green pea strain. In the F_1, all the peas were yellow. In the F_2, 1/4 of the peas were green, and 3/4 of the peas were yellow.

Mendel soon discovered that there were two kinds of round seeds (round is a dominant trait).
1. The kind that resembled the parental tock, (rue breeding). This type would produce only round seeds when they self-crossed.
2. The kind that would bear both wrinkled around seeds when allowed to self-pollinate.

We now call the true breeding strain homozygous; it has only one kind of allele for the trait. The second type of organism is heterozygous, and has alleles for both traits.

It was impossible to tell the difference between the round seeds unless the seeds were allowed to mature and reproduce among themselves.

Mendel discovered the following:
- 1/4 of the total F_2 were round and true breeding (homozygous).
- 1/2 of the total F_2 were round and not true breeding 9heterozygous0.
- 1/4 of the total F_2 were wrinkled and true breeding (homozygous).

Mendel tested the seven types of traits, and all seven worked the same way. In every case, 1/4 of the total F_2 were true breeding (homozygous) dominant, 1/2 were non-true breeding (heterozygous) dominant, and 1/4 were true breeding recessive (homozygous).

Mendel used algebraic symbols to represent what was happening. E let upper case letters (A) represent the dominant factor and lower case letters (a) represent the recessive factors. The heterozygous had both factors (Aa).

If the heterozygous plant was 'Aa', the plant received 'A' from one parent and 'a' from the other parent. If a plant was homozygous dominant, it obtained one 'A' from each parent. If a female parent was 'AA' and the male parent was 'aa', Mendel reasoned that the female could only give 'A' to the offspring and that the male could only give 'a' to the offspring. All offspring would be 'Aa'.

If the 'Aa' offspring were allowed to mate, then 1/4 of their offspring would be 'AA', 1/2 would be 'Aa' and 1/4 would be 'aa'.

P_1 = AA x aa
F_1 = Aa x Aa
F_2 = AA 2Aa aa

Mendel's conclusions:
1) The seven characteristics were controlled by transferable factors. The factors came in two forms: dominant and recessive. Today, we call these transferable factors genes.
2) Every heterozygote (hybrid) had 2 different copies of the factor controlling each character – one from each parent. The dominant factor determined the appearance of the plant (phenotype).

C.   MENDEL'S FIRST LAW: THE LAW OF SEGREGATION
The two alleles for a trait separate (or segregate) when gametes are formed.
When a heterozgote reproduces, its gametes will be of two types in equal proportions. Either the gamete will have 'A' or 'a'.

Aa $\rightarrow\rightarrow\rightarrow$ 1/2 A or 1/2 a

When a heterozygous plant produces eggs, then it will produce 1/2 'A' eggs and 1/2 'a' eggs. The same is true with pollen (sperm): 1/2 'A' pollen and 1/2 'a' pollen.

The probability of the egg being 'a' is 1/2, and the probability of the pollen being 'a' is 1/2. The probability of 2 independent events occurring at the same time is equal to the product of their individual properties. The probability of 'a' egg meeting 'a' pollen is equal to the probability of the egg being 'a' multiplied by the probability of the pollen 'a'. Which is 1/2 X 1/2 =1/4. The probability of the offspring being 'aa' is 1/4. this is called the rule of multiplication.

The probability of getting 'a' pollen and 'A' egg is 1/4 (1/2 X 1/2). The probability of getting 'A' pollen and 'a' egg is 1/4 (1/2 X 1/2). These two possibilities are mutually exclusive (they can't happen in the same zygote). The probability of an event that can occur in two or more different ways is equal to the sum of their individual probabilities. Thus, the probability of getting an offspring who is 'Aa' or 'Aa' is 1/4 + 1/4 =1/2. Another example: coin tossing. The probability of a coin coming up heads is 1/2, and the probability of the coin coming up tails is 1/2. The probability of the coin coming up heads or tails is 1/2 + 1/2 = 1. This principle is called the rule of addition.

Early in the 20th century, these relationships were put into graphic form by Reginald Punnett. The forms are called punnett squares. Each little square represents a possible offspring. Above the squares are the parents' gametes

Parental Gametes → ↓		
	Possible offspring Genotypess → ↓	

If Mom Aa and Dad Aa decided to have a child, what are the possible genotype of the offspring and their probabilities? One can calculate the results using FOIL method.

AA	Aa	aA	aa
First	Outer	Inner	Last

Or construct a punnett square:
      Mom's gametes (A or a)
      Dad's gametes (A or a)

Parental Gametes	A	a
A	AA	Aa

a	Aa	aa

There is a 1 in 4 or 25% chance of the child being AA
There is a 2 in 4 or 50% chance of the child being Aa
There is a 1 in 4 or 25% chance of the child being aa

D.   MENDEL"S SECOND LAW OF INDEPENDENT ASSORTMENT
In gamete formation each pair of factors segregates independently of other pairs of factors. In chromosome terms, each pair of homologs segregate independently of every other pair in Meiosis I.

E.   Crosses
Mendel first studied one characteristic at a time. He next crossed plants with two sets contrasting traits, e.g. a plant that is true breeding for both round and yellow seeds with a true breeding plant with wrinkled and green seeds.

The F_1 seeds would all be round and yellow. A=round, a=wrinkled, B=yellow, b=green.
P_1=AABB X aabb F_1=AaBb
If we cross the F_1 together to get an F_2, then how can we predict the F_1 offspring? We first have to determine the parental gametes of the F_1, and then place these gametes in a Punnett square. The law of independent assortment is applied in determining the parental gametes.

Mendel suspected that the two traits were inherited independently. For the F_2 generation, the probability of displaying the two dominant traits is 3/4 (probability of being round) x 3/4 (probability of being yellow) = 9/16. Mendel observed 556 F_2 peas. If he was correct the 9/16 of the 556 peas should be round and wrinkled. 9/16 of 556=312.75. In fact, 315 of the peas were round and wrinkled. Here are his other observations on the 556 F_2 peas.

Peas	Fraction Predicted	# Predicted from 556	# observed from 556
Round and Yellow (a- B-)	9/16	312.75	315
Wrinkled and Yellow (aa B-)	3/16	104.25	101
Round and Green (A- bb)	3/16	104.25	108
Wrinkled and Green (aabb)	1/16	34.75	32

His count fit this model. He tried combinations of the other traits together, and in each case the different pairs of alternative traits behaved independently. This is because maternal and paternal chromosome pairs line up and separate during meiosis. If an organism is heterozygous at two unlinked loci (two genes for two traits are on different pairs of chromosomes), each locus will assort independently of any other.

Two parents AaBb mate; how can we determine the gametes?
We know that the parents will give their offspring one A (or a) gene and one B (or b) gene. What are the different combinations?

AB,Ab,AB, or ab with equal possibilities. There are four possible gametes from each parent. Below is the Punnett square.

Gametes	AB	Ab	AB	ab

AB	AABB	AABb	AaBB	AaBb
Ab	Aabb	Aabb	AaBb	Aabb
AB	AaBb	AaBb	AaBB	AaBb
ab	AaBb	Aabb	AaBb	Aabb

From this, one can determine the phenotypes.

Test Cross: A cross with a double recessive parental genotype is called a test cross. If we don't whether an individual with the dominant phenotype is a homozygous dominant or heterozygous, we perform a test cross.

    Matings Possible Offspring
    AA x aa →→   Aa Aa Aa Aa   (All Aa, giving 1 phenotype)
    Aa x aa →→   Aa Aa aa aa   (1/2 Aa and 1 2 aa giving 2 phenotypes)

F.   DOMINANT/ RECESSIVE
What happens when a dominant and recessive alleles occur together to form a heterozygote? How is the recessive gene suppressed? How does the organism "choose" between two sets of information?

There are actually several different ways in which dominance can occur.
1. The dominant allele codes for a produce where the recessive allele does not. Most genes make enzymes. In this case the recessive gene does not produce a functional enzyme. For example, albinos are homozygous recessive and lack the necessary enzyme for menalin. One half of the normal amount of the enzyme, produced by a heterozygous, usually allows enough pigment production so that the individual appears normal.
2. The recessive allele can produce "less" of a product which is masked by the dominant allele.
3. The recessive allele produces a fully functional enzyme that is masked by the dominant allele.

G.   DOMINANT RELATIONSHIPS
1. **Lethal recessive**
    Homozygous recessive organisms cannot survive.
2. **Partial dominance or Incomplete Dominance**
    The heterozygote is intermediate between the phenotypes of the two homozygotes, and not exactly like either one of them. Snap dragons r=red, w=white
          Rr x ww →→ rw = pink rw x rw = 1 red, 2 pink, 1 white
    Sometimes the phenotype of the heterozygote is not simply a blending o compromise between the two homozygotes, but has unique features of its own. E.g. Palomino horses are heterozygous for coat color. Crosses between two palominos result in brown, 2 palominos, and 1 white foal.

3. **Codominance**
    Sometimes one homozygote will show one phenotype, the other homozygote will have a different phenotype, and the heterozygote will show both phenotypes.
          Blood types. AA x BB →→ AB   Neither allele is recessive, both are equally dominant
4. **Multiple Alleles**
    There are more than two alleles possible at a single locus. For example, researcher have discovered 37 different alleles for eye color at one locus in fruit flies. Anyone individual has, at most, two different alleles of the 37 people.

H.   GENE INTERACTIONS AND THE MODIFIED MENDELIAN RATIOS
We have talked about Mendel and his peas. We have learned that if we cross two individual that are heterozygous (AaBb), we get a 9:3:3:1 phenotypic ratio for the offspring. This holds true only if the

two pairs of alleles act independently. For example, this does not work out for coat color of mice. At one locus, B is dominant over b. BB and Bb mice are black and bb mice are brown.

BB x bb →→ Bb = black mice
Bb x Bb →→ 3/4 black mice, 1/4 brown mice.

At another locus, there is a gene C which is dominant over c. CC and Cc mice can make pigment. cc mice cannot make pigment, they are albinos.

1. **Epistasis**
   Msking of a trait determined by one pair of genes by the actions of another pair of genes. If we cross pure-breeding brown mice (Ccbb) with true-breeding white mice (ccBB) we get all black mice (ccBb). A cross between these F1 black mice result in: CcBb x CcBb = 9 black, 4 white, 3 brown mice. The Cc locus is epistatic to the Bb locus.

Gametes	CbCb	cB	Cb	Cb
CB	CCBB	CCBb	CcBB	CcBb
Cb	CCBb	Ccbb	CCBB	Ccbb
CB	CCBb	CcBb	CcBB	CcBb
cb	CCBb	CCbb	CcBb	ccbb

2. **Pleiotropy**
   Pleitropy occurs when a single gene can affect more than 1 characteristic (e.g. coat color in cats: white cats often have blue and eyes and are deaf).

3. **Nature vs. nurture**
   Phenotype depends not only on genes but also on environment interactions. For example, nutrition influences height, exercise alters build, sun tanning darkens skin. The product of a genotype is not a rigidly defined phenotype, but a range of phenotypic possibilities subject to environmental influences. The phenotypic range is called the norm of reaction for a genotype. Sometimes the norm of reaction is a very specific phenotype (e.g. blood types). The norm of reaction is broadest for polygenic traits. We refer to thesetraits as multifactorial. Many factors, genetic and enviormental, influence the phenotype. An example of an environmental effect on gene expression: Siamese cats. In these cats an enzyme for pigmentation is temperature sensitive and will not function above a certain temperature. As a result, pigmentation of the fur occurs primarily in the colder extremities (ears, tail, feet, and nose). If a cat is kept indoors, then the cat can be white. If the cat is put outdoors, then it will be much darker.

4. **Incomplete Penetrance**
   The individual may have an abnormal genotype without showing it (e.g. Polydactyly: a dominant genetic trait in which people have a tendency to express an extra digit). Persons carrying the gene may show variable expressivity such that all four extremities, or just the hands, feet, or none of each may show the trait. Both the hands and feet have the same genes, and the same environment but many differ in the number of digits. This could indicate developmental chance in that a person may be lucky to have only five fingers and toes, but can pass the gene on to their children who have a 50% chance of getting the gene and have more than five digits.

5. **Sex-Limited and Sex-influenced Effects**
   A trait is only limited to or affect one gender more often than the other is a sex-limited or sex-influenced trait (e.g. a dominant gene is responsible for a rare type of uterine cancer). This is sex-limited, since males do not have a uterus. One type of baldness is due to a dominant gene; usually it doesn't affect women.

   Variable Age of Onset: Some traits do not appear until later in life. Not all are sex limited. Muscular dystrophy, a sex linked trait, appears at different ages, even in brothers. Huntington's Chorea is severe neuromuscular disorder which is due to a dominant gene. A person doesn't exhibit symptoms until s/he is about 40 years old. Symptoms include muscular shakiness, similar to intoxication, and people usually die within 15 years after the onset of symptoms. The most famous case: Woody Guthrie.

I.   THE GENETICS OF SEX
In 1910 Thomas Hunt Morgan began breeding experiments with the fruit fly Drosophila Melanogaster. The fruit fly is a model experimental organism. Cultures are easy to maintain, each female lays hundreds of eggs, insects mature in 10 days, they can be anesthetized for easy inspection, they have only four pairs of chromosomes and mutants can be easily recognized.

Moran found a single male with white eyes and was convinced that this was due to a mutation, since red is the normal eye color. Morgan took the white-eyed male and mated it with some red-eyed sisters. The F_1 generation among themselves. Of the flies in the F_2 generation: 1/4 were red eyed males, 1/2 were red eyed females and 1/4 were white eyed males. All the white eyed flies were male. He performed a test cross, mating the F_1 daughters (red eyed females) with white eyed males. He expected a 1:1 ratio of dominant and recessive traits. However, there were approximately equal numbers of red eyed males, red eyed females, white eyed males, and white eyed females.

Morgan crossed the white eyed females with red eyed males. The resulting flies were all white-eyed males and all red eyed females. Morgan surmised that the gene carrying the white eye color was located on the sex chromosome, specifically on the X chromosome.

While female fruit flies are truly diploid, the males are only partially diploid because the X and Y chromosomes are not homologous, that is, they don't carry the same types of genes. While X carries thousands of genes, the Y chromosome bears only a few genes.

Morgan is credited with the following findings.
1)   He determined that Mendel's factors were located on the chromosomes
2)   He delineated the concept of linkage.

J.   SEX LINKAGE IN HUMANS
Several recessive traits are carried on the X chromosomes; many cause abnormalities.

Colorblindness: The most common type is red/green colorblindness. There are 3 types of cones in the eye (cells that respond to color) red, green and blue. People who are colorblind lack one of the three types of cones. 10% of all male are colorblind and only .4% of females are colorblind. To be affected, a man only needs to receive one recessive gene from his mother (on the X chromosome) since Y is not allelic to X and cannot mask the recessive allele. Affected women must receive the recessive gene from both parents. Another example of a sex linked disease is Duchenne's muscular dystrophy; one out of every 3500 males born in the US is affected. They rarely live past their early twenties. Characteristics of the disease include progressive weakening of the muscles, loss of coordination, and hemophilia.

K.   X INACTIVATION IN FEMALES
Although female mammals inherit two X chromosomes, one X chromosome in each cell becomes inactivated during embryonic development. The inactive X condenses into a compact object called a barr body. The barr body lies along the inside of the nuclear envelope.Although small regions of the chromosome remain active, most of the genes of the X chromosome that form s the barr body are not expressed. Barr bodies are "reactivated" in the cells of gonads that undergo meiosis to form gametes. The selection of the X chromosome that will be inactivated occurs randomly and independently in each of the embryonic cell present at the time of X activation. The female consists of a mosaic of two types of cells—one with an X derived from the father and those with an X derived from the mother.

L.   CHROMOSOMAL ALTERATIONS
1.   **Alterations of Chromosome Number**
Nondisjunction occurs when homologous chromosomes do not separate properly during meiosis I or the sister chromosomes fail to separate in meiosis II. The result is an abnormal chromosome number, called aneuploidy (2n+1 or 2n –1).

2.   **Polyploidy**

More than two complete chromosome sets, for example, Triploidy: 3n and tetraploidy: 4n. Polyploidy occurs when there is nondisjunction of a complete set of chromosomes. Polyploidy is common in the plant kingdom.

3. **Alterations of Chromosome Structure**
   The breakage of a chromosome can lead to a variety of rearrangements affecting the genes of the chromosome.

   Fragmennts without centromeres are usually lost when the cell divides. The chromosome from which the fragment originated will be missing certain genes (deletion). In other cases, the fragment may join to the homologous chromosome (duplication). The fragment may reattach to the original chromosome inverted (inversion). The fragmen may attach to a nonhomologous chromosome (translocation).

   During the crossing over process, some chromatids break at different places, and one partner gives up more genes than it receives.

4. **Examples of the types of chromosomal anomalies**
   The following are results of nondisjunction because of irregular meiosis:
   a.   An extra autosomal chromosome (e.g. trisomy 21 (Down's Syndrome), Edwards syndrome
   b.   An extra sex chromosome (e.g. XYY, Klienfelters Syndrome, and Triple X syndrome)
   c.   Missing a sex chromosome (e.g.. Turners Syndrome, XO)
   The following are not results of nondisjunction:
   d.   Deletion of a piece of an autosomal chromosome (e.g. crit du chat).
   e.   Translocation: piece of one chromosome is added to a non-homologous chromosome (e.g. translocation 21 to 14, one cause of Downs Syndrome).

M.   **PARENTAL IMPRINTING OF GENES**

Recently geneticists have identified traits that seem to depend on which parent passed along the allele for these traits. Prader-Willi Syndrome: Mental retardation, obesity, short, small hands and feet. Angelman Syndrome: Spontaneous laughter, jerky movements, and other motor and mental symptoms.

Both these syndromes have the same cause – deletion of a particular segment of chromosome 15. Prader-Willi Syndrome occurs when a child gets the defective chromosome from the father, while Angelman Syndrome occurs when the child gets the chromosome from the mother. A process called genomic imprinting may explain this phenomenon. According to this hypothesis, certain genes are imprinted in some way each generation. The imprint is different depending n the gender of the gene. The same allele may have different affects on the child depending on whether it arrives in the sperm or the egg. In the new generation, both maternal and paternal imprints are "erased" in gamete-producing cells and all the chromosomes are recoded according to the gender of the individual they compose.

N.   **HUMAN GENTICS AND CHROMOSOMES**
The number of chromosomes in the human species is 46; 44 autosomes and two gender (sex) chromosomes. A graphic representation of the chromosome present in the nucleus of a cell is known as karyotype. From a karyotype, we can determine the number, size, and shape of the chromosomes as well as identify the homologous pairs. Sometimes, it is difficult to distinguish between similar looking chromosomes. However, the chromosomes can be stained to show a banding pattern. The chromosomes with the similar banding patterns are homologous chromosomes.

1. **Prenatal Detection**

   a.   **Amniocentesis**

This procedure obtains fetus cells that float in the amniotic cavity. A needle goes through the abdominal wall into the amniotic cavity to obtain fetus cells. The fetal cells are then grown and used to prepare a karyotype. This procedure usually occurs while an ultrasound is performed, so the fetus is unharmed.

      b.   **CVS: Chorionic Villus Sampling**
A piece of the chorion is removed. These villi contain fetal cells which are examined for fetal anomalies

2. Human Genetics
Human genetic anomalies can be caused in the following ways:

      a.   **Autosomal dominant Gene**
One gene causes the anomaly (e.g. Achondroplasia, polydactyly, Neurofibromatosis, etc.)

      b.   **Autosomal recessive gene**
Two genes cause this anomaly (e.g. PKU, Tay sachs, Sickle Cell Anemia, etc.)

      c.   **X-linked recessive gene**
Found on the X chromosome (e.g. Color blindness, muscular Dystrophy)

      d.   **Chromosomal Anomalies**
(e.g. Trisomy 21, Turners Syndrome, Crit du Chat, etc.)

      e.   **Multifactorial**
Combination of Genes and Enviorment. Both factors must be present in order to have the genetic anomaly. (e.g. Cleft lip, Cleft palate, Spina Bifida, etc.)

3. Pedigree
Family tree showing parents and children across generations. We can trace genetic disorders and predict probabilities of some disorders.
      a.   Recessive inherited disorders.
      b.   Dominant inherited disorders.
      c.   Multifactorial disorders.

O.   GENES AND CHROMOSOMES

1. Linkage
Genes that are on the same chromosome should be transmitted to the same gamete during meiosis. Genes that tend to stay together are said to be linked.

2. Recombinatin
The process of crossing over causes that ratios of some traits to not meet Mendelian predictions. If the crossing over takes place between genes for two different traits on the same chromosome, then the alleles for those traits will not segregate in meiosi I. These two genes are said to be linked and will not assort independently. The chromatids that have the new combination of genes are called recombinants.

It was determined that the percentage recombination was directly related to the distance between loci – the spacing along the chromosome. Using the recombinant frequencies, we can determine the map distances between loci (i.e. map the chromosome). It was thought that:

      a.   genes are arranged in a linear order on the chromosome, like beads on a piece of string
      b.   genes that are close together will cross over less frequently than will genes that are farther apart.

c. It should be possible to plot the sequence of the genes on the chromosome and relate distances between them. These distances are map distances only and are not proportional to the actual spacing of loci along the chromosome.

The right hand values are the recombinant, alleles that were not linked because of crossing over between the several loci.

3. Polygenic Inheritance and Continuous Traits
In 1918 R.A. Fisher showed that the continuous traits were controlled by many genes a different locations on the chromosomes. The combination of these many genes allows such wide variation in polygenic traits.

Any trait that varies along a continuum is a polygenic trait. These are called quantitative characteristics.

P. MUTATION RATES AND GENETIC VARIATION IN A POPULATION
Rates of mutation measured in a variety of organisms are lower in bacteria than in multicellular organisms. Mutants usually appear in about 1/100,000 to 1/1,000,000 gametes in eukaryotic organisms.

Although the mutation rates seem low, mutants appear regularly in nature. For example, a typical insect species consists of 100 million individuals ($1x10^8$). If the mutation rate is 1/100,000 gametes, the number of mutations appearing would be $2x10^8$ x 10^{-5} = 2,000 mutations per generation. The mutation rate is multiplied by the number of individuals in the population then multiplied by 2 (the result of the union of the two gametes).

The probability that a given individual will have a new mutation is extremely low. However, the probability that a given individual will have a mutation in its genome is high. Fruit flies have 10,000 genes. The mutation rate is 10^{-5}. The probability that the fly will have a new mutation is 2 x 10^4 x 10^{-5} = 0.2.

Humans have 100,000 genes. If we assume the same mutation rate, then this is the possibility of new mutation: $2x10^5$ x 10^{-5} = 2. the average human carries two new mutations.

These calculations have been based on the number of mutations that we see. In the genome, as a whole, the mutation rate has been calculated to 7 x 10^{-9} per nucleotide pair per year. In mammals the number of nucleotide pairs per genome is 4 x 10^9. The mutation rate for mammals is 4 x 10^9 x 7 x 10^{-9} = 28 mutations per year per genome. This is a large amount of genetic variation.

UNIT V

DNA/MOLECULAR GENETICS

DNA

A. **NUCLEUS BACKGROUND: DNA AND DNA SYNTHESIS**
The fluid material of the nucleus is surrounded by the familiar double membrane called the nuclear envelope. This membrane is often continuous with the endoplasmic reticulum. The nuclear membrane has numerous pore-like structures that can be observed. These pores account for as much as 25% of the nuclear membrane in some cells. The nuclear membrane is known to be highly selective in what it permits to pass in or out of the nucleus. We know that large mRNA molecules are assembled in the nuclear fluid and move into the cytoplasm. Yet smaller molecules are not allowed to pass through the membrane. The only obvious feature of the nuclear fluid (nucleoplasm) is the nucleolus (pl. nucleoli) which is a structureless dense mass. It is the site of rRNA reproduction and appears to be the source of ribosomes.

Most importantly, the DNA, chromatin and chromosomes can be found inside the nucleus. Chromatin is DNA that is combined with proteins, including histone and non-histone proteins. When the cells are dividing, the chromatin is coiled into larger, highly visible bodies that are called chromosomes. When the chromosomes 'relax' and diffuse, they are long and thread-like. Human chromosomes per cell measure approximately 12 cm long end to

end. Diffuse chromosomes occupy the cell most of the time. DNA is bunched up as tiny bead-like globules, each consisting of about 200 DNA base pairs wound around the cluster consisting of 8 molecules of proteins called histones. Between each of these bead-like globules are 50 DNA base pairs (open space). Each chromosome consists of one long DNA molecule wrapped around globules of histones and non-histone proteins.

Chromatin occurs in one or two forms: euchromatin or heterochromatin. Euchromatin contains nearly all the functional genes. These are genes that we have been able to map and identify. Heterochromatin contains the DNA that hasn't been identified as genes.

B. **DNA STRUCTURE**
DNA stands for deoxyribonucleic acid. All cells need a set of instructions in order to survive. The instructions are provided in the form of DNA.

The "deoxy" implies that there is one less oxygen atom in each unit of DNA than RNA. The DNA molecule can be broken down into three parts.
1)   Nitrogen Bases
2)   Sugar backbone
3)   Phosphate groups

The nitrogen bases are broken down into two groups.
    a.   Pyrimadines
            Single ring bases: cytosine and thymine

    b.   Purines
            Double ring bases: guanine and adenine

The basic unit of DNA is a deoxynucleotide. These nucleotides can exist s free-floating triphosphates in the cell fluids. When they're stung together, they form DNA strands. In DNA synthesis, the bonds between two of the phosphates are broken to form strong covalent bonds between nucleotides. In this process the two phosphates are freed leaving one phosphate attached to the sugar. This phosphate will link two sugar together. Eventually a long chain of nucleotides is produced. The backbone of the chain consists of alternating sugar and phosphates. Linked by shared oxygen atoms. The nitrogen bases are side groups of the sugar and are not part of the backbone. The nucleotide chain has two ends. The end with the phosphate attached to the #5 carbon of the sugar molecule is known as the 5' end. The end with the OH group attached to the #3 carbon of the sugar molecule is called the 3' end. In most cases, the nucleic acid chains are pictured with the 5 end on the left and the 3 end on the right. Synthesis of the nucleic acid chain always proceeds from the 5 to the 3 end.

C. **DOUBLE HELIX**
DNA is almost always found in a double strand, while RNA is almost always a single strand. Each strand of the DNA is forged of strong covalent bonds, but the two strands are only weakly attracted to each other by H bonds. The configuration of the two strands of DNA wound around each other is a double helix. As the sugar and phosphate are wound around each other, the nitrogen bases point inwards. It looks as if someone had twisted a ladder with the base pairs as rungs. Following this image, we can see that the sugar and phosphate groups make up the backbone or the sides of the ladder. We see that adenine will always form two hydrogen bonds with Thymine and that Guanine will always form three hydrogen bonds with Cytosine. The strands are antiparellel with sugar and phosphate backbones going in opposite directions. One strand runs in the 5' to 3' direction and is paired with the second strand which runs 3' to 5'. The geometry of the base pairs is very precise. The A:T, T:A, C:G, and G:C pairs lie perfectly flat one pair on top of the next, like a stack of pennies.

D. **FORCES THAT HOLD DNA TOGETHER**
    1.   **Hydrogen bonding**
            Between base pairs.

    2.   **Hydrophobic Interactions**
            DNA bases are insoluble in water, so they stick together in aqueous solutions.

3. **Base Stacking**
When the bases lie on top of each other, base stacking interactions result.

E. **CONDITIONS THAT DENATURE DNA**
The hydrogen bonds may be broken or disrupted in three ways.
a. Add a base and raise the pH. If the pH is raised above 12, hydrogen bonds break.
b. Add urea and formamide, both are strong hydrogen bonding solvents.
c. Increase the heat. The heat disrupts the hydrogen bonds.

DNA REPLICATION AND SYNTHESIS

A. **DIRECTION**
DNA synthesis occurs in a 5' to 3' direction. First an unwinding protein unwinds the two strands of DNA, so that there is a region, a few hundred nucleotides long, in which two strands are unpaired with their nucleotides sticking out into the cell fluid. Helicase is an enzyme responsible for separation of DNA strands. Once the strands are separated, a replication fork is established. In prokaryotic cells, the DNA is in a circular form. As the helicase unwinds a portion of the DNA, the other portion of the molecule is stressed, due to the increased winding of the circular molecule. In order to relieve this stress, an enzyme called topoisomerase breaks and reattaches the DNA molecule.

B. **STEPS OF DNA SYNTHESIS**
An enzyme, DNA polymerase, begins to match the free-floating deoxynucleotides found in the cell fluid to the bases presented by the opening up of the DNA strand. As nucleotides of the unwound segment finds new partners, helicase unwinds more of the DNA strand creating a moving replication fork.

C. **LAGGING STRAND SYNTHESIS**
If we say that DNA synthesis occurs bidirectionally, then we can see that if one strand is put together in a 5' to 3' direction, then the other part of the same strand must be put together in a 3' to 5' direction. This is not precisely true. The strand that will be synthesized in an overall 3' to 5' direction is called the lagging strand.

The lagging strand is made up of Okazaki fragments which are 1,000 to 2,000 base pairs on length and synthesized in a 5' to 3' direction. Lagging strand DNA synthesis starts at the RNA Primer which is a sequence of approximately 10 nucleotides of RNA. The RNA primer is placed down an enzyme call Primase. The DNA polymerase lays down bases from the preprimary complex in a 5' to 3' direction until DNA polymerase hits the primer, it stops laying bases and the primer is replaced by DNA bases. Then DNA Ligase seals up the newly laid DNA bases and Gyrase winds the DNA molecule up.

Review of enzymes of DNA synthesis
1) *Helicase*: unwinds
2) *DNA Polymerase*
3) *Ligase*: seals the bases up.
4) *Gyrase*: winds the DNA molecules

D. **ENERGETICS OF DNA REPLICATION**
The nucleotides for DNA synthesis are assemble as triphosphates: deoyadenosine triphosphate (dATP), deoxyguanosine triphosphate (dGTP), deoxycytosine triphosphate (dCTP), and deoxythymosine triphosphate (dTTP). The energy from the bonds between the phosphates provide the energy to power the reactions catalyzed by DNA polymerase. After the two phosphates have been removed, another enzyme breaks apart the two phosphates recently cleaved from the triphosphate. These phosphates are now released as inorganic phosphates. The energy released allows the synthesis of DNA to be highly exergonic which prevents the reaction from going in the reverse direction. DNA synthesis is semi-conservative. Each new double helix is made up of one new strand and one old strand. DNA synthesis is very accurate. DNA

polymerase makes very few errors. But what happens if there is a mistake in DNA synthesis? How are mistakes corrected?

DNA REPAIR

A. **DNA POLYMERASE (3' TO 5')**
   DNA polymerase not only puts bases down in order, but it also proof reads what it has laid down. If the nucleotide that is laid down is the wrong one, polymerase will undo what it has done by going back and removing the wrong base. However, 10% of all bases put down are removed by DNA polymerase even if the base is correct. If the DNA polymerase continues two bases past the mismatch, the probability of DNA plymerase going back two bases to get the mismatch is very low. In a 5' to 3' direction DNA polymerase lays down the base, but in the 3' to 5' direction it proof reads.

B. **PHOTOREACTIVATING ENZYME**
   U.V. light is the easiest mutagen to work with. With U.V. light the mos ommon lesion that occurs and is called the pyrimidine-pyrimidine dimmer or the thymine-thymine dimmer. The T-T dimmer can be fixed by the photoreactivating enzyme (overhead).

$$T-T \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow T-T$$
Photoreactivating Enzyme

This enzyme is activated by the sunlight and breaks the thymine to thymine dimers

C. **EXCISION REPAIR**
   Excision repair is responsible for repairing a broad spectrum of DNA damage from U.V. damage to bulky lesions. The damages are all repaired by the excision repair system.

   1. Abilities
       a. Repair compounds of different structures.
       b. Make repairs when compounds bind in different places.
       c. Detect damage in DNA.

       There are three enzymes that make up the excision repair ystem: Uvr A, Uvr B, and Uvr C.

   2. Mechanisms for Repair
       a. Recognition
          Some sort of recognition of damage. Enzymes bind in the vicinity of DNA lesion.

       b. Incision
          Two nicks are made on eiher side of the lesion.

       c. Displacement and Resynthesis
          Lesion is removed and DNA is resynthesized. This requires the use of other enzymes (polymerase).

       d. Seal the new DNA
          Ligase does this.

   Excision repair requires the presence of the complimentary strand of double helix during repair. Repair is done by complimenting the bases.

D. **SUMMARY**
   We've discussed three types of DNA repair systems.
   1) DNA polymerase: It is the proofreader in a 3' – 5' direction
   2) Photoreactivating Enzyme: usually fixes t-T dimmer
   3) Excision Repair System: Uvr A,B,C fixes bulky lesions

MUTATIONS
Mutation: Inheritable change in DNA molecule.

A. **RAMIFICATIONS OF MUTATIONS**
These changes may result from errors in replication, from damage that repair enzymes do not correct, or from spontaneous rearrangements in the DNA molecule. A change in one or two nucleotides may have no effect on a cell or may be disastus for the cell. Mutations occur from mutagenic agents, mutagens such as radiation (X-ray and UV light). Certain chemicals can cause a change in DNA. Mutagens produce variations in genetic material. Genetic variation are the raw material for evolution.

B. **TYPES OF MUTATIONS**
There are different types of mutagens.
1.   Change of one nucleotide to another.

GA<u>T</u>TCCTTAA →→→   GA<u>A</u>TCCTTAA

2.   Insertion of one or more nucleotides into the DNA sequence.

GATTCCTTAA →→→   GA<u>A</u>TTCC<u>C</u>TTAA

3.   Deletion of one or more nucleotides from a DNA sequence.

GATTCCTTAA →→→   GA-T-C-TAA

4.   Inversion of part of a nucleotide sequence.

GATTCC<u>TTAA</u> →→→   GATTCC<u>AATT</u>

5.   Breakage and loss of a fragment of DNA

GATTCCTTAA →→→   GATTCCT---

6.   Extra copies of DNA

GATTCCTTAA →→→   GATTCC<u>TTCC</u>TTAA

PROTEIN SYNTHESIS: NUCLEUS AND RIBOME

A. **INTRODUCTION**
Protein synthesis involves two processes.

1.   Transcription
The synthesis of messenger RNA from a DNA template.

2.   Translation
The synthesis of a polypeptide from the messenger RNA sequence.

Proteins are composed of amino acids; proteins are made in the ribosome. The DNA sequence determines which proteins are made. mRNA delivers the information from the DNA to the ribosome.

B. **TYPES OF RNA**
RNA: ribonucleic acid.

2.   Three Main Differences between RNA and DNA
a.   The RNA sugar is ribosome vs. deoxyribose for DNA

b.   Uracil replaces Thymine in RNA
                    c.   RNA is single stranded
   3.   There are Types of RNA
           a.   RRNA
   Ribosomal RNA, the principle component of ribosomes. Amino acids are synthesized into
   polypeptides in the ribosome.

           b.   MRNA
   Messenger RNA, carries the DA code to the ribosome. The information is encoded in the DNA,
   but the DNA doesn't make the proteins or move to the ribosome. mRNA is the physical link in
   protein synthesis between the blue prints (DNA) and the factory (ribosomes).

           c.   TRNA
           Transfer RNA, carries amino acids to ribosome

           d.   HnRNA
   Heterogeneous nuclear RNA, the pre-edited transcribed RNA found in the nucleus.

C. **STEPS IN PROTEIN SYNTHESIS**
   How mRNA is formed: The two DNA strands unwind, and only one of the two strands is copied. The two
   DNA strands rewind.

   The base pairing rules of RNA synthesis are very similar to those of DNA replication except that RNA
   contains uracil instead of the thymine found in DNA. Instead of T, a U is matched up to adenine in making
   RNA. For every G in DNA, RNA polymerase puts in a C. For every T in DNA, RNA polymerase puts in
   A. For every A in DNA, RNA puts in a U. When the process is completed, RNA has the same order of
   bases as the appropriate non-copied (non-transcribed) strand of DNA except that all thymines have been
   replaced with uracil. This process is called transcription.

   RNA is synthesized in a 5'-3' direction using triphonucleotides and RNA polymerase. Many RNA
   molecules can be transcribed simultaneously from different parts of the same DNA molecule. There are
   also spaces, called spacer regions, between DNA that are not transcribed.

   The length of the DNA molecule on which RNA is being transcribed is equivalent to a gene—or a gene that
   codes for a polypeptide. Only a specific portion of the DNA molecule is being copied.

D. **STEPS IN TRANSCRIPTION**
      1.   Helicase unwinds the DNA molecule.
      2.   RNA polymerase matches down a RNA base with the appropriate DNA base. In bacteria,
              there is a single type of RNA polymerase. In eukaryotic cells, there are three types of RNA
              polymerase. RNA polymerase II is specialized for mRNA synthesis.
      3.   Ligase seals the RNA strand.
      4.   The RNA strand, now called the mRNA strand, leaves the DNA molecule and the nucleus.
      5.   Gyrase winds up the DNA strand.

              There are specific nucleotide sequences on the DNA molecule.
              a)   Promoters start signal for RNA synthesis. A promoter includes an initiation site where
                   transcription begins, and some nucleotides before the initiation site. There are certain
                   areas within the promoter region that are important for the recognition by RNA
                   polymerase. The TATA box is a region named because it is enriched with T and A
                   nucleotides. A TATA box is about 15 nucleotides before the initiation site. The RNA
                   polymerase II cannot recognize and bind to the promoter without transcription factors
                   which bind to the promoter. RNA polymerase II recognizes this complex and will bind
                   to the DNA strand.
              b)   Terminator sequences serve as stop signals for RNA synthesis. The most common form
                   is a AATAAA sequence in eukaryotes.

E. **CODE**

The mRNA molecule is synthesized on DNA and has the information that is encoded in the DNA. This information is written in a gentic code. Each code word or codon is made of 3 adjacent nitrogen bases. The 3 nitrogen bases specif one of 20 amino acids. For example the GAG is a codon and specifies the amino acid glutamic acid.

Since there are 4 different RNA nucleotides that can occur in the first position of a codon, four different nucleotides can occur in the second position and four different nucleotides can occur in the third position. Thus we end up with 4x4x4=64 codons.

There are 64 possibilities for different codons, three of these codons are stop codons: UAA, UAG, and UGA. Most of the amino acids are coded for by more than one of the 61 remaining codons.

There are only two codons that are not clear: AUG and GUG. They either code for the amino acid methionine or valine, or they serve as a signal that directs the cell to begin protein synthesis. AUG and GUG are called initiator codons (usually AUG). Actually the first amino acid, if it is AUG, is fmet. Fmet stands for N formylmethionine. This may later be removed from the amino acid chain.

F. **RIBOSOMES AND TRANSFER RNA**

1. **Ribosome**

The mRNA carries the coded message to the ribosome. The ribosome is made up of mostly rRNA. There are two major components of the ribosome. There is a 50S subunit and a 30S subunit. S stands for Svedberg unith which is the sedimentaion factor, the heavier the particle the higher sedimentaion rate and the higher the Svedberg unit.

There are two sites found within the ribosome, a P site and an A site. The P site is the peptide binding site and the A site is the amino acid binding site.

The coded message is decoded in the ribosome. The ribosome itself cannot tell one codon from the next, except for the initiator and the terminator codons. Deciphering codons si the job of tRNA.
There is one specific tRNA for each amino acid.

The enzyme reaction linking an amino acid to the tRNA molecule takes two stages.

a. Energy Supplier. ATP is cleaved. A molecule is produced consisting of AMP and the ammo acid (the amino acid is bonded to the AMP).
b. This complex stays intact until the appropriate LRNA arrives. AMP is released from the enzyme and a bond is formed between the Y end of the tRNA and amino acid.

2. tRNA molecule
There are 20 different amino acids coded for by 61 codons. There are 31 tRNA molecules for the 61 codons. There is some doubling up of the codons and the tRNA molecules.

The differences between the 31 LRNA molecules must be such that the correct ammo acids can be loaded onto the correct LRNA molecule. But they must be similar enough so that they will work within the ribosome.

Structure of tRNA molecules:
a. Acceptor arm: all tRNA molecules end with the sequence CCA. The amino add is linked here.
b. D arm: a base called dihydrouridine is located here. This why it's called the D arm.
c. Anticodon arm: can recognize specific codons on the mRNA molecule.
d. Extra arm: variable loop. This small loop and are the most variable region on the tRNA molecule. Thesecan be broken down into two classes: 1) 3-5 bases and 2) 13-21 bases.

e. T psi C arm: a base called pseudouradine is surrounded by T and C in this arm.

The unusual bases (pseudouradine and dihydrouridine) in the LRNA molecule allow the reactions that allow the proper folding of the molecule to occur.

G. TRANSLATION
The AUG initiator codon is recognized by the smaller of the two ribosome units.

The recognition initiates protein synthesis: The 509 subunit then binds with the 309 subunit. A special initiator tRNA molecule recognizes the AUG site, and binds with the codon inside the ribosome.

At this point, the P site has the first mRNA codon and the second codon is in the A site. The tRNA molecule with the corresponding anticodon will come and match itself to the codon at the A site. The mRNA and the tRNA bind to each other with hydrogen bonds. The two ammo acids are linked together by a dehydration reaction. Now both sites are occupied, and translocation happens.

H. TRANSLOCATION/ELONGATION
Translocation is the movement of the ribosome on the mRNA strand.
The ribosome will move three base pairs to the right The first tRNA leaves and the A site is open for another tRNA molecule with the correct anti-codon.

This process uses an enzyme called the elongation factor P, and energy from GTP. The ribosome continues translocating until it encounters a stop codon and terminates the protein.

Wobble Effect: The reason that 31 tRNA molecules carry 61 codons. Here is how the anticodons and codons match up.

$3' - x_3 \, x_2 \, x_1 - 5'$ Anticodon (tRNA strand)

$5' - y_1 \, y_2 \, y_3 - 3'$ Codon (mRNA strand)

This is not a linear relationship as the anticodon (tRNA) is curved. Since the anticodon arm is slightly curved, the result is different bases binding with each other.

These amti-codon bases bind with the codon bases.

X1	Y3
tRNA anti-codon	mRNA codon
U	A or G
C	G
A	U
G	C or U

This allows the 31 tRNAs to bind to the 61 codons.

One ribosome can make an average-sized polypeptide in less than a minute. However, several ribosomes work on the same mRNA strand at the same time. Once a ribosome moves past the initiation site, another ribosome binds to the site. These dusters of ribosomes are called polyribosomes.

From Polypeptide to Functional Protein: During and after the synthesis of a polypeptide, the peptide begins to fold and coil spontaneously to form a functional protein with a specific 3-D shape (conformation). This

polypeptide may be altered before it does its job in the cell. Certain ammo acids may be modified or removed. The polypeptide may be cleaved or joined to other molecules.

Protein Targeting: There are two types of ribosomes found in eukaryotes.
1) Free: produce proteins that are found in the cytoplasm.
2) Bound: make membrane proteins and proteins that are secreted.

What determines if a ribosome is free or bound? The synthesis of all proteins starts in the cytoplasm (with a free ribosome). The growing polypeptide causes the ribosome to remain free or to attach to the ER. Proteins that are to be extracted are moved by a signal sequence which is about 20 ammo acids long. This sequence allows the ribosome to attach to a receptor site on the ER. Synthesis of the polypeptide continues there. The polypeptide moves into the cisternal space where the signal sequence is removed by enzymes.

PROTEIN SYNTHESIS IN EUKARYOTES AND PROKARYOTES
Protein synthesis is essentially the same in both types of cells. However, in prokaryotes the ribosomes can attach directly to the mRNA molecule while the mRNA is being synthesized. In eukaryotes, the nuclear membrane separates transcription from translation. This separation allows for the RNA to be processed.

1. RNA processing in Eukaryotes
Enzymes in the eukaryotic nucleus modify the mRNA before the genetic message is dispatched to the cytoplasm.

a. Alteration of the mRNA ends
1) The 5' end during transcription is capped with a modified guanine. This process serves two functions:
    a) It protects the mRNA from hydrolytic enzymes.
    b) After the mRNA reaches the cytoplasm, the 5' cap acts as a signal for small ribosomal subunits.
2) On the 3' end, there is synthesized (last during transcription) a poly-A tail (150 - 200 A nucleotides). Like the 5' cap, the poly- A tail helps prevent degradation of the mRNA. The tail may also play a regulatory role in protein synthesis-- it may facilitate the export of mRNA from the nucleus to the cytoplasm.

b. RNA splicing
Most of the RNA is cut and pasted during RNA splicing.

c. Transcription
The average length of a transcription unit along a DNA molecule and the newly transcribed mRNA is 8,000 nucleotides. However, the average protein is made of about 400 amino acids or 1,200 nucleotides. This means that most of the RNA transcript is not translated and apparently does not code for any protein. The non-coding sequences are interspersed between the actual coding segments. The coding segments of DNA are called exons. The non-coding DNA sequences are called introns.

Both introns and exons are transcribed to form a molecule of hnRNA (heterogeneous nuclear RNA). hnRNA never leaves the nucleus--- it is first edited. (i.e. cut and spliced)

2. The Mechanisms of RNA Splicing
A molecule called a spliceosome interants with the ends of an RNA intron, cuts the introns at specific points, releases the intron and joins the adjacent exons.

Introns have a couple possible functions.
    a. Introns may play a regulatory role in the cell.
        1) They may control gene activity in some way.
        2) The splicing process is part of a mechanism that regulates the passage of mRNA from the nucleus to the cytoplasm.

    b.   Introns may allow different cells in the same organism to make different proteins from common genes. Some introns may be exons in some cells.

    c.   Evolution of protein diversity: proteins are able to change one part of one gene and keep the another part of the gene unaltered.

3.   **Mutations**

What happens if the DNA sequence changes permanently due to the breakdown of the DNA repair systems? Here are some examples of the implications of mutations in DNA and how a change in the DNA will change a protein.

All the mutations will be compared to this mRNA strand.

AUG	UUU	GCU	GCG	CAC	CGC	UAG
Start	phe	ala	ala	hist	arg	stop

Base Substitution: mismatch.

AUG	UAU	GCU	GCG	CAC	CGC	UAG
Start	tyr	ala	ala	hist	arg	stop

Insertion of one or more bases:

AUC	GUU	UGG	CUG	CGC	ACC	GCU	AG
ile	val	tryp	leu	arg	thre	ala	

Deletion of one or more bases:

AUG	UUG	CUG	GCA	CCG	CUA	G
Start	leu	leu	ala	pro	leu	

Inversion of part of the nucleotide sequence:

AUG	UUU	GCG	UCG	CAC	CGC	UAG
Start	phe	ala	ser	hist	arg	stop

Breaking and loss of fragment of DNA:

AUG	UUU	GCU	GCG
Start	phe	ala	ala

Extra copies of DNA:

AUG	UUU	GCU	GCG	GCU	GCG	CAC	CGC	UAG
Start	phe	ala	ala	ala	ala	hist	arg	stop

The loss or gain of bases is called a frame shift. If three bases are added or deleted, the mutation may or may not change the protein.

There are three types of mutations. In non-scientific terms they are as follows:

1) Harmful: the mutation changes the protein so much that the protein is non-fictional. This harms the cell and organism. It can be deduced that most mutations are harmful.

2) Harmless: the mutation may or may not change the protein. H no change occurs, then the cell and organism are not hurt. If a change does occur and the change does not affect the protein fiction, then the cell and organism are not hurt.

3) Beneficial: the mutation changes the protein shape, but this change makes the protein function more efficiently. This makes the cell and organism better.

Mutations can be described using a car analogy. If you opened the hood of your car and blindly did something to the engine, then most likely the change would hurt the car (harmful mutation). Sometimes, you may not to anything to your car (harmless mutation). Then again, by some luck, you may actually help the car run better Coeneficial mutation).

VI. DNA - MOLECULAR GENETICS OF PROKARYOTES AND VIRUSES

A. INTRODUCTION
The chromosome of E. coli (a bacterium) is a single continuous (circular) thread of double stranded DNA (approximately 1 mm long, 2 run in diameter). There are about 4.5 million base pairs in this chromosome (about 2,000 genes). Add this DNA is about 1 / 1000th as much as the DNA found in a eukaryotic cell. The DNA forms a nucleotide which is a tangled loop of DNA.

Replication: When the chromosome replicates (during DNA synthesis), it occurs bidirectionallv. The replication begins at the point of original, called the origin of replication (Ori C). There is 5' to 3' leading strand and 3' to 5' lagging strand synthesizes. When the circular DNA replicates, it looks like the greek letter theta (q), so the DNA synthesis in bacteria is called theta replication.

B. TRANSCRIPTION AND REGULATION

1. Transcription
The segment of DNA that codes for a protein is called a structural gene. Genes coding for polypeptides (proteins) with related functions can be transcribed at the same tune. In transcription, genes that code for proteins are transcribed into a single retiNA strand. The process begins when the RNA polymerase attaches to the DNA at a specific sequence site known as the promoter. This conformational change of polymerase causes ten base pairs of DNA to open. The single stranded DNA acts as a ternplate for transcription. As transcription continues, the RNA molecule grows and remains hydrogen bonded to the DNA ternplate briefly. Only 10-12 nucleotides rentam hydrogen bonded to the DNA at one time. The other tRNA bases peel off m a single strand. Transcription occurs at a rate of about 45 nucleotides per second. The newly svnthesized mRNA molecule has a small leader at the 5' end. This 'leader' may help the mRNA strand brad to the ribosome. On the mRNA strand there may be numerous start and stop condons, Different genes can be on the same mRNA strand. There is an extra trmler at the 3' end.

2. Regulation of Transcription
Prokaryotes primarily eat and grow. E. coli could reproduce once every 20 mutes. How can this happen? E. coli are very efficient. In fact, prokaryotes (and other orgarusms) do not make all of these proteins at once. In fact, they ordy make proteins, in the proper amounts, when the proteins are needed.

For example, when E. coli uses lactose to produce energy, an enzyme called b-galactoside is used to break the sugar. The presence of lactose causes the enzyme to be produced. The enzyme is inducible. At the same time, other enzymes are repressible. Some routant cells cannot regulate the enzyme, The regulation in prokaryotes usually takes place at the level of transcription. Regulation revolves interactions between the chemical environment of the cell and regulatory proteins that are coded for by regulatory genes. These proteins can either repress (negative control) or enhance (positive control) transcription.

a. Operon
An operon is composed of a promoter, operator, structural genes, and terminator. The operator is a sequence of DNA located between the promotor and structural genes. The operator is an "on / off switch." it controls the access of RNA polymerase to the structural genes. Transcription of structural genes is dependent upon the supercoling of DNA, changes m polymerase structure, and activators/ repressors. The regulator is located anywhere on the bacterial chromosome. This regulator gene codes for a protein (called a repressor) which binds to the operator. The RNA polymerase and repressor binding sites are thought to be overlapping so that one enzyme binding prevents the binding of the other. When the repressor binds to the operator, the operator is obstructed. That in turns obstructs the promoter and turns the operator "off". When this occurs, RNA polvmerase cannot transcribe the gene. When the repressor is removed, then transcription

can occur. The gene that produces the repressor is called the regulatory gene. These enzymes are repressible enzymes. The operon is under negative control by a repressor and no transcription takes place until the repressor is removed. The ability-v of the repressor to bind to the operator depends on another molecule called the effector. Depending on the operon, an effector can either deactivate or activate the repressor.

b. Deactivation
For example, lactose is present in a medium. Bacteria produces a sugar called allolactose (an intermediate un lactose metabolism). Allolactose binds to and inactivates the repressor by causing a covdormataonaJ change, removing it from the operator of the lac operon. RNA polymerase can begin transcmpUon. Allolactose is an anti-repressor.

c. CAP-Cyclic AMP System
The Catabolite Activator Protein (CAP) is a protein that exerts a positive control on the operon. CAP combines with a molecule called cAMP (cyclic AMP), an effector. This causes a confrontational change in CAP such that it has a high ajfirUv,., for DNA. These two molecules bind to the promoter region of the operon. After the CAP-cAMP molecule binds to the promoter region, the complex facilitates the attachment of RNA polvmerase to the promoter, and maximum transcription takes place. It facilitates the binding of RNA polvmerase to the DNA strand 20-50 fold.

d. Inducers
Usually function in catabolic pathways, thev breakdown nutrients, (e.g. CAP)

e. Repressors
Usually function in anabolic pathways, in the synthesis of molecules, (e.g. lac repressor). Regulatory systems were observed first in E. coil These bacteria do not use lactose as an energy source when glucose is present. The lac operon remains repressed even though lactose is presev2. The intermediary, in this process of tunn.mg on the lac operon is cAMP. As the level of glucose decreases, repressor level decreases, the level of cAMP increases and more CAP-cAMP complexes formed. These complexes now bind to the lac operon. More enzymes frorn the lac operon are produced, more lactose is broken down.

TRANSPOSONS (TRANSPOSABLE GENETIC ELEMENTS)

A type of movable genetic element is called a transposon. These are pieces of DNA that can move from one location to another. They can move from one locus to another, from a plasmid to the chromosome (or visa versa), or from one plasmid to another. They can combine several genes for antibiotic resistance into a single plasmid. Transposons are segments of DNA that are integrated into the chromosomal DNA. Transposons contain a gene that codes for an enzyme called Transposase. This euyme catalyzes the insertion of the transposon unto the new site. These are also called jumping genes; however, these genes do not jump. In conservative transposition these genes are not replicated, but move so the number of these genes is conserved. In replicative transposition the transposon replicates at its original site and a copy inserts at some other location in the genome. The transposon's genes are added at some new site without being lost from the old site.

At either end of the transposon are repeated nucleotide sequences.

These sequences may consist of direct repeats -- ATFCAG ATTCAG or inverted repeats -- ATTCAG GACTTA.

These repeated sequences are about 20 - 40 nucleotides in length.

When the transposon inserts into the chromosome two things happen.
1) The site of the insertion is duplicated.
2) The target sequence (5-10 base pairs) ends up on either side of the transposon.

Sometimes the transposon can be duplicated. The new transposons can end up elsewhere.

There are two types of transposons.

l. Simple (also called Insertion Sequences)
These are about 600 - 1,500base pairs in length. These do not carry any genes beyond those that are necessary for transposition. There are at least six different simple transposons found *in E. coIi* They contain a gene that codes for transposase, an enzyme that catalyzes transposition. The gene is bracketed by a pair of DNA sequences called inverted repeats. Transposase recognizes these repeats as the boundaries of the transposon. The enzyme brings the two boundaries together, cuts the DNA and reseals the DNA-- the transposon can now move to another area.

If a simple transposon inserts into a gene, the transposon inactivates the gene. This process can cause mutations. Some simple transposons contain promoter sequences that may inappropriately activate inactive genes. Simple trampens have no function but to duplicate themselves. There are no positive effects of these transposons.

2. Complex Transposons
Larger than simple transposons, these carry genes that code for additional proteins. These genes are sandwiched between two insertion sequences. Genes that are part of the complex transposon can move about from chromosome to plasmid back to the chromosome.

Drug resistance genes have been transferred from plasmid to plasmid, plasmid to chromosome to plasmid again. Complex transposons have been found with two simple transposons on either end. This suggests that the complex transposon may have come about by two simple transposons jumping at the same time and taking everything between them.

Transposons are not unique to prokaryotes.

VII. MOLECULAR GENETICS OF EUKARYOTIC CELLS

A. EUKARYOTIC GENOME
1. The amount of DNA per cell differs among species.

Drosophila   1.4 X 10~ base pairs per haploid cell

Human   3.5 X liY base pairs per haploid cell.

Toad   3.32 X I(Y base pairs per haploid cell.

Salamander   8 X 10x° base pairs per haploid ceil.

Not all DNA. is used to produce proteins. It is estimated that less than 1% of human DNA is expressed.

Almost half of the DNA of eukaryotic cells consists of nucleotide sequences that are repeated hundreds to millions of times.

B. GENE AMPLIFICATION AND SELECTIVE GENE LOSS
The number of copies of a gene or gene family may temporarily increase in some tissues during a stage of development. For example, the rRNA gene has multiple copies already in the genome. A developing egg synthesizes a million or more additional copies of rRNA genes which exist as extra chromosomal circles of DNA. This process is called gene amplification and allows the egg to make an enormous number of ribosomes for a huge increase in protein synthesis. After development has begun, the extra copies are hydroyzed.

C. MULTIGENE FAMIUES

Some genes are represented in the genome by more than one copy, and others resemble each other in nucleotide sequence. A collection of identical or similar genes is called a multigene family. The members of a multigene family may be clustered or dispersed in the genome; usually identical genes are clustered.

These multigene families may arise through repeated gene duplication which results from mistakes made in DNA replication and recombination. Pseudogenes are evidence for the process of gene duplication and mutation. Pseudogenes have sequences similar to real genes, but they lack the sites (promoters) necessary for gene statement. The pseudogenes also lend evidence to the assertion that duplicated genes may move in the genome by transposons.

D. INTRONS

Protein coding sequences of eukaryotic genes are not continuous but are interrupted by non-coding sequences.
1) Introns are non coding sequences of DNA.
2) Exons are cooling sequences of DNA.
The introns are transcribed into the mRNA molecule, but are cut out before translation.

The length of introns varies considerably. In general, the more complex the organism, the more abundant the introns.

It is suggested that introns may promote recombination. Crossing over during meiosis is more likely to occur in genes with introns than in genes lacking introns because of the distances involved.

CLASSES OF DNA: REPEATS AND NON REPEATS

There are three classes of Repeating DNA

l. Simple Sequence DNA
Short sequences of 5-10 base pairs. These sequences can be found in large quantities. For example, haft of the DNA in a species of crab consists of this sequence: ATATATATAT. A type of fruit fly has the sequence ACAAAC~ repeated 12 million times. About 20-30% of human DNA is composed of these types of short repeating sequences.

Simple-sequence DNA was thought to be vital to chromosome structure. Long blocks of short repetition sequences have been found around the centromere and may actually De the centromere. The tips of the' chromosome are made of the repeating sequence CI'rAGGG). It is thought that these tips play a role in the chromosome integrity and stability.

2. Intermediate-Repeat DNA
Intermediate-Repeat DNA differs from simple-repeat in the following ways. a. Sequences are longer. about 150 - 300 base pairs. b. Similar, but not identical to each other. c. Scattered throughout the genome. d. Some have known functions. The most studied intermediate-repeat DNA sequence are the genes coding for histone and rRNA. The histone genes are present in the cells of all eukaryotes. Eukaryotic cells may also contain
anywhere from 50 – 50,000 copies of the rRNA gene.

3. Single Copy DNA
The rest of the DNA (50-70%) is made up of non-repeating DNA sequences (or those which repeat only a few times). These sequences can code for proteins. However, about 1% of the total single copy genes code for proteins. These transcription units contain both introns and exons. Introns are usually longer than exons.

F. EUKARYOTIC CHROMOSOMES

There are 46 chromosomes in the human somatic cell. Each chromosome is believed to be 6 crn long, each cell contains around 2 meters of DNA. The human body thus contains about 25 billion km of DNA.

In the nucleus the DNA is combined with proteins to form chromatin. Chromatin is more than half histone proteins. Histones are positively charged and are attracted to the negatively charged DNA. Histones are synthesized during

the S phase of the cell cycle and are responsible for packaging the DNA.

There are 5 types of histones: H1, H2A, H2B, H3 and H4. Histones are found in large amounts in the cell. There are about 30 million molecules of H1 and about 60 million molecules of the other 4 histones per cell. The ammo acid sequences for the histones are very similar among a wide variety of organisms.

The packaging unit of chromatin is the nucleosome (diameter of about 10 nm and about 14 run apart). The nucleosome is composed of a core of two molecules each of histones H2A, H2B, H3 and H4 (8 molecules in all) that is wrapped by DNA. About 146 DNA base pairs are mapped around the nucleosome, and 30-60 DNA base pairs are found between two nucleosomes.

G. REPLICATION OF THE CHROMOSOME
DNA synthesis in prokaryotes is the similar to DNA synthesis in eukazyotes. In eukaryotic chromosomes, there are many points where the DNA synthesis occurs bidirectionally until the replication forks merge. Replication is much slower in eukaryotic cells than they are in prokaryotes. Approximately, 50 base pairs are replicated per second in the replication fork. The nucleosome directly in front of the replication fork needs to be disassembled prior to replication and this causes this slower replication in eukaryotes.

1. Organization of Eukaryotic Gene
There are promoter-like sequences, TATA or CAAT boxes, which are 25-80 base pairs upstream from the transcription start site. RNA polymerase will bind to these "boxes." There are also enhancer sequences which may be located thousands of base pairs away from the promoter.

2. Transcription and Processing mRNA in Eukaryotes Transcription is the same in principle as in prokaryotes.

3. Differences between eukaryotes and prokaryotes
a. Eukaryotic genes are not grouped in operons where 1 or 2 genes are transcribed into a single mRNA molecule. Each gene is transcribed separately.
b. There are 3 different RNA polymerases in eulr2ryotic cells:
1) RNA Polymerase I transcribes genes for the large ribosomal RNA.
2) RNA Polymerase II transcribes the precursor RNAs that will be processed into mRNAs. RNA polymerase II is also responsible for transcribing most vital RNA in infected cells.
3) RNA Polymerase transcribes a variety of small RNAs, including tRNA and the small ribosomal unit.
c. Post transcriptional modification of RNA occurs at different sites in eukaryotes.

d. Eukaryotic DNA is inaccessible to RNA polymerase because of the histone complexes.

4. Transcriptional Control of the Eukaryotic Gene
RNA synthesis depends on RNA polymerase and proteins called transcriptional factors. RNA polymerase and transcriptional factors bind to specific sequences within the promoter region (upstream of the gene). In eukaryotes, additional transcription factors bind to enhancer regions of DNA and may be thousands of bases away from the promoter gene.

One hypothesis states that a hairpin loop in the DNA stimulates transcription. The hairpin loop forms when the transcription factors on the enhancers bind with the transcription factors on the promoter.

Over 100 different transcription factors have been discovered m eukaryotes.

5. mRNA Modification and Editing
In prokaryotes, the ribosome attaches to an mRNA molecule and begins to translate even before transcription is completed. In eukaryotes, transcription and translation occur at separate tunes and places. Prior to leaving the nucleus RNA is modified in the following ways.

a. Even before transcription is completed (when the mRNA is about 200 bases long) an unusual nucleotide, 7-methyl guanine, is added to the 5' end of rnRNA. This cap is necessary, for the binding of mRNA to the ribosome.

b. After transcription is completed and the mRNA has been released from the DNA, an enzyme adds a string of adenine nucleotides, known as the poly A tail, to the 3' end of the rnP, NA. The poly A tail can be up to 200 nucleotides long.

c. Before the modified mRNA leaves the nucleus, the introns are excised and the exons are spaced together to form a single continuous molecule.

d. The mRNAs that are transported to the cytoplasm are associated with proteins called ribonucleoprotein particles (gAPs). These proteins may help in the transporting of the mRNA through the pores in the nuclear envelope. They may also help the mRNA bind to the ribosome.

6. Regulation of mRNA Degradation
In prokaryotes, mRNA is degraded very quickly. In eukaryotes, mRNA has a variety of life spans which last from hours to weeks. The longer the life span, the more times the mRNA molecule can be used to create proteins.

7. Translational and Post Translational Control
Protein factors are involved in translation, especially proteins known as INITIATION FACTORS. There are many opportunities for the control of gene statement at the translational level.

The last opportunity for controlling gene statement is after translation. Often, the polypeptide needs to be cut and chemical groups or sugar chains need to be added prior to gene activation.

H. REGULATION OF GENE statement IN EUKARYOTES
Problems of gene regulation of eukaryotes are different from those of prokaryotes. The multicellular organism starts off as a fertilized egg, a zygote. The zygote divides through mitosis and cytokinesis. At some point the cells begin to differentiate. Each cell begins to produce proteins different from the other cells.

There is evidence that all the genetic information present in the zygote is present in every diploid cell. Since each type of cell produces different proteins, it is apparent that the differentiation of the cell depends upon the inactivation of certain genes/proteins and on the activation of others.

l. Condensation of the Chromosome and Gene statement
There has been evidence to show that the degree of condensation plays a major role in the regulation of gene statement in eukaryotic cells. Staining the chromatin reveals two types of chromatin:

a. Euchromatin (swollen form)
More open chromatin that stains weakly.

b. Heterochromatin (compact form)
More condensed chromatin that stains strongly. (A Barr Body, found inside the nuclear membranc - near the nucleolus is primarily heterochromatin)

During interphase, heterochromatin remains condensed, but euchromatin becomes dispersed. Transcription of DNA to RNA only occurs during interphase when euchromatin is dispersed.

Some heterochromatin regions-are constant from cell to cell and are never transcribed, ie. chromatin in the centromere region. Other regions of condensed chromatin vary. form one type of cell to another. This variation reflects the synthesis of different proteins.

2. Methylation and Gene statement

Once the DNA helix is formed, an enzyme adds methyl groups to cytosine. Inactive DNA (i.e. Barr Bodies) is highly methylated compared to active (transcribed) DNA. When scientists compare active genes to inactive genes in different cell types; inactive genes are usually heavily methylated. Also, drugs that inhibit methylation can induce gene activation. Methylation may control gene statement or may be a cause of reduced gene statement.

3. Regulation by Specific Binding Proteins
In eukaryotic cells, transcription is also regulated by proteins that bind to specific sites on the DNA molecule. The level of transcriptional control is much more complex in eukaryotes than in proka.ryotes. A gene in a eukaryote seems to respond to the sum of many different regulatory proteins. Some turn off the gene, others turn on the gene.

These proteins may bind 100s and 1000s of DNA bases away from the promoter sequence where the RNA polymerase binds to the DNA and where transcription begins. Thus it is difficult to identify regulatory molecules.

4. Arrangement of Coordinating Controlled Genes
Genes of related functions that are switched on and off as a unit are arranged all over the genome. They are usually expressed together. This process may occur in the following way: each group has a specific nucleotide sequence that is recognized by a regulatory gene.

5. Action of Steroid Hormone in Vertebrates
Steroids are soluble in lipids and diffuse across the plasma membrane and the cytoplasm. The steroid enters the nucleus and encounters a soluble receptor protein. Without the steroid, the receptor protein is associated with an inhibitory protein that inhibits the receptor from binding with DNA. The steroid binds with the receptor, the inhibitor is released, and the complex binds with specific sites on the DNA. These sites are within enhancer regions which controls transcription. Steroids thus activate transcription.

6. Inhibitors of RNA metabolism

a, Bind to DNA
Some compounds can bind to certain DNA sequences. RNA polymerase can still bind, but the RNA chain elongation in both prokaryotes and eukaryotes is blocked.

b. Bind to RNA Polymerase
Some compounds can bind to RNA polymerase and can prevent the proper functioning of the enzyme.

Review: Five Key Points About Control of Gene statement in Eukaryotes

1. The various cell types of a multicellular organism express different genes.

2. Physical and chemical rearrangements of the genome make certain genes available for statement and other genes unavailable.

3. For genes that are available for statement, regulatory opportunities exist at each step in the pathway from gene to functional protein.

4. Control of transcription is important in determining which genes are expressed. In eukaryotes, selective binding of regulatory proteins to enhancer sequences in DNA stimulates transcription of specific genes.

5. The regulatory activity of some of these DNA-binding proteins is sensitive to certain hormones and other chemical cues.

I. Genes on the Move

Eukaryotic chromosomes are subject to rearrangements, deletions, and additions. Examples of such occurrences are the antibody coding genes, viruses, and transposons.

1. **Antibody-Coding Genes (Immunoglobin Genes)**
   a.   Antibody (Ab)
        Complex globular proteins by the B cells (lymphocytes- WBC) in response to foreign molecules
   b.   Antigens (Ag)
        Provokes response of Ab. All foreign proteins and some foreign polysaccharides are antigens. The Ab responds to and binds with a specific Ag, just as an enzyme responds to a specific substrate. After binding to the Ag, the Ab will help destroy the Ag.

   Problem: a single organism is capable of making at least 10 million different antibodies. There aren't enough genes on our chromosomes to account for all these proteins.

   Looking at the amino acids of the Ab, one notices that they are made of two heavy chains) long polypeptide chains) and two light (short polypeptide) chains. For each chain there are two regions.
   1) Constant region
   2) Variable region

The variable region binds to different Ag. There are only 100 amino acids in the variable region. It is thought that the constant and variable regions of the molecule are coded for by separate genes. The same constant genes could combine with different variable genes. In fact, the DNA for the variable regions of the heavy chains is made of at least 400 different variable sequences (V). There are about 12 diversity sequences (D), and 4 joining (J) sequences. These can be assembles in millions of diffenert ways.

   The DNA that codes for the variable regions of the Ab is moved into a new place or to the chromosome during the differentiation of the lymphocyte, ie. During the times it takes for the WBC to produce a specific Ab. Take one type of V gene, add a D and J gene and add together. Place these together with the C gene.

2. Viruses
   When the DNA of a virus incorporates in the eukaryotic cell, it is now called a PROVIRUS. These are mobile genetic elements. In eukaryotes the two viruses that move about and incorporate are the DNA viruses and RNA retroviruses.
   a.   DNA viruses
        A number of DNA viruses insert themselves into the chromosomal DNA of the host cell. These viruses can introduce new, functional genes into the DNA of the host cell.
   b.   RNA Retroviruses
   The enzyme reverse transcriptase allows the RNA strand to be a template for a new DNA strand. The reverse transcriptase is injected/ carried into the cell by the virus (the enzyme is in the capsid).

        The reverse transciprtase also directs the duplication of sequences at the end of the virus. This produces sequences called long-terminal repeats (LTRs). LTRs are a distinctive characteristic of retroviruses.

        Once integrated, the viral DNA uses RNA polymerase to produce proteins that are made into new viruses. The DNA from the virus may cause mutations by interfering with a gene, ie. Can either inhibit or active them.

3. Eukaryote Transposons
   These resemble bacterial counterparts in structure. They, too, can cause mutations. In eukaryotes, transposons are copied to RNS then back into DNA before insertion on the chromosome can occur (it was thought that only retroviruses did this). Also, eukaryotic transposons may contain pseudogenes (non-functioning genes). If these " jumps" in a sequence involved in the regulations of transcription, it mai increase or decrease transcription. The transposon can also carry a gene. This gene can be activated when it is inserted just downstream from a promoter.

J. GENES, VIRUSES, AND CANCER

Cancer is caused by carcinogens. These carcinogens cause mutations that alter gene expression. Cancer cells escape regulatory controls for cell growth. Cells multiply out of control, invading and destroying tissue.

Cancer is considered to be a group of diseases due to the fact that over 200 different types of cells can beomce malignant. The prognosis of the disease depends on which type of cell becomes malignant.

There are three pieces of evidence that points to a cancer link with changes of genetic material.
a. Once a cell is cancerous, all the daughter cells are cancerous.
b. Chromosomal changes are often seen in cancerous cells.
c. Most carcinogens are mutagens.

Cells that have their genetic makeup changed and become cancerous are called transformed cells. These cells can cause cancer when transplanted into other animals. Studies have uncovered a group of genes called oncogenes, which resemble normal genes of eukaryotic cells. Viruses may serve as vectors for oncogenes. They may turn on the oncogenes and cause the cell to become malignant. So far, about 50 oncogenes have been discovered. Normal cellular genes are called proto-oncogenes. These code for protein products that normally regulate cell growth, cell division, and cell adhesion. What changes a proto-oncogene into an oncogene? Four things: 1) gene amplification, 2) chromosomal translocation, 3) gene transposition, and 4) point mutations.

Changes to genes that inhibit cell division can also be involved in cancer (e.g. Tumor Suppressor Genes). These produce a protein that helps prevent uncontrollable cell growth. Any mutation that prevents the normal tumor repressor protein from being made may contribute to the onset of cancer.

Thus, viruses can bring about changes in the genetic makeup which can cause cancer.

VII.   RECOMBINANT DNA: DNA MOLECULE CARRYIN A NEW COMBINATION OF GENES

Current techniques have allowed us to determine the nucleotide sequences of specific DNA and RNA fragments. In fact, the base sequence of an entire bacteriophage genome has now been determined to contain an entire page of 5315 A's, T's, and G's. Our own DNA sequence would fill 1,000 books that are 1,000 pages long with 4 letters.

A. DNA TECHNOLOGY TOPICS
1. Methods for obtaining specific uniform DNA sequences
2. DNA cloning
3. Nucleic Acid Hybridization
4. DNA sequencing
5. DNA Technology
6. Uses for DNA technology

B. ISOLATING AND OBTAINING DNA SEGMENTS
Bacterial plasmids replicate autonomously in bacterial cells. Foreign genes can be isolated then inserted into plasmids, and the plasmids can be returned to bacterial cells. The bacterium will produce a protein corresponding to the newly inserted gene. Many DNA recombination techniques have been founded on the use of the following enzymes: restriction endonucleases and reverse transcriptase. These enzes are part of the Restriction Modification System that all cells have and enables cells to exclude foreign DNA by cutting it up.

1. Restriction Endonucleases: gDNA
Restriction Endonucleases were discovered in the 1960's. Restriction endonucleases cut DNA at specific sequences which are referred to as recognition sequences. There are more than 150 different recognition sequences.

EcoRI is a restriction endonucleases that cleaves DNA at this sequence
(5')-GAATTC-(3')

(3')-CTTAAG-(5')

This sequence is called a palindromic sequence. EcoRI cleaves the DNA like this:

(5')-G   AATTC-(3')
(3')-CTTAA   G-(5')

The EcoRI leaves a 5' overhang which is called a sticky end. Some restriction endonucleases make straight cuts through the DNA. The one that do not leave 'sticky ends.' These sticky ends can rejoin when hydrogen bonds from spontaneously with complementary bases and can join with other DNA segments that have been cut by the same enzyme. This adding of DNA fragments together is done with the sticky ends because they complement each other. For example:

Gene you want with sticky ends   Bacterial DNA with sticky ends
5'-G   AATTC-3'
3'-CCTTAA   G-5'

A small amount of the DNA fragments will bind covalently with the bacterial DNA. DNA ligase will covalently join the DNA fragments. More than 200 restriction endonucleases have been isolated, making it possible to cleave a DNA molecule at only one of the more than 150 recognition sequences. The DNA fragments produced by the restriction endonuclease cutting of DNA are called genomic DNA, gDNA. Through the use of restriction endonucleases, it is now possible to splice gDNA from a variety of sources.

STEPS:
a.   Isolate two kinds of DNA: Bacterial plasmid and gene from eukaryotic cell.
b.   The DNA from the plasmid and eukaryotic cell is treated with the same restrictions enzyme. The enzyme cuts the plasmid and the eukaryotic DNA creating thousands of fragments; one of the fragments will carry the gene of interest. In making the cuts, sticky ends are created on both the eukaryotic fragments and the plasmid. The eukaryotic DNA and plasmid sticky ends complement each other.
c.   DNA ligase joins the two DNA molecules.
d.   The recombinant plasmid now carrying the eukaryotic gene, is introduced into the bacterial cell by adding the DNA to bacterial culture. Under the right conditions, the bacteria will take up the plasmid from the solution.
e.   Gene clonging is the production of multiple copies of the gene of interest. As the bacteria replicates, plasmids replicate. We identify the bacteria with the plasmid by placing the bacteria on agar with ampicillin and tetracycline. The transformed bacteria will live because the plasmid also carries resistance to the two antibiotics while the nontransformed bacteria dies.

2. Reverse Transcriptase: cDNA

We can obtain specific DNA segments for cloning and manipulation via retroviruses. Retroviruses are RNA viruses in which the RNA serves as a template for DNA. Reverse transcriptase transcribes RNA to DNA. DNA molecules synthesized by reverse transcriptase from an RNA tamplate are known as complementary DNA or cDNA. cDNA molecules can be spliced into other DNA molecules by artifical sticky ends.

In this method we obtain artificial genes that lack introns. We use the mRNA after it is prepared (transcription and splicesomes). These molecules are used as templates to synthesize complementary DNA strands using reverse transcriptase. After the single DNA is made, mRNA is degraded and the second strand is made using the first as a template. In order for DNA to be transcribed in bacteria, it must be attached to a bacterial promoter and have other transcription signals.

3. Isolate DNA from an organism

We can isolate the DNA from a cell, cut with restriction enzymes, isolate the fragments by electrophoresis, mix with cloning vectors (e.g. plasmids), add ligase, and introduce to bacteria. This is the shotgun approach which means that no single gene is produced.

4. Synthetic Oligonucleotides

Obtaining uniform DNA or RNA: We have methods for synthesizing short sequences of DNA and RNA, called synthetic oligonucleotides.

C. CLONES AND VECTORS

Once we obtain the DNA(gDNA, cDNA, shotgun approach or synthetic olignucleotides), we need to duplicate it. The machinery for duplicating DNA is already present in E. coli and other bacterial cells. There needs to be vectors in order for the DNA to be transported to the bacteria. Prokaryotes and viruses provided the solutions for transportation.

1. **Plasmids as Vectors**

   Plasmids are useful vectors because theu multiply rapidly and easily taken up through the bacterial cell membrane. We are able to take a plasmid, cut it open with a restriction endonuclease, join it with a gene cut with the same restriction endonuclease and then seal with DNA ligase. This plasmids can now be placed into a competent bacterial cell. The bacteria will now synthesrze the protein from the gene that has been inserted. These plasmids will be copied in the bacterium. The copied segments of DNA can be isolated with restriction endonucleases and separated by electrophoresis and analyzed. Let's see how it works. A piece of DNA with the gene that you want has some Eco RI sites. The piece of DNA is cut with the enzyme EcoRI to give us DNA fragments. On these DNA fragments are the wanted genes. In order to separate these DNA fragments, which fragments will be added to pieces of bacterial DNA.

2. **Polymerase Chain Reaction (PCR): Amplifying DNA**

   In this process, the Dna is quickly copied in vitro. DNA is incubated with DNA polymerase and short pieces of nucleic acid called primers. This process is much faster than gene cloning with plasmids or phage DNA.

   STEPS:
   a. Make a solution of DNA with the "Target" sequence.
   b. Add DNA polymerase, a supply of all four nucleotides, and primers. Primers are chemically synthesized sequences that are complementary to the ends of the target DNA.
   c. DNA is heated and denatures.
   d. Primers bind to the single stranded DNA.
   e. DNA polymerase extends the primers. Within a short time, DNA amount has doubled.
   f. DNA is heated again, repeat steps 3-5. Take about 5 minutes per cycle.
   PCR is specific for DNA sequences desired. There is no need to isolate the segments. DNA is very stable and can be amplified by PCR from sources thousands or millions of years old. PCR is used to amplify DNA from a 40,000 years old mammoth, and semen from a crime scene. Once the genes are isolated and cloned, they are inserted into cells

3. **Inserting genes into cells**
   a. A plasmid is a cloning vector which carries genes into bacteria. The plasmid is usually taken up by the bacterium through transformation.
   b. Lambda Phage and Cosmids are part of the viral DNA and are injected into the cell by the virus.
   c. Electroporation is a procedure that gets DNA into eukaryotic cells. A brief pulse of electricity is supplied to the cell, this causes temporary holes in the cell membrane. The DNA enters the cell through these holes.
   d. DNA can also be injected directly into a single cell. This can be done with plant cells.

D. RADIOATICE PROBES

Before any manipulation can be performed on the DNA and/or RNA, it has to be located and isolated. One way of doing this is through radioactive probes. These probes are short segments of single stranded DNA or RNA, cDNA or gDNA. These may be used in many ways

E. MAKING GENE PRODUCTS USING GENETIC ENGINEERING

It is difficult to have eukaryotic cells produce eukaryotic proteins, even after inserting the cDNA into the cell. The solution to this problem is to use eukaryotic cells. The prokaryotic genome is relatively simple to manipulate. Prokaryotes can be grown in fermenters and they can produce large quantities of proteins. Yeast cells are a simple eukaryotic cell used for genetic engineering.

F. OTHER DNA TECHNOLOGIES

1. RFLP Analysis/Restriction Fragment Length Polymorphisms (pronounced "Riflip")

RFLP examines homologous segments of DNA. These segments will show different pattens when treated with restriction enzymes. For example, GAATTC in one segment may by GAATTC in another. The first will be cut by EcoRI and the second will bot cut at all. RFLP is based on naturally occurring minor differences called polymorphisms, in DNA sequences.

STEPS:
a. DNA is extracted from white blood cells. A restriction endonulcease is added to the sample.
b. Electrophoresis is performed on the fragments which will begin to separate.
c. The DNA on the gel is heated and is denatured. The sample strands, now single stranded, are transferred onto a special paper by blotting, a technique known as the soughtern blotting method.
d. Radioactive probes are added to the DNA bands. These probes are complementary to the DNA fragments. The probes match up with the complementary bases.
e. After the probes are added, the excess probes are rinsed off. A sheet of photographic film is laid over the gel. The radioactive probes expose the film to form a film with corresponding bands.

RFLP shows a large amount of variation and is referred to as DNA fingerprinting.

2. Nucleic Acid Hybridization

This method is used to study DNA and RNA. Nucleic acid hybridization takes advantage of the base pairing properties of nucleic acids. If DNA is heated up, the hydrogen bonds between nitrogen bases break. When cooled, the hydrogen bonds reform, forming the double helix again. When DNA samples from different sources are mixed together and heated up, they undergo random collisions. If two strands with almost complementary base sequence find each other, they form a hybrid double helix. One can tell similarities between nucleotide sequences and then determine the evolutionary relationships between organisms. When denatured, DNA mixed up with RNA (single stranded) will form DNA-RNA hybrids. These can be used to isolate DNA sequences.

G. APPLICATIONS OF DNA TECHNOLOGY

Genes can be cloned, proteins can be produced, genes can be used as probes to seek out similar genes, and radioactive probes can target genes. We can learn about regulatory and non-coding sequences. Probes can help map out the eukaryotic chromosomes by bonding with chromosomes. We can produce gene and protein catalogues.

1. Human Genome Project

The aim is to map out the entire human genome. Four approaches:
a. Genetic (linkage) mapping of the human genome with 3,000 genetic markers. RFLP technology is used.
b. Physical Mapping: Cut each chromosome into a number of fragments and determine the order.
c. Sequencing the Human Genome: Determine the order of nucleic acids.
d. Analyze the genomes of other species.

2. Medical Uses

a. Diagnosis of Diseases
We can use PCR probes to track down pathogens; HIV was extracted from a British sailor who died in 1959. PCR can also be used to diagnose over 200 human genetic disorders. We can use RFLP technology and run gels and compare fragments. Mutations of genes may change the banding patterns.
b. Human Gene Therapy
We maybe able to cure some genetic disorders in individuals. For example, for a single gene disorder the properly functioning could be inserted into the individual.
c. Vaccines

          1) rDNA can generate large numbers of protein molecules from the coats of pathogens; these can trigger an immune response later.
          2) The genome of a pathogen can be modified to decrease its virulence.
    d. Pharmaceutical Products
    Are produced in this way; for example: Insulin, Human Genome Hormone, and Erythropoietin.

3. Forensic Uses

DNA fingerprinting/RFLP. The chance that two people have the same set of RFLP is very small.

4. Agricultural Use
    a. Animal Husbandry
    Treat animals with rDNA treated products, such as;
        1) Vaccines
        2) Antibodies
        3) Growth hormones
    b. Manipulating Plant Genes
        1) Make plants resistant to herbicides-carry prokaryotic genes.
        2) Retard spoiling
        3) Resist pathogens
        4) Increase nitrogen fixing ability of bacteria
        5) Transgenic organisms which contain genes from other species have been engineered; for example, tomatoes.

UNIT VI
EVOLUTION/SPECIATION

I. EVOLUTION
Microevolution: Changes in gene frequencies

A. GENETIC STRUCTURE OF POPULATIONS
1. Population Genetics
Branch of genetics concerned with heredity in groups of individuals.
2. Population
Community of individuals linked by bonds of mating and parenthood that are found in a common geographical area. Community of individuals of the same species.
3. Species
A group of organisms that can have fertile offspring.

A population has continuity from generation to generation. The genetic constitution of a population may change over time. Genetic variation is necessary for this change (evolution). *Note*: Populations evolve. Individuals cannot evolve.

B. EVIDENCE OF EVOLUTION
How do we know that changes in population have occurred?
1. Fossils
Fossils are the remains or imprints of organisms that have been preserved.
    a. **Mold Fossil**
    Impression left in surrounding rock by the decay of organic material
    b. **Cast Fossil**
    Natural filling of a mold left behind after a fossil has been removed from the rock by solution
    c. **Permineralization**
The process by which shell or skeletal material is infiltrated by mineral matter making the hard part denser and heavier. Also called petrification as in petrified wood. In petrified wood, there is still wood, but the little holes have been filled by minerals.
    d. **Replacement fossils**

Process of fossilization in which the original mineral material of a hard part is replaced by another kind of mineral. It is an actual molecular level replacement molecule by molecule. Eventually, there are no more organism molecules.

e.   Organic matter

Some organic material can be left behind, such as bones, teeth, and materials that are rich in minerals. Some organic matter can be "pressed" in layers of sandstone or shale.

f.   Preservation

Organisms are entrapped quickly and completely in an oxygen free environment. This prevents decay. Examples include insects in amber, tar pits, peat bogs, glacial ice, and volcanic ash.

2. Comparative Anatomy

a.   Homologous Structures

Structures or parts of organisms that have the same origin, but may or may not have same function

b.   Analogous Structures

Parts of different organisms that have similar function, but not similar origins

c.   Vestigial Structure

Structures or organs that have no apparent function. These structures are thought to have had a function in ancestors or organisms, for example, appendix, wisdom teeth, fingernails, hair, etc.

3. Comparative Embryology

Developmental patterns are similar in organisms with similar evolutionary relationships. There are fewer differences in organisms that are closely related. We can see a closer relationship between organisms if we compare them earlier in their fetal development.

4. Biogeography

The distribution of species first suggested common descent to Darwin. Islands have many species of plants and animals that are both endemic (found nowhere else) and that are closely related to species on the nearest mainland or neighboring island.

5.   Comparative biochemistry

The sequence of DNA and the proteins that the organism produces. Evidence suggests that organisms with similar DNA and proteins are closely related evolutionarily.

6.   Fossil Dating

a.   Relative dating

Due to different rates of sedimentation in seas and lakes, the rocks form layers or strata. The fossils in a stratum are a local sampling of the organisms that existed at that time period. Younger sediments are on top of older sediments. Thus, the layers of sediments give us relative ages of the fossils.

b.   Absolute dating

The determination of the actual age of the fossil. This does not imply 'errorless.'

1) *Radioactive Dating:* Fossils contain radioactive isotopes accumulated when the organisms were alive. Once dead, the organisms do not accumulate any more of the isotopes. Each radioactive isotopes has a fixed rate of decay which can be used to date the fossil. A half-life is the time it takes for 50% of the isotope to decay. The decay is unaffected by temperature, pressure, or other environmental factors. For example, C^{14} has a half life of 5,600 years.

2) *Amino Acid Racemization:* Amino acids exists in two isomer forms: either left handed (L) or right handed (D) symmetry. Organisms synthesize only L amino acids. After the organism dies, L amino acids change to a mixture of D and L amino acids. In a fossil, the ratio of L and D amino acids can be measured. Knowing the rate of conversion (racemization), we can determine how long the organism has been dead. However, this process is temperature sensitive.

C. EVOLUTIONARY THEORY

How did changes in population come about? Here are a couple of evolution theories.

1. Jean Baptiste de LeMarck

Two theories of how organisms changed over time.

a.   Acquired Characteristics

Organisms can change their body when needed and pass these changes onto their offspring.

        b. **Law of Use and Disuse**
If you don't use a body part, it will be lost in the next generation.
   2. Charles Darwin
        a. Darwin was appointed Naturalist o board the H.M.S. *Beagle* which went on a five year voyage (1831-1836). He observed plants and animals on the Galapagos Islands off the coast of Ecuador. Some of these organisms were: Finches, Giant Tortoises, Iguanas, Orchids.
        b. In 1859 Darwin published a book entitled *The Origin of Species by means of Natural Selection*. In this book he outlines his principles of natural selection.
            1) Individuals in a species vary.
            2) Some variations are heritable.
            3) More individuals are produced than the environment can support.
            4) Competition for resources occurs.
            5) Individuals with favorable traits (and genotypes) will survive and reproduce. These traits will then be passed to the offspring.

D. NATURAL SELECTION

Darwin used natural selection to explain how these changes came about. Natural selection states that nature is acting upon a phenotype. These phenotypes, or traits, are coded for by genes. If an organism is adapted it will live and reproduce. If the organism is not adapted, it will move to a new environment or die. Organisms must adapt, migrate or die. Darwin's theory does not emphasize survival, but reproductive success. Organisms can, after all, live their full life span and never reproduce.

E. VARIATION

Where does the variation come from?

1. Mutations

Permanent, random chemical changes in the DNA molecule that are passed on to offspring.

2. Variation from Recombination

The creation of genetic variation by recombination can occur more swiftly than it does when due solely to mutations.

3. Variation from Migration

Migration of individuals into a population from other populations can introduce new genes into the population, or remove genes from a population when individuals leave.

Every species of organisms examined has revealed considerable genetic variation (polymorphism), this is reflected in the phenotype. Here are some examples of variations in a population

        a. **Morphological Variation**
        Different body shapes and colors. For example, the shell of the land snail (*Lepea nemoralis)* may be mink or yellow depending on the two alleles at the single locus.

        b. **Chromosomal Variation**
In some species the organisms vary in chromosome number and shape. Extra chromosomes, reciprocal translocations and inversions occur naturally in populations of plants, insects and a few mammals.

        c. **Protein Variations**
        There are instances of amino acids substitutions in proteins of animals within a species.

F. MAINTAINENCE OF GENETIC VARIATION

Genetic variation is promoted and preserved through preservation and promotion of variability.

1. Sexual Reproduction Produces New Genetic Combinations
        a. Independent assortment at time of meiosis.
        b. Crossing over with genetic recombinations.
        c. Combination of two parental genomes at fertilization.

2. Mechanisms that Promote Outbreeding
   a. Plants
       1) Some plants only have male or female parts.
       2) Anatomical arrangements of some flowers do not promote self fertilization.
       3) There are genes for self sterility.
   b. Animals
       1) Hermaphrodites rarely self fertilize.
       2) Mammals
           a) Males leave communes to mate
           b) Human cultural taboos against incest

3. Diploidy
In haploid organisms genetic variation is directly expressed in the phenotype which is exposed to selection process. In diploid organisms the variation may be stored as recessive alleles. The recessive alleles are protected from exposure to selection.

4. Heterozygote Superiority
Recessive alleles may be harmful in the homozygous state but they may make the heterozygote have greater reproductive success. An example is the sickle cell trait.

G. CHANGES IN GENE FREQUENCY: NATURAL SELECTION
   How are gene frequency changed?

1. Gene Pool
All the genes of any population at a given time is called a gene pool. The variation in this pool can change over time.

   Evolution is any change in allelic frequencies in the gene pool. Evolution can proceed randomly or it can proceed under the influence of natural selection. Sometimes traits are favored by an environment, the organism will reproduce, and those genes will be passed on to the offspring. Other times, the traits may be less favored and the organism will have fewer or no offspring.

2. How Gene Pools Change
   Random changes in the gene pool are forms of evolution without natural selection

   a. Gene Flow
The movement of alleles into or out of a population. This can be a result of immigration or emigration of breeding individuals or the movement of gametes between populations (as in pollination).

   Gene flow can introduce new alleles into a population or change allelic frequencies. The overall effect is the decrease in the difference between populations. Natural selection increases the differences.

   b. Genetic Drift
This is a change in the gene pool that takes place as a result of chance. There are two situations where chance plays a role in evolution.

       1) *Founder Effect*: A small population branches off from a larger one. This population may or may not be genetically representative of the large population from whence it came. As the population increases in size, a different gene pool will develop from that of the parent population. For example, Afrikaaners in South Africa are descended from about 30 Dutch families and show a high frequency or recessive diseases. The Amish also have their own groups of recessive disorders.
       2) *Population Bottleneck*: A population is drastically reduced by an event such as a flood or volcanic eruption having little or nothing to do with the usual forces of natural selection. The individuals that survive may have rare alleles. The gene frequencies of these rare alleles would increase dramatically after the disaster.

   c. Nonrandom Mating

All individuals prefer to mate with those of a particular phenotype. Nonrandom mating may cause changes in gene frequencies.

Individuals typically mate more often with close neighbors than with distant members of population. Thus, individuals of a neighborhood tend to be related, and inbreeding occurs. Inbreeding over the long term will increase the frequency of homozygous recessive traits. Another type of nonrandom mating is assertive mating. Individuals select partners that are like themselves in certain phenotypic characteristics.

d. Mutations

A new mutation transmitted by gametes immediately change the gene pool by substituting one allele for another. However, the mutation by itself doesn't have much affect on a large population in a single generation. Mutations are a very rare event and are the ultimate source of all genetic variation.

3. Changes in gene frequencies due to Natural Selection

a. Description

The Hardy-Weinberg Equilibrium considers the gene frequencies in a population. Let's look at the frequencies of three genotypes produced by a pair of alleles (AA, Aa, aa). "A" is dominant, "a" is recessive.

Alleles: A and a
The frequency (f) of A in a population = (f) AA and 1/2 (f) Aa
The frequency (f) of a in a population = (f) aa and 1/2 (f) Aa.

Let the frequency of A = p and the frequency of a = q.
p = (f) AA + 1/2 (f) Aa
q = (f) aa + 1/2 (f) Aa

The frequency of both genes in a population is equal to
P + q = (f) AA + (f) Aa + (f) aa = 1 (the whole population).

In other words p + q=1, then q=1-p. With this information, if we know q, then we can determine p and visa versa. If the frequency of A is 0.7, then the frequency of a is equal to 1-0.7=0.3.

The probability of A meeting A is $p*p=p^2$.
The probability of A meeting a and a meeting A is $p*q+p*q=2pq$.
The probability of meeting a is $q*q=q^2$.

The three genotypes (AA, Aa, aa) together add up to the whole poulation or 1 or $p^2+2pq+q^2=1$. This is called the Hardy-Weinberg equilibrium.

We can determine the genotypes of a population if given these values.
A=.3
Q=1-p, q=1-0.3=0.7
AA=p^2=0.3*0.3=0.9
aa=q^2=0.7*0.7=0.49
Aa=2pq=2*0.3*0.7=0.42
Therefore, in the population, 9% are AA, 49% are aa, and 42% are Aa.

In a population 16% of the people are recessive. Determine the frequency of the three genotypes. 16% of the population =aa=q^2. If q^2=.16 then q= the square root of .16=.4. If that is the case then p=1-q or 1-.4=.6. If p=.6, then p^2 (frequency of AA) is =.6*.6=.36. 2pq (frequency of Aa) =2*.4*.6=.48. In this population, 36% of the people are AA, 48% of the people are Aa and 16% of the people are aa.

If we use this equation and if we can trace a change in gene frequency over a period of time, we can substantiate that evolution has occurred.

b. **Rules**
Hardy-Weinberg has a number of rules that must be followed in order to be valid.
1) One must use one trait that is controlled by a pair of alleles.
2) There must be a random sampling of a population.
3) The trait appears equally in both sexes.
4) Mating is random.
5) No net change in alleles through mutations.
6) Population size must be large enough for the rules of mathematical probability to be valid.

c. **Usefullness**
Why is the Hardy-Weinberg Equilibrium useful?
1) Most of population genetics theory and quantitative evolution theories are built upon models. The Hardy-Weinberg Equilibrium is the ground work for most of the models.
2) Hardy-Weinberg Equilibrium predictions are useful when studying populations since they provide a benchmark genetic equilibrium against which change can be noted.
3) It permits an estimation of gene frequencies, especially useful in estimating the number of carriers of lethal alleles in human populations.

H. FITNESS
Darwin's idea of fitness is measured by the relative contribution an individual makes to the gene pool of the next generation.

Fitness is the contribution of many factors that affect both survival and fertility.

1. Relative Fitness
Contribution of a genotype to the next generation compared to the contribution of alternative genotypes for the same locus. Consider, for example, three flower colors, AA-red, aa-white, Aa-pink. White flowers produce 80% as many offspring than the red flowers. Since the red flowers produce more offspring, they give a relative fitness of 1. The relative fitness of the white flowers is therefore 0.8.

2. Selection Coefficient
The difference between the most fit genotype's relative fitness and the less fit genotype's relative fitness is called selection coefficient. For the above example, the selection coefficient is 0.2(1-0.8).

The rate of harmful recessive alleles decreases in a population, but is never eliminated because they are protected in the heterozygote condition. Selection is greater against harmful dominant alleles because it is expressed in the heterzygote.

A new recessive mutation spreads very slowly in a population even if it is beneficial. This is because two copies of the allele need to be present for expression in the phenotype. A new dominant mutation spreads more quickly because the parent has a 50% chance of passing on the mutation.

I. WHAT IS SELECTED IN NATURAL SELECTION?
A phenotype is an expression of many different genes. The phenotype includes all observable attributes of an organism. The entire phenotype of an individual is the unit of selection.

It is rare that a single allele can determine a successful phenotype. In fact, groups of genes usually determine the success of an organism. These groups are called coadaptive gene complexes, or, if they are linked together, supergenes.

At the same time, the phenotype isn't determined by genes alone, but by the interactions of the phenotype with the environment.

1. **Stabilizing selection**
Extreme individuals are eliminated and intermediate forms are favored. The mutant forms are probably eliminated quickly.

2. **Disruptive selection**
Increase the two extreme types in a population at the expense of the intermediate forms. The result is usually a marked difference between the two groups.

3. **Directional selection**
Directional selection results in an increase in the proportion of individuals with an extreme characteristic. There is a gradual replacement of one allele or group of alleles by another allele in the gene pool.

4. **Frequency Dependent selection**
Decreases the frequency of the more common phenotype and increase the frequency of the least common phenotype, as in many predator/prey relationships.

5. **Sexual Selection takes two forms**
   a. Intrasexual Selection
   Competition among members of one gender for the other.
   b. Intersexual Selection
   Members of one gender exert strong selective pressures on the characteristics of the opposite gender through the choice of mates.

6. **Mating Systems**
   a. Polgyny
   Where few males mate with many females.
   b. Monogamy
   One male mates with one female for a single or many reproductive seasons.
   c. Polyandry
   Where one female mates with many males.

   These three mating systems differ in the energy investment by the different genders.

   The chief cause of sexual dimorphism, difference between males and females, doesn't deal with reproduction per se, but deals with obtaining a mate. Examples include extravagant plumage of male birds and oversized antlers of some male ungulates.

7. **Result of Natural Selection: Adaptation**
   Adaptations occur over many generations. Individuals are being selected. Certain individuals with certain traits (and genes) reproduce and pass their genes to the next generation.

   Adaptations are a result of natural selection and can be clearly correlated with environmental factors or with the selective forces exerted by other organisms

   a. Adaptations to Physical Environment
   Some phenotypic variations within a species follow geographic distribution and correlate with gradual environmental changes. This graded variation of a trait or complex of traits is called a cline.

A species that occupies different habitats may show phenotypic differences among habitats. Each group of distinct phenotypes is known as an ecotype and have a genetic basis.

b. Adaptations to the Biological Environment
Coevolution occurs when populations of two or more species interact closely so that each exerts a strong selective force on the other.

c. Mimicry
One example of coevolution.

d. Muellerian Mimicry
In insects, unrelated and unpalatable species often resemble each other in their warning coloration as means to avoid a predator.

e. Batesian Mimicry
Other palatable insects resemble unpalatable ones to avoid predation.

J. NATURAL SELECTION AND EVOLUTION: SUMMARY
Natural selection pushes populations toward better solutions to specific problems. Natural selection doesn't always produce the perfect solution.

1. Developmental and Structural Constraints
Natural selection can only work with available genetic traits. The jerry building that is a result of natural selection should be convincing evidence that evolution takes place.

2. Loss of Capacities
Natural selection may lead to a loss of complexity. For example, some animals that live in darkness lose eyes and the ability to see.

3. Patterns of Evolution
a. Convergent evolution
Organisms that occupy similar environments often resemble one another although they may be only distantly related. When they are subjected to similar selection pressures, they have similar adaptations.

b. Divergent Evolution
When populations become isolated from each other, different selective pressures lead to different phenotypes.

K. MECHANISMS OF MICROEVOLUTION
1. Preadaptation
Most biological structures have the ability to serve alternative functions. This is evolutionary plasticity. Preadaptation is the term used for a structure that evolved in one context but is used for another function. This does not imply that a structure was formed in anticipation of a future use. Instead the organism solved problems with what was available.
2. Developmental and Macroevolution
How can a slight genetic difference become magnified into major differences between organisms?
a. Allometric Growth
Genes that control development controls when and how changes in an organism's form occurs from a zygote to an adult. Allometric growth is a difference in the relative rates of growth between various body parts and helps shape the organism. Even slightly altering the rates of growth and the adult form is changed

b. Paedomorphosis
Genetic changes can also affect the timing of developmental events, such as the sequence in which different organs start and stop developing. An example is paedomorphosis in which sexually mature adults in one species keep structures that were in the juvenile form of evolutionary ancestors.

c. Developmental Timing

Changes in developmental timing has been important in human evolution. Humans and chimpanzees are closely related. A major difference is the brain size, a difference due to developmental timing. The growth of the brain stops much later in human development and human brains grow for several more years than the chimpanzee brain.

All examples of temporal changes in devlopment fit into two categories.
1. *Heterochronic:* changes in the timing or rate of devlopment.
2. *Homeotic:* changes which alter the placement of different body parts.

L. EVOLUTIONARY TREND

1 Gradualism

Gradualism is a gradual change of organisms over time.

2 Punctuated Equilibrium

Long periods of no change, punctuated by short periods of drastic changes. This could be brought about by natural disasters and intense natural selection.

3 Adaptive Radiation

An ancestral species gives rise to many different species.

II. SPECIATION

A. DEFINITIONS

1. Biological species concept

A population of organisms that can produce fertile offspring.

2. Population

A group of organisms that are of the same species and are in one area.

3. Gene Pool

All the hereditary material of a population.

4. Speciation

Long term change in the gene pool. A change in the gene frequency of a population which splits a population and which occurs over a long period of time. Speciation is the formation of a new species by the isolation of the gene pools of related populations.

Even though many populations live side by side, they may become reproductively and genetically isolated and cannot produce fertile offspring. Any factor that impedes two species from producing fertile hybrids contributes to reproductive isolation. A geographic barrier is not a form of reproductive isolation.

B. ISOLATION OF GENE POOL

If populations cannot exchange genes, their gene pool are isolated. This raises questions. How did one gene pool split from the other? And, how can two species that are similar to each other inhabit the same place at the same time and remain reproductively isolated?

1. Races

Members of the same population that differ somewhat genetically but can still interbreed.

2. Subspecies

Races that are different phenotypically. Races and subspecies can become full species if geographic barriers arise preventing gene flow.

C. ALLOPATRIC SPECIATION (GEOGRAPHIC ISOLATION)

1. Isolation

Populations in one geographic area are split into two or more geographically separated populations. Initially this blocks gene flow between two parts of a population. For example, a glacier cuts across a plain. A small number of indivudals colonize the new habitats on either side of the glacier. The populations are geographically isolated. Other examples include islands and island like situations such as, lakes for fish, the break up of pangea into continents, mountain tops for animals and plants, and forest extent for small mammals.

The populations may begin to diverge genetically under the pressure of different selection forces. If enough time passes and the selective pressures are significant, the isolated gene pools of the populations diverge. Differences accumulate such that microevolution occurs, causing changes in the respective phenotypes. Even if the small isolated populations were reunited with the parent population, interbreeding under natural conditions would no longer occur

2. Allopatric speciation
Allopatric speciation usually occurs at the fringe of the parent population. Peripheral groups are good candidates for speciation for three reasons.

      a. The gene pool of the peripheral group is probably different from the parent group initially.
      b. Unless the peripheral group is large, the gene pool is likely to change because of genetic drift, new mutations and lack of gene flow.
      c. Evolution caused by selection may take a different direction in the peripheral groups from the parent population.

3. Adaptive Radiation
Adaptive radiation is the emergence of a number of species from a common ancestor, as the population spreads to new environments.

Darwin's finches represent an important example of speciation. The different finch species live on different islands and, therefore, cannot interbreed. Different environmental pressures and thus different selective pressures occur and the populations differ from each other. Darwin was able to identify 13 different species of finches on the Galapagos Islands; all have apparently risen from one ancestral species. The finches were not able to mate, so the genes were isolated. Natural selection occurred on each island, selecting for different genes. Eventually, the gene pools diverged.

A hybrid organism is the offspring of two parents from different species. Hybrids can occur in animals (mule), but they are more common in plants.

The gene frequencies in a population start to change over a period of time depending on the environment and selection pressures. Once the gene frequency change, the gene pool changes, and new species develop.

D. AFTER ISOLATION
Once two animals populations have become separated and have evolved into separate species, why can't the different species reproduce? Why can't the different species have fertile offspring? There are two categories of isolating mechanisms which prevent the formation of fertile offspring. These are prezygotic isolating mechanisms and postzygotic isolating mechanisms. These categories can be altered slightly and termed pre-mating and post-mating isolating mechanisms.

E. PREZYGOTIC ISOLATING MECHANISMS
These occur before the zygote is formed. They prevent the fertilization of the mother's egg.

1. Habitat differences
Two species may inhabit different habitats. They never encounter each other to mate.

2. Differences in breeding times.
Two species may reproduce at different times.

3. Mechanical difference

Organisms genitals work on the lock and key method. If the male and female genitals do not fit, mating will not occur.

4. Behavioral differences
Courtship behavior may differ. If so, no mating will occur.

5. Gametic differences
Even if the gametes meet, they rarely fuse to form a zygote. The sperm may not be able to survive the environment of the female reproductive tract, the gametes may not recognize each other, or the sperm may not fuse with the ovum.

F. POSTZYGOTIC ISOLATING MECHANISMS
These prevent successful reproduction after fertilization of the mother's egg has occurred.

1. The zygote does not survive the gestation period.
2. The offspring are sterile. The incompatible chromosomes undergo meiosis. However, whenever the offspring mate, the sperm/egg will not be able to combine wit the egg/sperm of the other male.
3. *Hybrid Breakdown*; Hybrids are fertile but produce infertile or inviable offspring in the F_2 generation.

G. SYMPATRIC SPECIATION
Sympatric speciation refers to the production of a new species within the parent population, without geographical isolation. Sympatric speciation usually involves the incomplete separation of homologous chromosomes (nondisjunction) or the homologous chromosomes do separate properly but cytokinesis does not occur.

1. Polyploidy
A new species forms by polypoidy (multiplication of chromosomal numbers, i.e. 2n—3n or 4n) when the chromosomes fail to segregate during meiosis.

Sympatric speciation through polypoidy is a common occurrence in plants. Some polypoidy plants are able to survive harsher environments better than nonpolyploids. Some polyploid plants that have an odd number of chromosome sets cannot produce sexually, but survive through vegetative propagation, (i.e. Bananas have flowers but the fruit yields no seeds).

2. Autopolypoidy
Autopolyploidy is the doubling of the chromosome number within a population and hence the formation of a new species. Tetraploid plants can only mate with tetraploid plants and produce fertile offspring. If they mate with diploid individuals, the offspring are sterile because synapsis of homologous pairs does not occur properly.

Hybrids are usually sterile, since the chromosomes cannot pair up in meiosis (no homologues). If polypoidy occurs within the hybrid, its chromosomes can line up during meiosis. They are, however, reproductively isolated from their parents.

3. Allopolyploidy
If two species contribute gametes, a new species can be generated by a doubling of the chromosome number in the hybrid offspring. This is called allopolyploidy. In allopolypoidy, two species interbreed and combine their chromosomes. Usually the organism will be sterile because the chromosomes cannot synapse properly in meiosis. If the chromosome number first doubles, and nondisjunction creates a new set of homologes, then the organism can self fertilize to create fertile offspring.

H. INTROGRESSION
Alleles from different species cross the reproductive barrier and enter the gene pool. This usually occurs in plants. For example, corn has some alleles that can be traced back to wild grass. A fraction of the grass and corn hybrids back crossed with corn plants. Thus, the genes ended up in the corn gene pool.

I. GENETIC MECHANISMS OF SPECIATION

When two populations adapt to different environments, they accumulate differences in frequencies of genotypes and phenotypes. In the course of the gradual adaptive divergence of the two gene pool, reproductive barriers between the two populations evolve. Hence, two species arise.

These reproductive barriers can come about without being favored by natural selection. Reproductive isolation is usually a consequence of the divergence of the two populations in response to other selective pressures.

Postzygotic barriers may be attributed to differences in regulatory genes that control development. Prezygotic barriers can come about as products of the gradual genetic divergence of two populations.

1. Gradual

The rate of change in the composition of a gene pool is relatively constant and gradual. Large changes occur by the accumulation of many small ones over long periods of time.

2. Punctuated Equilibrium

Changes occur in relatively short spurts interspersed among long time periods or relatively little change. Speciation events occur rapidly on a geologic (evolutionary) time scale. These rapids changes interrupt or end long periods of little change in species' gene pools.

III. CLASSIFICATION

A. PATHS OF SPECIATION

The fossil record reveals that the diversity of organisms that have populated the earth is the result of these broad paths of speciation, with the effects of extinction.

1. Phyletic Change

Under pressure of directional selection-a species gradually accumulates change until it is so distinct from the original population that it is a new species.

2. Cladogenesis

Splitting of lineages. Species formed by cladgenesis are descendants of a common ancestor. This can occur radially instead of linearly.

3. Adaptive Radiation

Sudden diversification of a group of organisms that share a common ancestor that itself has newly evolved. This is a combination of cladgnesis and phyletic change. Also occurs radially.

B. PHYLOGENETIC TREES

Phylogenetic trees portray common ancestry, relative divergence from the ancestor, and evolutionary relationships in reference to living representatives of the groups.

Phylogenetic trees start off with a common ancestor. Speciation occurs in the common ancestor population with changes in the gene pool. New populations (new species) branch off from the common ancestor population. These new populations will be exposed to environmental conditions, and, over time these populations will undergo evolution and speciation, thus creating new branches and populations.

Populations with a recent common ancestor are closely related evolutionarily and the branches should be close to each other.

The organisms in these closely related groups will tend to exhibit homologous structures (similar structures, may have different functions), similar DNA sequences (and similar biochemistry), and similar embryonic development.

The development of new species from a common ancestor is not necessarily a linear development. It is more of a radial event that shows more than one species developing from a common ancestor.

C. TWO EVOLUTION THEORIES

1. Gradualism
Change occurs at a regular rate, gradually over time.

2. Punctuated Equilibrium
Refers to the tempo of evolution, assuming that new species formed principally in small populations on geographic periphery of the range of the species, speciation occurred rapidly, and the new species then outcompeted the old ones. The population changed faster at sometimes than at other times. These changes can come about by sudden changes in environmental conditions. This story was developed by Nils Eldredge and Stephen J. Gould.

D. CLASSIFICATION SCHEME
We have to take into account variability, relationships, and evolutionary relatedness to classify organisms into various categories. The largest categories are called kingdoms ad the smallest are species.

Binomial, meaning two names, refers to the way scientists label living things. The two names come from the

genus and species of the classification system.

This system was developed by Karl Von Linne, who latinized his own name to Carl Linneus (1701-1778). He is responsible for creating categories within categories. He chose to use Latin because of two reasons: 1) Latin is not commonly spoken anywhere outside of a few academic halls or in religious ceremonies and not likely to change 2) Latin forms the roots of many words in a number of languages. In a monumental feat, Linneus single handedly named and classified many of the earth's organisms. Since Linneus' time, the rules for assigning names are rigidly enforced by international commissions.

Here are the categories for classifying organisms from the highest to the lowest level. Each level is called a taxon.

Categories:	How to remember them:		
Kingdom		King	Kings
Phylum	Philip		Play
Class		Came	Chess
Order		Over	On
Family		From	Fat
Genus		Greece	Guys'
Species	Singing	Stomachs	

These are just names applied to groups of organisms that are thought to be related to one other.

Taxonomy has two main objectives.
1) To sort out closely related organisms and assign them to separate species and to name newly discovered species.
2) To organize species into higher taxonomic categories.

E. PHYLOGENY
Phylogen is the evolutionary history of a species or a group of related species.

1. Evolutionary Systematics
Biologists wanted taxonomies to be not only convenient and useful but also to accurately reflect the phylogenetic relationship among organisms. These taxonomies are hypotheses about evolutionary histories. Some of these hypotheses can be tested and revised if necessary. The study of evolutionary relationships is known as evolutionary systematics.

2. Monophyletic

A classification scheme that accurately reflects evolutionary history is termed monophyletic. This means that at each level, all members of the taxon should be the descendants of a common ancestor.

Monophyletic classification is difficult to achieve for two reasons.
1) It is difficult to know completely the evolutionary histories of organisms.
2) Convenience and utility may be more important than an accurate reflection of phylogeny. We usually see that a taxon contains members that have descended from more than one common ancestor (polyphyletic taxon).

3. Homology and Phylogeny
Organisms are grouped in a process based on similarities in structure and other phenotypic characteristics. Superficial similarities are not always useful in deciding the taxon for the organism.

A big question in evolutionary systematics concerns the origin of similarities or differences between two organisms. Does the similarity reflect inheritance from a common ancestor, or does it reflect an adaptation to similar environments by organisms that do not share a common ancestor? Does a difference between two organisms represent different phylogenetic histories or does it reflect the adaptation of closely related organisms to different environments?

Similarities that have a common origin but do not necessarily the same function are termed homologous. Structures that have a similar function, but have different evolutionary backgrounds are said to be analogous.

F. TAXONOMIC METHODS AND TOOLS
Several steps for the traditional taxonomic method.
1. An organism is assigned a taxon based on the outward similarities to other organisms in the taxon.
2. The similarities are tested for homologies. Fossil evidence is examined whenever possible.
3. Various stages in the lifecycle and the patterns of embryonic development are also compared.

When constructing a taxon in the traditional way, two factors need to be considered.
   a. Some factors produce evidence of genealogy (branching patterns that show the evolutionary history of the organism).
   b. The taxon should reflect the degree to which the organisms have diverged since they began to travel in different evolutionary paths. Traditional taxons contain information about the sequence in which branching occurred and the extent of the biological changes.

Problem: Not all similarities are due to a common ancestor, some are due to convergent evolution. However, the more complex two similar structures, the more improbable it is that they came from two separate ancestors.

G. OTHER TOOLS OF TAXONOMISTS: MOLECULAR BIOLOGY

1. Amino Acid Sequences
Compare the amino acid sequences of the same protein in different organisms. The greater the number of amino acid sequence differences, the more distant their evolutionary relationship. The smaller the amount of differences, the closer the relationship.

Some biologists suggest that a change in an amino acid represents a functional difference in the molecule. Other biologists say that amino acid changes occur at random and that they do not represent the result of the selection process, such changes simply mark the passage of time. Instead of functional differences, changes in amino acid sequences are a molecular clock. This clock can be used to determine the time at which groups diverged.

2. Nucleotide Sequences/DNA Observations

Since it is now possible to sequence nucleotides, the comparison of homologous proteins has been largely abandoned. Nucleotide sequencing is more sensitive and easier to do than comparing amino acids.

The nucleotide sequences of different species are placed into a computer and compared. Taxonomic relationships can be determined with there comparisons.

    a. **DNA-DNA Hybridization**
This is usd to compare the DNA strands of different species. It is an important tool in conjunction with other methods.

    b. **Restriction Mapping**
A process which obtains restriction fragments (RFLP) with restriction endonucleases and compares this with the restriction fragments of other species. The mitochondrial DNA (mtDNA) of several species can be compared in this way.

3. Molecular Clocks
Proteins evolve at different rates, but for a given protein the rate seems to be pretty constant. If homologous proteins are examined and compared, the number of amino acid differences is proportional to the amount of time that has elapsed since the branching of the populations.

DNA comparisons are more promising than protein comparisons.

Molecular clocks are calibrated by graphing the number of amino acid and/or DNA base pair differences against time. This is done for a series of evolutionary branch points from the knowh fossil record. If no clear fossil evidence is present, the graph then estimates the time of species divergence.

The consistent rate of protein and DNA changes implies a large number of neutral mutations. This is a controversial pint among scientists who use the molecular clock.

4. Alternative Methodologies (Schools of Taxonomy)

    a. Numerical Phenetics
This is based only on a species' observable characteristics. These characteristics are dividedi into 'unit characteristics'. These unit characteristics are assigned a value, and these values are compared by a computer. Homology/ Analogy is not considered. Phenetics suggests that the problems with this method are resolved if enough characteristics are compared.

    b. Cladistics
This is based on phylogeny. Cladistics suggest that the branching of one lineage from another in the course of evolution is the one event that can be determined objectively.

The goal of cladistics is to construct a holophyletic taxa. The holophyletic taxa must contain ALL of the descendants from the common ancestor plus the ancestor.

H. BACK TO KINGDOMS
In the beginning of taxonomy (naming things) there were two kingdoms; either something was an animal or a plant. From there scientists devised a three kingdom system – plants, animals, and protests. Currentrly, scientists use a five kingdom system.

1. Moneran: Prokaryontes: bacteria and cyanobacteria

2. Protista: Eukaryotic: various simple, single celled eukaryotes including protozoa (formerly animals) and chlorophyta (formerly plants).

3. Fungi: Eukaryotic

4. Plants: Eukaryotic, nonvascular and vascular

5. Animal: Eukaryotic, multicelluar from sponges to humans

Unit VII

Viruses / Protists / Fungi

I. Viruses

A. PHYSICAL CHARACTERISTICS
A large virus is 300 nm in diameter; the smallest is 20 nm in diameter. Viruses can cause disease (e.g. AIDS, Herpes, Chicken pox, the common cold and the flu) and they can also cause permanent inheritable changes in the cell/

1. Properties
A virus is a piece of double stranded DNA, single stranded DNA, or PNA surrounded by a protecting protein coat called a capsid. All viruses are classified by he type of nucleic acid (DNA or RNA) contained in the capsid. The smallest virus contains 4 genes, and the largest virus has several hundred genes.

Viruses cause diseases or cancer. For example, the HIV virus causes the disease AIDS and the Epstein-Burr Virus causes the disease Mononucleosis.

2. Virus Shapes
There are three main shapes of viruses.

a. Icosohedrons or Polyhedrons
Crystal shaper that contains 20 triangular sections. The AIDS virus is a polyhedron surrounded by a lipid coat. We will construct and icosahedral virus.

b. Spiral form
RNA surrounded by many proteins called capsomeres. This looks like a phone chord surrounded by proteins.

c. Bacteriophage
Includes a head for DNA storage, contractile tail sheath, and tail fibers

d. Other shapes
Filovirus shaped such as Ebola and trapezoid shaped such as HIV.

B. HOW DOES A VIRUS INFECT A CELL?
Viruses are oblogate ontracellular parasites. They have no enzymes for metabolism and they have no ribosomes to produce proteins. Viruses must be transported form one organism to another, because they cannot move by themselves. Viruses remain inactive until they arrive on an attachment site of the correct cell. A virus can only attack a specific cell with the correct receptor site. For example, the HIV virus only attacks the T4 cells of the immune system.

1. Attachment
Virus lands on the correct cell with a specific receptor site. The capsid fits into the receptor on the cell. There is a limited range of host cells to which a virus can attach. Receptors on the surface of the virus fit in a lock and key fashion to receptors found on the surface of cells.

2. Penetration

The virus can enter the cell. Once this happens, enzymes in the cell destroy thee capsid and the nucleic acid (RNA or DNA) is freed. Many viruses inject the DNA or RNA into the cell, leaving the capsid on the outside.

C. MRNA

Most RNA acts as mRNA to produce proteins. Other RNA, use reverse transcriptase (also in the capsid) to produce DNA form the RNA is inside the cell the virus can take one of two life styles, lytic or lysogenic.

Either way, the virus diverts the host cell's resources to produce new rival parts. After the parts are produced, they are assembled by themselves (often spontaneously) into new viruses. This process is called self-assembly.

1. Lytic

The viral DNA incorporates into the cell's DNA. The cell then makes the part of thee virus. The virus is put together by the cell. When there are too many viruses in the cell, either the cell bursts, releasing the viruses, or the viruses exit the cell one by one. The released viruses search for the appropriate cells. A cold virus is an example of this type of virus. These are virulent viruses.

2. Lysogenic

The viral DNA incorporates into the cell's DNA and remains dormant. At any time, thee viral DNA may become lyctic. The AIDS virus is an example of this type of virus. These are called temperate viruses.

The virus can also cause drastic changes in thee DNA of the cell so than the cell becomes a tumor cell. There are two types of tumors.
a) *Benign*: Harmless, confine to a local area.
b) *Malignant*: These tumors are the ones that spread through out thee body and can kill an organism.

D. DEFENSES

There are no drugs that you can take that will cure you from a virus infection. There are drugs that can lessen symptoms, but they cannot cure. The body has three ways to combat the virus.

1. Phagocytes

This is the first line of defense. The phagocytes surround and destroy the virus by eating the virus or the infected cell.

2. Antibodies

Antibodies are proteins that react to a specific type of virus. Antibodies are produced and the body mounts an immune response; the antibodies flood the blood stream and target the invading organism. Vaccines cause a person to build specific antibodies to a virus that causes a specific disease.

3. Interferon

Interferon is a protein produced by the cell. It prevents the virus from reproducing in three ways.
a. Prevents the virus from attaching to the cell's attachment site.
b. Prevents the virus from injecting the viral DNA.
c. Prevents the viral DNA from taking over the host's cell machinery.

E. ANIMAL VIRUSES

There are two types of animal viruses. Other viruses can combine these two elements.

1. Viruses with Envelopes

There is a membrane surrounding the capsid. The membrane is a lipid bilayer, which is just like the membrane that surrounds cells. This membrane helps the virus enter the host cell. Glycoproteins on thee capsule (membrane that surrounds the virus) act as receptors. Once the receptor on the capsule binds with a receptor on the cell membrane, the virus membrane fuses with the cell membrane. The virus is then taken into the cell, and thee cell's enzyme removes (destroys) the capsid releasing the RNA / DNA into the cell.

Provirus: DNA that becomes integrated into the host cell's DNA (e.g. the Herpes virus). Herpes symptoms keeps reappearing in an individual because the virus as been incorporated into the host DNA.

2. **Viruses with RNA Genomes**
   These are the most complicated of all viral reproductive cycles. These viruses are called retroviruses. Inside each retrovirus there is the TNA genome and an enzyme called reverse transciptase. Reverse transcriptase makes a DNA molecule from an RNA template. This newly formed DNA then integrates into the host cell's DNA as a provirus, for example, Rhinovirus, which causes the common cold, and the HIV virus, which causes AIDS.

3. **Viroids and Pirons**
   Viroids and pirons are infections agents that are even simpler than viruses. Viroids are naked RNA molecules found mostly in plants. Pirrons are small proteinaceous particles found in animals. Both pirons and viroids can reproduce in susceptible cells.

II. KINGDOM: PROTISTA

A. CHARACTERISTICS OF PROTISTS
1. Unicellular or simple colonial.
2. Eukaryotic.
3. May have diverse nutritive modes including photosynthesis, ingestion, and absorption.
4. May reproduce sexually or asexually.
5. May have motility by the eukaryotic cilia or undulipodia or by other means (pseudopods) or may be non-motile.

The different Phyla for the Kingdom Protista
Note: The taxonomy off protist undergoes constant revision since it is a polyphhyletic taxon and the evolutionary relationships are uncertain. The following taxonomy is one that is combination of taxonomies from the following textbooks: Wallace, King and Sanders (1981); Arms and Camps (1987); Curtis and Barnes (1989); and Campbell (1993).

Pyrrophyta (Dinoflagellates)
Euglenophyta (Euglenoids)
Chrysophyta (Ciatoms and Golden Algae)
Zoomastigina
Sarcodines
Apicomplexa (Sporozoa)
Diliophora
Chlorrophyta
Phaeophyta
Rhodophyta
Gymnomycota
Chytridomycota
Oomycota

B. PHYLUM PYRROPHYTA (DINOFLAGELLATA)
Pyrrophyta (fire plants) are commonly known as dinoflagellates because of their two undulipodia. Most dinoflagellates are photosynthetic, possessing chlorophyll a and c and carotenoids; some are heterotrophic. Dinoflagellates store their food in the form of starch and are abundant in warm oceans. Ancient dinoflagellates formed large oil deposits. The majority of dinoflagellates reproduce asexually through binary fission.

Dinoflagellates have two flagella, one wrapped around the middle off the cell in a characteristic groove, and the other projecting along the length of the cell. Some are naked, and others are covered with a cellulose armor. Several species are bioluminescent.

Some dinoflagellates produce a nerve poison that can kill humans and fish. During population explosions of Gonyaulax (a dinoflagellate), shellfish that have eaten large quantities of this organism become unfit for human consumption. Since Gonyaulax contains a red pigment, the population explosion may color the water red, a warning signal of "red tide."

C. PHYLUM EUGLENOPHYTA

Most members of this group live in fresh water, and are abundant in polluted habitats. These protests have two flagella, one for locomotion, and the other specialized to help detect light. Euglenophytes lack cell walls but have elastic, transparent pellicles made of protein just beneath their plasma membrane. They contain chlorophyll a and b and carotenoids.

Euglenophytes reproduce asexually through binary fission.

Euglenas can either be autotrophic or heterotrophic. For example, euglenas raised in the dark loses their green color and become heterotrophs, ingesting food through a gullet.

D. PHYLUM CHRYSOPHYTA (DIATOMS AND GOLDEN ALGAE)

Chrysophytes include diatoms and golden algae, most of which are photosynthetic. These protests are found in the sea, freshwater and in wet spots on rocks, plants or wood.

Chrysophytes contain chlorophylls a and c and an accessory pigment fucoxanthin which gives the organism its yellow-brown color. They store much of their excess food as oil and are important in the formation of petroleum deposits. The golden algae have two unequal flagella for locomotion and reproduce asexually.

Diatoms are similar to golden algae in pigmentation and storage of food. However, thee diatoms have a rigid cell wall impregnated with pectin and silica glass. (SiO_2). Often the cell wall is strikingly patterned. The siliceous walls of diatoms are quite resistant to decay and have accumulated on the ocean floor in enormous numbers. Where the sea floor has been raised by geological activity, thee deposits (diatomaceious earth) may be mined for commercial uses as fine abrasives in silver polishes and toothpaste and as packing in air and water filters.

E. PHYLUM ZOOMASTIGINA (ZOOFLAGELLATES OR ZOOMASTIGOPHORA)

The phylum Zoomastigina contains heterotrophic flagellates. Some are free-living, others are parasitic, and still others are symbionsts. The parasitic form often has complex life cycles involving two hosts. Thee symbionts are found in thee guts of termites and wood roaches; these flagellates engulf and digest the wood eaten by their insect hosts.

A parasitic genus Trypanosoma, which live in the flood of vertebrates, mainly mammals, causes many disease including sleeping sickness and Dhaga's disease (a disease in which the protists damages thee heart and other organs). Nagana is a trypanosome disease that kills cattle. These diseases are transmitted by blood sucking insects.

Giardia, found in lakes and reservoirs causes diarrhea, cramps, fatigue, and loss of weight.

F. SARCODINES

The sarcodines are protists that move and engulf their prey with pseudopodia. Because thee ameba (Ameba proteus) is such a familiar creature, sarcodines are often thought of as naked and amoeboid. Many amebas have shells, and all members of the three other classes in the phylum (foraminifferans, heliozoans, and radiolarians) also have shells.

Foraminiferans inhabit the warmer oceans of the world and secrete shells made of calcium carbonate with many holes. It is through these holes that they poke their long thin pseudopodia. The pseudopodia branch and join outside the shell to form a net that traps and digests the organism's prey. When the foraminierans die, their shells sink to thee bottom. Millions of years' worth off dead foraminiferans have formed chalk rocks or limestones, such as the famous White Cliffs of Dover.

Radiolarians secrete elaborate outer shells usually made of silica. Like foraminiferans, they extend their pseudopodia though holes in the shell, and they draw their food into their shell for digestion.

Heliozoans, or "sun animals" live in fresh water. They may be free or attached o a surface by a stalk. Some are naked; some have skeletons of silica or foreign particles. They also extend the long thin pseudopods to capture food.

G. PHYLUM APICOMPLEXA (SPOROZOA)

All of the sporozoan are parasitic with complicated lifecycles. Some have gametes that are flagellated and others have gametes with pseudopods. Most feed by absorbing small organic molecules from their hosts.

The sporozoan Toxoplasma may be the most common human parasite. It causes the disease Toxoplasmosis, whose symptoms may be so slight that they go unnoticed, and is sometimes diagnosed as a form of arthritis.

Human malaria is caused by a sporozoan, Plasmodium. These malaria parasites require two different hosts to complete the lifecycle: humans and the female Anopheles mosquito, which transmits the disease from one person to another.

H. PHYLUM CILIOPHORA

The ciliates are heterotrohic protists with cilia either all over the body or in specialized areas on the cell surface. The body wall contains trichocysts, thread-like organelles that can be discharged to the outside   some trichocycts have barbed tips, and some eject poison. Trichocysts can be used as anchors, for defense, or to capture prey.

Most ciliates prey on bacteria, small animals or other protists. Specialized cilia around thee mouth region sweep food into a gullet. The food enters a vacuole, and is then digested by a lysosome containing digestive enzymes. The products are absorbed and the undigested materials are discharged. A contractile vacuole discharges excess water.

Ciliates also have a micronucleus, which contain one copy of the complete genome, and a large macronucleus, containing up to 500 times more DNA than the micronucleus. The micronucleus is involved in sexual reproduction and heredity; thee macronucleus controls growth, metabolism, and asexual reproduction.

Paramecium is the most familiar of the freshwater ciliates.

I. PHYLUM CHLOROPHYTA: GREEN ALGAE

There are 7000 named species of green algae; most are fresh water forms, while a few species are marine. Clorophyta contains both unicellular and multicellular types. Chlorophyta has species with sexual and some with asexual reproductive cycles. Various species live as plankton, or inhabit damp soil or snow, or occupy cells, body cavities of protists and invertebrates as symbionsts. Many unicellular green algae are photosynthetic symbionts in lichens, ciliates and invertebrates. They all contain chlorophyll a and b, and store food as starch. Chlorophyta occur in single-cell flagellated or unflagellated forms, as chains or filaments, as inflated fingers or as delicate flattened blades.

1. **Volvox (simple colonial)**
   Volvox is composed of identical cells each one similar to a single chlamydomonas cell. The structure off volvoz suggests a way that multicellularity could have arisen.

   a. The sphere swims in an organized manner. The flagella in front pull and the flagella in back push.
   b. In the sexual phase, some cells differentiate and specialize for reproduction.
   c. In the asexual phase, pockets of the sphere depress inwards, and new spheres bud off. However since the flagella originally point inwards, the cells have to turn themselves inside out within the colony.

2. **Ulonthrix**
   These multincellular organisms have haploid and diploid generations. In the Ulonthrix, there is an alternation of generations with the domination of the haploid generation over the diploid generation.

Alternation of generations continues in the evolution of land plants with the diploid generation becoming increasingly dominant.

Molecular evidence, life history and morphology suggest that Coleocheate, a green alga (Charales), was the closest relatives of land plants.

J. PHYLUM PHEOPHYA: (BROWN ALGAE)
There are about 1,500 named species. They are distinguished by their characteristic brown pigment, fucoxanthin. Brown algae store their carbohydrates and laminarin and mannatol. They have flagellated sperm; some female reproductive cells are also flagellated. Brown algae only live in the ocean, especially in cold costal water. They come in all shapes and sizes; kelp (necrocystis) can be 30 m (100 ft.) tall.

1. **Macrocystis**
   This is another giant kelp that has highly specialized tissues and organs.

   a. **Holdfasts**
      Anchors the algae to the bottom.

   b. **Stipes**
      These stems are like supporting structures. With trumpet hyphae, they demonstrate parallel evolution with conducting tissue of higher plants.

   c. **Blades**
      Structures that resemble leaves.

   d. **Bladders**
      Spherical and hollows, they help keel the photosynthetic cells near the surface.

   e. **Thallus**
      Thallus refers to the seaweed body that contains the above structures.

2. **Laminaria (Brown Algae) Life Cycle**
   The brown algae life cycle shows us alternation of generations. In the brown algae, a zygote grows into a sporophyte through mitosis. Al sporophytes are diploid, and they produce SPORES. The haploid spores are produced through meiosis. Once the spores land on the ocean floor, they grow (through mitosis) into either a male or female brown alga. These organisms are haploid because they have half the diploid number of chromosomes. The female has a structure called an oogonium which produces an egg and the antheridium releases the haploid sperm. They will meet to form a diploid zygote, after which the process starts all over again. When you see brown algae at the beach, you are looking at the sporophyte (2n) generation. The antheridia and oogonia are very small and you probably will not see them without a microscope.

   The generations alternate between the diploid and haploid stages. The diploid stage (sporophyte), alternates with thee haploid stage (oogonium and antheridium).

K. PHYLUM PHODOPHYTA: RED ALGAE
There are 4,000 species of seaweed and a few freshwater species. Because of their color, red algae absorb blue light, which has thee greatest penetration in water. Some red algae are black or green. They contain the accessory pigment phycoerythrin from the family of pigments called phycobilins. The pigments of red algae are very similar to those in cyanobacteria. It is believed that the red algae are the result of symbiotic relations between eukaryotic hosts and cyanobacteria (actually, all photosynthetic euakaryotes are the result of symbiosis with cyanobacteria or other algae). Red algal cells, including sperm, contain no flagella or cilia. Nearly all types of red algae are marine, e.g. red seaweeds in the tide pools. Red algae grow on rocky coasts, where they attach firmly to the rocks firmly by structures using holdfasts.

They store food as a starch-like compound called floridan. They also produce another polysaccharide: agar-agar, which is used to thicken soups and prepare a jelly-like medium to grow bacteria. Irish moss, a red alga, is

harvested for carrageenan, the thickening agent in ice cream. It is non-caloric and contains no fat. Nori, Japanese seaweed, is also a red alga.

Rhodophyta presents us with a clear picture o alternation of generations. Both haploid and diploid are multicellular forms with thalli (branched bodies) that resemble each other. You can differentiate between the two by inspecting the reproductive structures under a microscope. Neither generation is dominant. The life history of red algae consists of three phases: haploid gametophyte, diploid carposporophyte and diploid tetrasporophyte.

A sperm from a gametophyte (n) lands on and fertilizes the egg in a female gametophyte (n). The diploid carposporophyte forms inside the female gametophyte. The carposporophyte produces diploid spores which leave and germinate into diploid tetrasporophyte through mitosis. Meiosis occurs in the tetrasporophyte and produces haploid tetraspores which germinate into haploid gametophytes (male and female). These structures will produce haploid gametes through mitosis.

L. PHYLUM GYMNOMYCOTA

Slime molds superficially resemble fungi, thus resemblance is due to convergent evolution. They have flagellated reproductive cells that fungi do not have, and their cell wall is not made of chitin as in fungi. Because of these traits, the following slime molds and relatives are classified as protists.

The slime mold starts as a slimy mass, a plasmodium which looks like a huge ameba. This is a giant cell that is multinucleated (coenocytic) cell that phagocytizes organic matter. The plasmodium seeks moist habitats.

During unfavorable conditions, the slime mold seeks drier areas. The drying mass will produce sporangia (round bodies on top of slender vertical props). Cells in each sporangium then undergoes a number of meiotic divisions, producing haploid spores. These spores can be carried to new places by winds. If the spore lands on a moist spot, it begins to divide and form an ameboid growth, myzameba. In some species – the spore will form flagellated sperm cells called swarm cells which can swim.

The myxameba or the swarm cells fuse together to form a diploid cell. These undergo numerous mitotic divisions, producing a plasmodium again.

Two types of organisms are commonly called water molds; but because they have flagellated cells, they are actually protists.

M. PHYLUM CHYTRIDOMYCOTA

Their cell wall is made of chitin. Most chytrids consist of a small, unicellular, vegetative body (thallus) that turns into a coenocytic sporangium with root-like structures called rhizoids. Rhizoids have no nucleus and absorb water and minerals from the substrate. When mature, the sporangium cleaves into uninucleated flagellated spores. Each spore will land and germinated into a thallus. Some chytrids have flagellated gametes and are found in fresh water, salt water, and in moist soil. They can live as parasites on algae, plants, and fungi. Usually they feed on dead algae, pollen grains, or other plant debris.

N. PHYLUM OOMYCOTA: EGG MOLDS

They resemble fungi, having coenocytic filaments known as hyphe. Some hyphae specialize to form gametangia, where gametes are produced. However, the cell wall, unlike fungi, contains cellulose. All oomycetes display oogamy which is the differentiation of gametes into male (sperm) and female (egg). All of these gametes are nonmotile and have no flagella.

O. REPRODUCTION

1. **Asexual cycle**
   Water molds produce sporangia which produce flagellated zoospores with two flagella. Swimming zoospores emerge and swim about in search of a food source. When food is available they form cysts that germinate into diploid hyphae to form new colonies. Swimming zoospores are not gametes because they are diploid and never fuse with another cell. They only grow asexually.

2. **Sexual cycle**
   The sexual cycle begins with the growth of unusually thick hyphae which produce haploid egg cells in spherical structures called oogonia (gametangia). Haploid male gametes, produced in male gametangia, reach the egg by way of hyphae. Notice that the male gametes do not swim. The male hyphae grows near the oogonium and send branches all over the spherical body. Inside these branches are sperm producing cells. The sperm penetrates the oogonium and fertilizes the egg.

   Most terrestrial water molds are saprobes that live off dead organic matter. Some are parasitic and pathogenic, for example, downy mildews and blights. The organism responsible for the potato famine blight is a water mold, *Phytophtoroa infestans*. It grows on moist leaves and absorbs the nutrients of the leaf.

III. KINGDOM: FUNGI

A. INTRODUCTION

Fungi are heterotrophs which secrete digestive enzymes into their surroundings, and take in the products after the food has been digested.

In this mode, the fungi are known as saprophytes or saprobes (live on dead matter). Those that aren't saprophyte are parasites. Most biologists believe that the closest living relatives of fungi are the colorless swimming protists known as chytrids.

Most fungi are multicellular. Some produce highly elaborate reproductive structures.

Fungi are decomposers which help with the cycling of important nutrients. Fungi are also used commercially in such products as cheese, antibiotics, bread and beer.

You will notice that when we talk about fungi, that many of their names end in mycota or myscetes. Myketos is Greek for fungus, the root word is also the source for the term mycelium – the body of many fungi. They mycelium is made up of tread-like structures known as hyphae. Septate hyphae are tubular cells with one nucleus per cell. Coencocytic hyphae have no cell wall separating the nuclei, so the hypha consists of a continuous cytoplasmic mass.

Cell walls are composed of chitin. The mycelium is the feeding structure that secretes the digestive enzymes and absorbs the products. The mycelium is usually the result of germination and growth from one spore. Growth occurs at the tips of hyphae. Parasitic fungi often have specialized hyphae called haustoria, which have nutrient absorbing tips that penetrate the tissues of the host. The rest of the hyphae remain outside the host cell membrane.

Many fungi develop erect spore producing organs, sporangia, which make tiny spores by the millions. Sporangia are made on specialized hyphae called sporangiophores. The spores are everywhere and are a means of asexual reproduction. Spores are small and able to survive long periods of drought and extreme temperatures. Often sporangia are raised above the mycelium by the sporangiophores. The spores are caught up and transported by air currents. The bright colors and powdery textures associated with many types of molds are the colors and textures of spores and sporangia. Fungi also reproduce sexually – often in complex lifestyles. In fact, the nuclei of hyphae and spores are almost always haploid.

Syngamy is the sexual union of cells from two different individuals; it occurs in two stages: 1) plasmogamy: the fusion of cytoplasm and 2) karyogamy: the fusion of the nuclei. After plasmogamy the nuclei don't fuse or form a dikaryon (a cell with two nuclei). These cells behave like diploids in that two haploid nuclei can compensate for harmful mutations. Finally the nuclei fuse to form a diploid nucleus (zygote), but the immediately undergo meiosis, forming haploid nuclei again.

They are divided into for divisions named after the cells in which karyogamy occurs.
a) Zygomycetes: Conjugating molds (e.g bread mold).
b) Ascomycetes: Sac fungus (e.g. neurospora and yeasts).

c) Basidiomycetes: Club fungi, (e.g. toad stools and mushrooms).
d) Deuteromycota: Fungi Imperfecti. These include fungi in which sexual reproduction is unknown or lost evolutionarily or unobserved. It includes fungi whose sexual cycles are known to be closely related.

B. ZYGOMYCETES: CONJUGATING MOLDS

Most zygomycetes are terrestrial fungi that are saprobes. Zygomycetes have sexual reproduction characterized by the formation of zygospores. They can form mycorrhizae which are mutualistic associations with the roots of plants.

Common bread mold grows on many foods. The spores land on the food and germinate. Hyphae grow in all directions. Some of the hyphae extend vertical hyphae called rhizoids that anchor the fungus to the substrate, secrete digestive enzymes, and absorb dissolved organic matter. When the bread mold hyphae have grown for a long time, they develop horizontal hyphae called stolons. When sporangia appear on vertical hyphae, these hyphae are called sporangiophores.

Sex begins with conjugation. When opposing mating types are grown in the same medium, specialized hyphae are produced (no male or female, we will refer to the compatible types as + and -). The two types are attracted to each other by hormones that diffuse in gas. When + and – hyphae fuse, they form a gametangium (plasmogamy), which contains two haploid nuclei. The nuclei fuse, karyogamy, to form diploid zygospores. These can stay dormant for a long time (the structure is now called a zygosporanguim). When conditions are right, meiosis occurs within the zygospore followed by the degeneration of all but one haploid nucleus. A haploid sporangium is formed on a sporangiophore. Many spores are formed, each spore released may produce a new mycelial mass.

C. ASDOMYCETES

Ascomycetes, along with basidomycetes, is considered a higher fungus. There are 60,000 species of ascomycetes plus an additional 25,000 species of lichens, most of which have an ascomycete component. Ascomycetes include the edible mushroom Morchella, powdery mildew, blue and green molds; Neurospora, yeasts; and ergot.

If ergot infects rye bread, it has the strange property of constricting blood vessels in the body's extremities. People on a continuous diet of ergot-infected bread suffer from "holy fire" or "St. Anthony's fire" which causes hallucinations and burning sensations in the hands and feet. The restricted blood flow in these parts can result in gangrene and subsequent loss of extremities (last reported case in 1960's in France). Ergot is now used to control internal bleeding.

The most famous ergot produces a compound called lysergic acid diethylamide, LSD.

1. **Asexual Reproduction**
   Ascomycetes produce conidiospores during the asexual stage. Conidiospores are produced in long chains at the end of specialized hyphae known as conidiophores.

2. **Sexual Reproduction**
   There is great diversity in the sexual characteristics of ascomycetes. The name "sac fungi" originates from the production of ascosphres in a sac like container called an ascus. A group of asci can be found in a fruiting structure known as an ascocarp which is usually spherical in shape. What goes on inside the ascocarp is unusual. The diploid soccer is produced by delayed fertilization.

   When the hyphae if different mating types come into contact, one hypha produces a large multinucleated swelling called an ascogonia (a sort o ovary). The other hypha produces a multinucleated antheridium (sperm producing organ).

   The antheridium grows towards and contacts the ascogonium, releasing nuclei into it. Each reproductive structure supplies many nuclei. The nuclei do not immediately fuse. The hyphae which emerge from the ascongonium contain one nucleus of each mation type in each cell. The fusion of the nuclei occurs after the ascocarp is formed. Meiosis immediately follows, completing the sexual process.

The four products of the meiotic division undergo one round of mitosis to produce haploid ascospores. When mature, the ascus breaks open, and the spores are forcibly ejected.

D. BASIDIOMYCETES: INCLUDES MUSHROOMS, RUSTS, SMUTS, AND SHELF FUNGI

The mycelial mass of the common mushroom lies deeply embedded in organic mater, breaking it down and using the nutrients. The mushroom that we see is the spore-producing basidiocarp which produces basidiospores. The mature basidiocarp develops a large number of gills or pores or teeth on its underside. These contain spore-producing cells called basidia (singular:basidium). Meiosis occurs in each basidium producing four haploid spores. The spore nuclei migrate through minute projections form the basidium.

Each mushroom can develop millions to billions of spores.

The sexual phase of the mushroom occurs before the basidiocarp develops. The basidiocarp contains two nuclei in each cell (like the ascocarp). The nuclei of the terminal cell fuse, making the basidium diploid. Then the basidial cell nucleus quickly undergo meiosis, producing four haploid nuclei that will develop into basidiospores.

E. DEUTEROMYCOTA: FUNGI IMPERFECTI

This group encompasses a number of fungi in which sexual reproduction is unknown. Asexual reproduction is the production conidia on specialized hyphae called conidiosphores.

There are about 25,000 species, some of which are parasitic (ringworm, athletes foot, and thrush.)

Some are important in the production of Roquefort and Camembert cheeses. They can also produce the antibiotics penicillin and the drug cyclosporin, which suppresses the human immune system and allows successful transplants to take place.

F. SYMBIOSIS AND FUNGI

1. **Lichens**
   There are 25,000 types of lichens. Lichens are formed by a symbiotic relationship between an algae (or canobacterium) and a fungus. They are important soil builders. Lichens erode rock surfaces and harbor bits of organic matter in their crusty bodies. Lichens can live in harsh conditions such as the tundra without many nutrients.

   Lichens may be found on rocks, trees, or soil. They reproduce asexually by fragmentation.

2. **Mycorrihizae**
   These are the symbiotic relationships between zygomycetes and the roots of vascular plants. In some mychorrihizal associations, endomychorrihizae, the fungal hyphae extend into the root cells, forming coils, swellings or bridges. The hyphae also extend into the surrounding soil. About 80% of vascular plants have endomycorrihizal associations.

3. **Ectomycorrhizae**
   The ascomycete or basidiomycete forms a sheath around the root, but it doesn't penetrate the root. This relationship is found in some trees and shrubs including pines, beeches, and willows. Truffles are an example of ascomycetes forming ectomycorrhizae relationship.

   No one understands the precise relationship between the fungi and roots. Roots secrete sugar, amino acids, and other organic substances used by the fungi. The fungi can convert minerals in the soil and decaying matter into available forms for transport into the plant. It has en shown that mycorrhizae transport phosphorous from the soil to the roots. Fungi also facilitate water uptake.

PLANT KINGDOM

I. PLANT KINGDOM

A. CHARACTERISTICS OF PLANTS

Plants photosynthesize, produce cellulose cell walls, are non-motile, have specialized tissues and organs, and can produce sexually. The aerial parts of most plants – stems and leaves – are coated with a waxy cuticle that prevents desiccation. Gas exchange occurs very slowly across the waxy surfaces, so oxygen and carbon dioxide diffuse between the leaf interior and the environment. This is done through tiny pores called stomata (single: stoma). The cell walls of plants are made of cellulose (not chitin as in fungi).

In the plant kingdom, there are 12 divisions.

B. NON-VASCULAR PLANTS

Divisions: bryophyta, Halatophyta, Anthercerophyta. These divisions include mosses, liverworts, or hornworts. They are multicellular plants with well-differentiated tissues. Terrestrial plants, they still have reproductive features which resemble those found on aquatic algae.

1. **Bryophytes**
There are 23,000 species of bryophytes. These are the plants that made the first important step from water to land, Let's look at some problems that the first land plant faced.

   a. *Desiccation*: in order to keel from drying up, the skin covering had to be waterproof or moist.
   b. *Support*: On land, gravity had to be dealt with because water no longer buoyed the plant body.
   c. There was little water to provide sperm and egg easy passage.
   d. Water, minerals and carbon dioxide had to be absorbed and wastes removed.

Bryophytes produce flagellated sperm and require at least a thin film of water so hat sperm can swim to the egg.

They have no roots, stems or leave. But, there are structures to protect embryological development in land plants. Since they are multicellular, certain tissues do different jobs: water absorption, anchorage, foliage support, and photosynthesis.
a) *Rhizoids*: roots-like cells which anchor the plant in soil and absorb water and minerals.
b) *Central Cylinder*: stem-like, a complex cylinder of several cell layers which is surrounded by photosynthetic epidermal cells. The central cylinder acts as a central support system and a place where food is stored.
c) *Leaf Scales*: leaf-like structures which make up most of the thallus. They lack the complexity of real leaves.
d) *Cutin*: A moisture barrier which covers the epidermis.

Another adaptation- multicellular reproductive organs that are surrounded by a layer of sterile (non-reproductive) cells. Archegonia gives rise to the egg cells. Antheridium gives rise to the sperm cells.

The haploid form is the dominant form in the alternation of generations.

Mosses are representativenon-vascular plants. Mosses absorb moisture through above ground structures. Bryophytes usually grow in moist and shady places. They are comparatively simple in structure and usually less than 20 cm in height.

Bryophytes have a clear alternation of generations; the haploid gametophyte form is dominant. The haploid form is the leafy and large structure that bears the male and female sexual structures. The diploid form takes the form of a capsule (sporangium), which forms on a lengthy stalk that grows out of the thallus

(body) of the gametophytes. In the sporangium, cells undergo meiosis and become haploid cells. When the capsule matures (filled with spores), the cap falls away and the spores are scattered.

Once a spore has established itself, it will absorb water and germinate to form thread-like structures called protonema which will eventually produce the haploid forms of on or the other gender. The male produces antheridia and the female produces archegonia. When enough water is available, the sperm are released and swim to the arghegonium of the other haploid form, developing a diploid cell (zygote).

C. VASCULAR PLANTS: BACKGROUND INFORMATION

Tracheophytes: vascular plants. Vascular tissue solved the problem of getting water from the soil to photosynthetic tissue. An important development in vascular plants is vascular tissue (xylem and phloem) which permits the production of roots that anchor the plant and absorb minerals and leaves which are the site of photosynthesis.
Note: We have made the arbitrary decision too use the terms "roots," "stems," and "leaves" only for structures which contain vascular tissue.

1. **Conducting Tissues: Two Distinct Types**

   a. **Xylem**
   Provides water and ion transport from roots to leaves. Xylem is composed of many types of cells tracheids, vessel elements, fibers, and wood parenchyma.

   b. **Phloem**
   Carries products of photosynthesis to non-photosynthetic cells. Phloem is also made of many types of cells: sieve cells, sieve tube members, albuminous cells, companion cells, parenchyma, and fibers.

2. **Reproduction**
   There is a reduction in the size of the gametophyte. The gametophyte in vascular plants is smaller than the sporophyte. In primitive plants the gametophyte may be separate from the sporophyte. In recently evolved groups, the gametophyte has been reduced to a microscopic and dependent plant. Plants also moved towards production of two different kinds of spores. One germinates to form male gametophytes; the other, female.

3. **Vascular plant types**
   Vascular plans have true roots, stems, and leaves. There are nine main divisions of vascular plants.

   a. **Seedless Plants**
      1) Psilophyta: naked plants: whisk ferns
      2) Lycophyta: spider like plants: club mosses and small club mosses
      3) Sphenophyta: wedge plants: horsetails and scouring rushes
      4) Pterophyta: winged plants: ferns

   b. **Seed Plants**
      5) Coniferophyta: conifers
      6) Cycadophyta: cycads
      7) Ginkophyta: ginkgoes
      8) Gnetophyta: gnetae
      9) Anthyohyta: flowering plants

   Out of 261,000 named species of vascular plants, the first three groups have only 1,000 species.

D. SEEDLESS PLANTS

1. **Division Psilophyta**

Psilophyta are represented by four species widespread in the tropics and the subtropics. It is known in the United States by the common name of whisk fen. They have no true roots, bear primitive sporangia, have scale like leaves, have well developed vascularity, and the sporophyte is the dominant generation.

2. **Division Lycophyta: Club Mosses**
   Lycophyta are often mistaken for pine seedlings. They have true roots, stems and leaves. The vascular system is well developed, and fertilization occurs only with sufficient water to allow the sperm to swim to the egg.

3. **Division Sphenophyta: Horsetails and Scoring Rushes**
   Sphenophyta were used as a pot cleaner before brillo because silica is embedded in the epidermal cell wall.

4. **Division Pterophyta: Ferns**
   There are 11,000 named ferns. In the diploid form there is an underground rhizome from which many fine roots arise. Single leaves emerge above the ground as fiddleheads, each unfolds into a large leaf.

   They have well developed vascular tissue; the diploid form is the dominant generation, and the spores are produced under the leaves, called sporophylls, of a sporophyte in sori (groups of sporangia). In most ferns, the spores are homospores – no sexual differentiation. The spores are wind-dispersed and grow into structures called prothallia, which are heart shaped. The prothallus of most ferns has both male or female sex organs (antheridia or archegonia). Water is needed for the sperm to swim to the egg. A fertilized egg develops into a new sporophyte which grows out from the archegonium of the parent.

E. SEED PLANTS
A seed is a protective structure in which the embryonic plant can be dispersed and remain dormant until conditions are favorable.

1. **Alternation of Generations**
   In some green algae, there are two generations (sporophyte and gametophyte) that are independent and usually the same size and shape. In primitive vascular plants (fern) the two generations are still separate, but the gametophyte is much smaller than the sporophyte. The gametophyte is reduced in size even further and dependent on the sporophyte in gymnosperms.

2. **Heterosporous Fertilization**
   All gymnosperms are heterosporous (produce two different types of spores in two different types of sporangia). Spores that germinate to become male gametophyte are called microspores and are formed in the microsporangia. Spores that germinate to form female gametophytes are called megaspores and are formed in the megasporangia.

   The megasporangium contains a single megaspore mother cell. Through meiosis it becomes a megaspore that is surrounded by non-reproductive tissue (integument). The entire structure is known as an ovule.

   The ovule is produced on the female cone scale, on of man in a large, scaled cone. The male cone, by comparison, is much smaller.

   In the male cone, the specialized microspore mother cells in microsporangia undergo meiosis to produce haploid microspores. Each microspore matures into a pollen grain. Wind blows the pollen grains to hopefully pollinate the ovule.

   Within the vulee the four cells produced by meiosis, three disintegrate. Thee remaining cell develops into a gametophyte. The gametophyte grows within the ovule and develops two or more archegonia, each containing a single egg cell. As the ovule ripens, it secretes a sticky liquid. As pollen lands on the cone, it falls between the scales and lands on the sticky liquid. This is because the shape of the cone with its scales and ovules causes air currents to be directed toward the sticky liquid. As the liquid dries, it draws the pollen grains into the ovule. A few months later, the pollen grain develops into a male gametophyte.

The male gametophyte produces two nonmotile cell (sperm) that are carried to the egg by the pull by a male gametophyte. The pollen tube grows through the tissues of the ovule. This takes about a year. The process takes a shorter time in white than yellow pines.

The sperm eventually meets the egg and a zygote is formed. The zygote begins to divide and forms and embryo (young sporophyte). As the ovule matures, the integuments harden into the seed coat that encloses the sporophyte and the female gametophyte tissue (which will become food for the embryo). After the cone matures, it opens and releases the seeds that are carried by the wind to a new spot.
Notice: Fertilization requires no swimming sperm.

Inside the Seed: three generations in one.
1) *Seed coat/Wings*: integument that is hardened from the mother sporophyte.
2) *Food*: from the female gametophyte- gametophyte tissue.
3) *Embryo* (from the next sporophyte generation) with cotyledons: seed leaves which will appear as the first leaves.

The conifer leaf is a needle or scale leaf which is only 1-3 mm in diameter. The center of the leaf contains a vein that carries water and sugar. Outside the vein are photosynthetic cells. The flat side of the leaf contains ducts that carry resin. Resin is releases when the plant is wounded and closes the break. The outer layer is the epidermis which contains stomata (where and how gas is exchanged). The leaf is well adapted for long periods off low humidity.

Gymnosperms and angiosperms are their informal classification names.

F.GYMNOSPERM: NAKED SEED

In gymnosperms water is no longer required to reproduce since pollen grains produce a pollen tube which allows sperm to move to the vicinity of the egg without swimming. Plants could now venture into the dryer climates. Pollen grains are airborne cells which contain the male gametophytes. These are very effective in protecting the male gamete. They also make excellent fossils. Seeds consist of any embryo, a seed coat, and stored food.

1. **Division Ginkophyta**
Only one species exists. This species is considered to be a living fossil. Male ginkgo trees produce air-born spores that germinate close to female ovules in female trees. The male gametophyte forms a pollen tube that grows toward the egg cell. Two motile multiflagellated swimming sperm cells swim down the tube to fertilize the egg. After fertilization, the female produces a seed.

2. **Division Cycaophyta**
Found in tropical regions (including Florida). The pollen is produced by cone like stobili and carried by the wind to the female cones.

3. **Division Coniferophyta: cone bearers**
There are nine families that contain 300 species in this division. The best-known conifers are pines, firs, spruces and hemlocks. They produce needles or scale like leaves. The leaves usually last a year and a growing season and then are shed (not all at once). They have a well-developed vascular system (tracheids in xylem). Conifers bear separate pollen bearing cones (small cones at the end of branches) and female cones (big cones on the older branches of the tree). Each tree is monoecious.

4. **Division Gnetophyta: Gnetum, Ephedra, and Welwitschia**

G. DIVISION ANTHOPHYTA: ANGIOSPERMS: FLOWERING PLANTS
There are 235,000 species of angiosperms that are divided into two classes.
1) Monocotyledons: 65,000 species
2) Dicotyledons: 170,000 species

1. Differnces between monocots and dicots

Cotyledon: (seed leaf) a leaf within which stored food is found

Monocots
Leaf veins: parallel

Cotyledon: two
(a leaf within which stored food is found)

Floral parts: three, or multiples of three

Vascular system: in scattered bundles – no vascular cambium

Roots: net like or fibrous

Secondary (woody) growth: absent

Dicots
Leaf veins: branching (net like)

Cotyledons: two

Floral parts: four, or multiples of four, or five, or multiples of five

Vascular bundles: in cylindrical arrangements around the stem.
Vascular cambium is produced

Roots; tap root or fibrous roots.

Secondary (woody) growth: usually present

There are exceptions to each of these characteristics. Any plant with two or more characteristics of the same list is almost certainly a member of the class exhibiting the characteristics in question.

2. **The Flower**
   Stamen: the male part of the flower, lie inside thee corolla. Each slender stalk is called a filament, and on top of the filament is the anther. The anther is the spore (pollen) producing structure. A group of stamens is called the androecium. The carpels, which are the center of the flower, are called the gynoecium. Each individual structure containing one or more carpels is called the pistil. Each pistil has three parts:

   a. *Stigma*: the top which is sticky and collects pollen
   b. *Style*: stalk that supports the stigma
   c. *Ovulary*: the base which contains the ovules

   A typical flower contains sepals (bud covering which protects the flower), petals (may attract insects), and stamens, and carpels. This is a complete and perfect flower. An incomplete flower is lacking petals. An imperfect flower is lacking either the androcium or the gynoceium.

3. **Reproduction**
   There are two types of reproduction in plants, asexual and sexual.

   a. **Asexual**
      Most asexual reproduction takes place in the form of vegetative propagation. Plants form new plants from portions of their own roots, stems, or leaves. We do this artificially by taking cuttings.

New plant growth can also emerge from stolons (runners) which have hidden buds along horizontal stems that sprout, sending young stems upwards.

Tubers: stems that are thick and underground. A potato doesn't look like much of a stem but its "eyes" are lateral buds. The lateral buds develop into ranch stems.

b. **Sexual reproduction in flowering plants**

How does a flower know when to flower? The critical factor is the length of night. The sensitivity to light and darkness cycles is called photoperiodicity. The most effective light for the established photoperiod is red or orange-red. Thecae signal that induces the flower to develop is delivered from the leaves to the other parts of the plant and is hormonal in nature. We have not found a flower-inducing hormone, but a flower-repressing hormone has been found.

1) In the ovulary megasporogenesis occurs. In the ovulary, ovules develop, These consist of a stalk and surrounding tissues called the nucellus and one or two integuments (skin like protective coverings) with a small opening called the micropyle.

2) In each ovule, a large cell called a megaspore mother cell win undergo meiosis and produce only one haploid cell that survives. This haploid cell will undergo three mitotic divisions to give eight haploid nuclei that will the incorporated into seven cells and become the female gametophyte or megagametophyte. One cell has two nuclei and is the endosperm mother cell.

3) In the anthers microsporogenesis occurs. The anthers contain four chambers called pollen sacs. Within these pollen sacs are numerous microspore mother cells which will undergo meiosis.

4) Each of four haploid nuclei produced undergoes mitosis, giving two nuclei: the generative nucleus and the tube nucleus. When the mitotic event is finished, a though coating is formed, and a pollen grain is the finished product.

5) Pollination occurs when the pollen is carried to the stigma. When the pollen lands on the stigma, it germinates. When the pollen germinates, it procures a pollen tube, (from the tube nucleus) which grows down through the stigma and into the long style (enzymes digests the tissue ahead). As the tube grows, the generative nucleus stays close to the tip of the tube and divides producing two sperm nuclei.

6) *Fertilization*: the tube penetrates the ovule at the micropyle. The sperm nuclei enter the embryo sac. One nucleus fertilizes the egg cell, forming a diploid zygote, and this will develop into the plant embryo. The second sperm nucleus penetrates the endosperm mother cell and fuses with the two nuclei present. This produces a triploid nucleus and forms the starch and food regions of the seed in seventy percent of angiosperms. The rest have a different pattern of megagametophytes.

   After fertilization, the flower begins to change. Seeds start to develop, the petals fall off, the ovule swells, and seeds and fruit develop.

7) *Embryo*: Following the double fertilization (the formation of the diploid embryo and the triploid endosperm), the 3n cell divides mitotically to produce endosperm. The zygote divides through mitosis to form the embryo the cells begin to differentiate into three tissues: protoderm, procambium, and ground meristem.

   As the differentiation continues, the result is the formation of three distinct embryonic tissues. This gradual change is called mophogenesis. In the early stages off embryonic

growth, cell division takes place throughout the body of the growing plant. As the plant grows and tissues differentiate, the cell division is restricted to certain parts of the plant body, especially to the apical meristems. The apical meristem is located at the tips of the roots and shoots,

8) *Monocot seed*:
The endosperm is the source of food for the monocot, and it is usually starchy.
The radicle is the embryonic root.
The hypocotyls is the shoot below the cotyledon.
The epicotly is the shoot above the cotyledon.
The silk scar is where the style was attached.
The plumule is the shoot with miniature leaves.

9) *Dicot seed:*
The micropyle is where the pollen tube enters.
The helium is where the seed attaches to the ovulary.
The cotyledons absorb food from the endosperm initial growth.
The seed coat is the tough outer covering that prevents water loss and protects against mechanical damage.
The plumule is the shoot with miniature leaves

10) *Seed and fruit:*
A seed consists of the embryo, a food supply, and a protective covering.
The stored food consists of or is derived from the endosperm.
The seed coat is outer layer or layers (integuments of the ovule.
The pericarp is the wall of the fruit.
The fruit develops from the wall of the ovulary and other tissues.
The fruits protect dormant sees and aid in their dispersal. A fruit is a mature ovulary.
As seed develop, after fertilization, the wall of the ovulary thickens.

11) *Types of Fruit:*
Fruits come in many different forms and this affect show the seeds are dispersed. Fruits are usually classified as a simple, aggregate or multiple. This classification depends on the arrangement of the carpels.

Simple fruits develop from the carpel or the fused carpel of a simple pistil.
Aggregate fruits have several separate carpels of a single flower. E.g. raspberry, strawberry.
Multiple fruits consist of the carpels of more than one flower. E.g. pineapple: the ovularies of the individual flowers fuse as they mature.

4. Adaptations to Seasonal Changes

a. Annuals
The entire life cycle of the plant takes place within a single growing season only the seeds are left after the one growing season. Seeds are resistant to cold, desiccation, and other environmental factors. The seeds bridge the gap between generations. Annuals are usually soft stemmed (herbaceous or non-woody.)

b. Biennial
The period from seed germination to seed formation spans two growing seasons. The first growing season results in a short stem and rosette of leaves near the soil and a root. The root is modified for food storage (beets and carrots). In the second growing season the stored food reserves in the root are mobilized for flowering, fruiting, and seed formation, after which the plant dies.

c. Perennials

Vegetative structures persist year after year. Herbaceous perennials remain dormant as modified underground structures during unfavorable seasons, woody perennials survive above ground and only flower when they become adult plants. These plants have an advantage in that height can be added during each growing season. The leaves of these plants an overtop their neighbors. Deciduous plants drop their leaves annually.

d. Seed Dormancy

Some seeds main dormant for long periods of time before germination. The seed coat plays a major role in dormancy. Sometimes the seed coat acts as a mechanical barrier by preventing the entry of water and gases. Growth can be initiated when the coat is worn away, burned by fire, abraded by sand or soil, or partially digested.

Some seed coats have chemical inhibitors. These inhibitors. These inhibitors undergo chemical changes in response to environmental factors such as light, cold, water, increase in temperature. Germination cannot begin until the seed has imbibed the water required for metabolic activities.

Hydration causes the seed to expand and the seed coat turpures. Metabolic changes in the embryo cause the embryo to grow. The enzyme alpha amylase is produced by the embryo. This enzyme breaks down the starch that is stored in the endosperm or cotyledon. The nutrients move to the growing areas of the embryo.

In dicots, the first organ to emerge is the radicle. The hypocotyls grows upward, and once stimulated by the light, straightens, thus raising the cotyledons and the epicotyl. The epicotyl now spreads its first leave. After the root has been established in the monocot, the coleoptile (the sheath enclosing the embryonic shoot) pushes through the soil and into the air. The shoot grows up through a tunnel created by the coleoptile.

II. PLANT TISSUES

A. EMBRYONIC TISSUE

1. **Three Distinct Embryonic Tissues**
   a) Protoderm
   b) Procambium
   c) Ground meristem

2. **Three tissue systems**

   a. **Dermal**
   Provides the outer protective cover for the entire plant body which is the epidermis. The epidermis has more specialized functions depending on the organ that the epidermis covers, such as the root, which forms the root hairs, and the leaf, which arms the cuticle.

   b. **Vascular Tissue System**
   This is comprised of the vascular tissue (xylem, phloem, and cambium).

   c. **Ground Tissue System**
   Fills the space between the dermis and the vascular system.

3. **Common cells**

   a. **Parenchyma Cells**
   These are the most frequently encountered cells in plant body. This cell is found in all systems and predominates in ground tissues. They are many sided and thin walled (lack secondary cell walls – remain flexible.) They contain thee nucleus, mitochondria, and plastids. In addition to photosynthesis, parenchyma cells respire, store food, and store water.

b. Collenchyma Cells

These cells also lack a secondary cell wall; however, they have an unevenly thickened primary wall. They are usually grouped in strands or cylinders and help support growing parts of the plant. In fact, they provide support without restraining growth.

c. Sclerenchyma Cells

These cells also support plants with a thick secondary wall – strengthened by lignin. These are more rigid than collenchyma cells. Mature sclerenchyma cells cannot lengthen. At functional maturity, a sclerenchyma cell may actually be dead- its rigid wall serving to support the plant. There are two forms of the cell.

1) Fibers are long, slender and tapered. These fibers usually occur in bundles and can be woven.
2) Sclerids are shorter than fibers and irregularly shaped.
   Some tissue systems also contain a variety of other specialized cells.

B. GERMINATION

Awakening of the dormant seed. The seed imbibes water, expands, and the seed coat ruptures. The aleurone (the outer layer of the endosperm) produces alpha amylase which begins to digest the starch in the endosperm thus providing glucose for the embryo. The radicle grows down, and the hypocotyls grows up. The first leaves open to the sun and photosynthesis occurs. The primary growth involves differentiation of the three tissue systems, elongation of roots and stems, and formation of lateral roots and branches.

C. OVERVIEW OF PLANT GROWTH

Most plants grow as long as they lives this is known as indeterminate growth. They can do this because of perpetually embryonic tissue called meristems in the region of growth. Meristematic cells are unspecialized and divide to produce additional cells Some cells stay in the meristem to produce more cells (initials) while others specialize (derivatives). The pattern of growth is determined by the location of the meristems. Apical meristems located at the tip of the roots and in the buds of shoots supply cells so the shoots and roots can grow in length. The elongation of shoots and roots is primary growth. In herbaceous plants primary growth alone occurs. In woody plants, secondary growth happens also. This involves a thickening of the roots and shoots that were earlier formed through primary growth.

Secondary growth is a product of lateral meristems the vascular cambium (cylinders of dividing cells extending along roots and shoots). The lateral meristems add layers of vascular tissue. Cells toward the outer portion of the growing stems and roots become meristematic and produce the periderm which replaces the epidermis as an outer protective layer.

D. ROOTS

Roots are the first structures to break through the seed coat. The embryonic root is called the radicle. As the plant gets older, the root system makes up more than half the plant,. They absorb water through numerous root hairs though a passive osmotic process.

1. Root types

a. Tap roots
A primary root that gives rise to lateral roots.

b. Adventitious Roots
These develop from the base of the stem or other parts of the plant. Adventitious roots are not primary roots, but form a fibrous root system.

c. Aerial Roots
Adventitious roots produced by above ground structures. These attach to structures and provide support to the plant.

2. Root tip

This is a growth point. The root tip contains the apical meristem which is tissue located above the root cap. The apical meristem is a region of small, rapidly dividing cells that contribute to the expanding and maturing of vascular tissue. It also contributes to the root cap below, Above the apical meristem are three concentric cylinders – protoderm, procambium, and the ground meristem.

3. **Zone of Elongation**
This zone is positioned above the apical meristem. Cells in this zone may elongate to more tan ten times their original length.

4. **Zone of Differentiation**
This zone is above the zone of elongation. The three primary tissues differentiate in this area. Te three tissues give rise to the following.

   a. **Protoderm**
   This gives rise to the epidermis and thee root hairs.

   b. **Procambium**
   This gives rise to the central vascular cylinder (stelee). The stele of dicots has a central core of parenchyma cells called the pith.

   c. **Ground meristem.**
   Between the dermis and the stele, it is mostly parenchymawhich includes the cortex.

5. **Epidermal tissue**
Covers the entire surface of the young root. The epidermis absorbs water and minerals. The epidermis protects the internal tissues and is characterized by the root hairs. Root hairs are slender extensions of epidermal cells. Most water and minerals enter the root through the root hairs.

6. **Root Cap**
This protects the apical meristem. This is worn away constantly and needs to be replaced.

7. **Cortex**
Occupies the greatest volume of the young root. The cortex is composed primarily of parenchyma cells, which are usually used for the storage of food. Secondary roots arise from the pericycle, which is part of the stele.

8. **Endodermal Cells**
These are encircled (top, bottom, and radial walls) by a band of suberin called the Casparian Strip. This band adheres to the cell wall. The cell walls are thus impermeable to water, and water must pass through the membrane of the endodermal cells. This allows the cells to regulate the movement of substances into and out of vascular tissue.

9. **Pericycle**
The pericycle is located inside the endodermis; it conducts water and minerals inward to the vascular tissue. Also, the pericycle produces secondary roots, periderm, and extends the vascular cambium around the protoxylem poles.

10. **Vascular cylinder**

   a. **Primary Xylem**
   Thick-walled water conducting cells (tracheids and vessel elements) with other cell types.

   b. **Primary Phloem**
   Cells with sieve-like side or end-walls (sieve cells and sieve tube members) which conduct food together with other cell types.

11. **Lateral Roots**
Lateral roots may sprout from established roots. They arise from the outermost layer of the stele (the pericycle). The stele of the lateral root retains the connection to the stele of the primary root. The vascular tissue is continuous throughout the root system.

E. STEM OF A WOODY PLANT

1. **Functions**
   a. Avenues of transport between the source of water (roots) and where the water is needed for photosynthesis (leaves).
   b. Supports and elevates foliage.
   c. Stores food.
   d. Produces new living tissue.
   e. Supports and elevates flowers and other reproductive parts.

   Most of he stem consists of xylem and related tissue. Between the xylem and phloem is the vascular cambium. The vascular cambium is composed of undifferentiated cells which produce both xylem and phloem.

2. **Vascular Tissue**
   Consists of specialized conductive cells, supporting fibers, and parenchyma cells (store food and water).

3. **Conducting Cells**

   a. **Phloem**
   Transport products of photosynthhesis.
   1) *Gymnosperm*: sieve cells
   2) *Angiosperm*: sieve-tube members

   Sieve-tube members form a vertical column joined by their end walls. End walls are called sieve plates which have pores leading from one sieve tube members to the next.

   Sieve-tube members are alive at maturity. They are filled with sap. Some monocots contain a proteinaceous substance called slime or P-protein (P = phloem). The P-protein may respond to phloem injuries. As sieve-tube members mature, the nucleus and other organelles disintegrate. Specialized cells (companion cells) may secrete substances into and out of the sieve-tube members.

   b. **Xylem**
   1) *Conducting cells*: tracheids and vessel members. Both cells are thick and have a secondary cell wall that has lignin. Both cells are dead at maturity.
   2) *Tracheids*: long thin cells with tapered ends. These ends overlap each other and are thin. They are also pitted. Water passes through the pits in their lateral walls.
   3) *Vessel members*: these are shorter ad wider. The ends are absent, so that they can form a continuous vessel. Most seedless vascular plants and most gymnosperms have only tracheids. Angiosperms have both tracheids and vessel members.

4. **Primary Growth of the Shoot System**
   Growth in the stem is similar to that of the root. There is an area of cell division, a region of elongation and differentiation. However, growth zones are not as distinct as in the root. Also, there is no cap over the apical meristem of the shoot.

   The epidermis is the outermost layer. It is covered by the cuticle. Cells under the outer layer from the ground tissues and the primary vascular tissue. Apical meristem of shoots give rise to new leaves, branches and

flowers. The apical meristem of the shoot is a dome-shaped mass dividing at the tip of the terminal bud. It gives rise to the primary meristem, also to the protoderm, procambium, and ground meristem. Leaves arise as tiny bulges to the side of the apical meristem. Growth is due to cell division, elongation, and differentiation.

Lateral extensions originate from the auxiliary buds located at the surface of the main shoot. The vascular tissue of the shoot is near the surface.

5. **Secondary Growth**
   Plants become thicker. This growth is produced by the lateral meristems: vascular cambium and corl cambium.

   Vascular cambium: develops from the procambial cells which are left over after development of primary xylem and phloem. The vascular cambium is a thin cylindrical sheath of tissue between the xylem and phloem. These cells divide continuously during the growing season, thus adding secondary phloem toward the outside, and more secondary xylem toward the inside.

   As the secondary growth continues, the epidermis stretches and breaks. The cork cambium produces cork (periderm) which replaces the epidermis as the protective covering. Cork is dead tissue. As the plant grows xylem in the center of thee stem and root becomes inactive. The vessels become clogged and cease to function. The non-conducting xylem is called heartwood.

   Season after season xylem forms visible growth layers or rings. Each season leaves its trace. The continuous formation o the secondary xylem and phloem increases the woody dicot's diameter.

6. **Cortex**
   Cortical parenchyma cells are thin walled and used as food storage. Collenchyma cells have unequally thickened primary cell wall and are located inside the epidermis. These cells provide support for the growing regions of the young stems and branches.

7. **Schlerenchyma Cells**
   There are two types of schlerenchyma cells
        a.   Fibers: Elongated cells often associated with vascular tissue.
        b.   Sclerids: Also common in stems.

   Schlerenchyma cells are hard because the cell walls are impregnated with lignin which hardens the cellulose. Schlerenchyma cells are often dead at maturity. The cell walls remain and usually occur in regions of he plant body that have completed primary growth.

8. **Anatomy of a stem**
   Stems are elongated organs on which the leaves and buds are produced.

        a.   **Nodes**
             Where the leaves and buds are attached
        b.   **Internodes**
             Between the leaves and buds

   Some plants have erect stems; others have horizontal stems or creeping stems. However, all stems are distinguishable by the presence of leaves, buds, nodes, and internodes.

   The tip of the stem bears a large terminal bud that usually develops before the other buds. Growth at this terminal bud results in the lengthening of the stem. Leaves and flowers also may arise from the terminal bud. At regular intervals along the stem, other buds may be seen. These are lateral buds. New branches and leaves and sometimes flowers will develop from these.

Below each lateral bud, there is a scar that was made when a leaf fell from the stem. This is thee leaf scar. Vascular bundle scars (bundle scars) may be seen within each leaf scar. Protecting the young, immature leaves of the bud are bud scales. These are a series of overlapping scales. These bud scales usually fall as the bud develops. This shedding of the leaf scales leaves a bud scale scar. These are rings of marks around the stem.

The part of the stem between the bud scale scar and the terminal bud is generally formed in one season. The growth may vary from year to year. The slightly raised areas on the bark are called lenticels. These small areas of non-suberized cells permit the passage of gas into and out of the stem.

F. LEAF
The vascular system of thee leaf is an extension of the xylem and phloem of the stem. Xylem and phloem run parallel through the petiole (stem of the leaf) and branch extensively in the blade (flat portion of the leaf). These are the veins (branched vascular bundles).

1. *Dicots*: one large mid-rib, the large vein
2. *Monocots*: parallel veins, but they are interconnected with really small vascular bundles.

In monocots and dicots the larger leaf vein is surrounded by parenchyma cells that have fewer or no chloroplasts. Smaller veins are enclosed by one or more layers of parenchyma cells. This layer is called the bundle sheath. Leaves contain intercellular spaces that are the principle avenue of as movement. CO_2 diffuses into the leaf through the stomata (stoma), which are pores on the surface of the leaf. Oxygen diffuses in and out in the same way. Each stoma is surrounded by two guard cells.

III. MECHANISMS OF TRANSPORT

PASSIVE AND ACTIVE TRASPORT OF SOLUTES
The plasma membrane controls the movement of solutes between the cell and the environment. Solutes tend to diffuse from an area of higher to lower molecular activity; the process is passive. Transport proteins help solutes move across the membrane – these are selective channels. In potassium channels in the cell, $K+$ passes but $Na+$ does not.

Tonoplast is the membrane of the central vacuole that is an important site of regulation. It controls the movement of solutes between the cytoplasm and the central vacuole.

1. **Short Distance Transport**
   This deals with the transport of substances along the radial axis of plant organs (not up and down).

   a. **Osmotic Substances**
   Move out of one cell, across the cell membranes and walls, and into the neighboring cell. This can be by active or passive transport.

   b. **Symplastic**
   The cytoplasm is continuous within plant tissues. The solutes and water move from one cell to the next via plasmodesmata.

   c. **Apoplastic**
   Outside the protoplasm substances move through the continuum of cell walls.

2. **Long Distance Transport**
   Movement of water up the xylem and sap up or down the phloem are examples.

3. **Water Movement**

   a. **Absorption of Water**
   Water and minerals enter the plant through the root epidermis, go across the cortex, and enter at the stele. They travel up the xylem into the shoot.

Root hairs account for most of the root surface area. Soil solution (water and minerals) enters the root hairs and passes through the root by the apolastic or symplastic pathway.

The endodermis acts as a selective membrane and sieves the solution as it passes into the stele. The casparian strip is a waxy strip that prevents the flow of water, allowing endodermal cells to regulate the movement of water.

Water and minerals flow upward in vessels at rates of up to 15 or more meters per hour. Veins branch throughout each leaf and place xylem vessels close to each cell. Plants lose a large amount of water via transpiration. An average sized maple tree will lose 200 liters of water per hour.

Plants need water for photosynthesis to occur. Water that is taken up in plants rapidly evaporates, this is called transpiration. C3 plants lose 400-600 grams of water per gram of carbon dioxide fixed in photosynthesis; C4 plants lose 250-300 grams; and CAM plants lose 50-100 grams of water.

During photosynthesis, enormous amounts of air go through the tiny stoma. The carbon dioxide must first dissolve through a thin film of water. The interior surfaces f the leaf must be wet. Most of the water from the roots goes here. A lot of water is lost by evaporation and diffusion through the stoma. When there is not enough water to meet the needs of the plant, the plant wilts. There is a loss of turgor pressure in the leaves and stem. The stomata close and this reduces water loss.

b. Root Pressure

How does water move from the root to the stem? Plants get water from root hairs almost entirely. Water moves slowly by diffusion and capillary action through the soil towards the depleted regions (of soil) near the roots.

Roots have a higher solute concentration than does the soil. Water enters the root cells through osmosis. The resulting root pressure moves the water a short distance up the stem. An example of root pressure is the morning dew. The drops of water on the edges of blades of grass early on a summer morning are pushed up by the roots. There is an excess of water and it is pushed out of the leaf. A loss of water in the liquid phase is called guttation. The loss of water in the gas phase is called transpiration.

Roots generate 3-5 atmospheres of pressure (34.1-73.5 psi). This pressure cannot push water up a tree, but it plays a key role in transpiration beginning from the time when the plant was small.

c. Transpiration: The Cohesion-Tension Theory

Transpiration is the movement of water up a stem. This process helps to supply water to leaves for photosynthesis, assists in the transfer of minerals, and acts as an evaporative coolant for metabolic processes.

Water is not pushed up a tree, it is pulled. There is a need to use two characteristics of water to help explain how this happens.

1) *Adhesion*: The attraction of water to other surfaces. Adhesion and surface tension explains how water is pulled up a glass tube by capillary action. Water adheres to the glass and its surface tends to be lower in the center. Water tends to creep upwards because surface tension pulls the water surface straight. The smaller the diameter of the tube, the higher the water will rise because the weight of water in a small tube is less than a comparable length of water in a large tube.
2) *Cohesion*: the attraction of water to itself. Capillary action is not enough to pull water to the top so most trees, so cohesion is important. Cohesion gives water tensile strength, which is the ability to be pulled without breaking. Water in the xylem shows a tensile strength close to that of a steel wire of the same diameter.

d. Transpiration Pull

Capillary action occurs and water rises. This cannot continue to the top of most trees but the tensile strength of water allows it to be pulled upward. This pull is provided by the free energy of evaporation. One water molecule pulls the next molecule out of the stoma when it evaporates.

The second pull creates tension within the xylem. The tension pulls the walls inwards. This pull is measurable. The secondary cell wall prevents the xylem from collapsing.

Factors influencing Transpiration:
1) *Temperature*: The rate of evaporation doubles for every 10°C increase in temperature.
2) *Humidity*: water is lost much more slowly into air laden with water vapor.
3) *Air Currents*: wind blows water vapor away from the surface of the leaf. This makes the diffusion gradient between the inside and outside of the leaf steeper.

GASEOUS EXCHANGE IN VASCULAR PLANTS

Plants exchange gases with the environment, but air must be kept out of the xylem. If air enters the xylem, there would be a break in the water column and there would be no tensile strength. Root hairs exchange gases with the soil atmosphere.

Guard cells regulate transpiration which makes them an important adaptation to the land environment by opening and closing the stoma and are usually located on the underside of most leaves. They regulate the size of the stoma by shrinking and swelling.

When they are not turgid, they relax and the stoma closes. When they are turgid, the cells swell and open. The guard cells are usually open during the day and closed at night.
The cell wall of guard cells has a thickened portion on the stomatal side. This causes the cell to buckle when the cell swells.

1. Mechanisms of Stomatal Movements

Osmosis is involved in the opening and closing of the stomata. Each stoma has two surrounding guard cells. Stomatal movement is controlled by changes in turgor pressure. When guard cells are full of water. They bow out and the stomata open. When the guard cells have less water, they relax and the stomata close.

Turgor is maintained due to osmotic movement of water. The active removal of solutes from guard cells results in the osmotic movement of water out of the cells.

The critical solute affecting the movement of water is the potassium ion (K+). An increase in K+ concentration causes the stomata to open; a decrease in K+ concentration causes stomatal closure.

In some plants Cl- ions accompany the K+ ions to keep electrical balance. In other species H+ ions leave the guard cells, decreasing H+ concentration within guard cell of open stomata.

K+ moves by active transport. The energy for this transport may come from guard cells. Guard cells have chloroplasts; they use ATP from photophosphorolation from the electron transport chain in the light dependent reaction.

K+ can also move trough specific membrane channels H+ can be actively transported out of the guard cell. The resulting increase in voltage drives K+ into the cell via the channels.

2. Factors influencing Stomatal Movements

There are a number of environmental factors that influence the movement of K+ into and out of the cells.

a. Availability of Water

Loss of water leads to a loss of turgor pressure and the guard cells close the stomata.

b. Abscisic Acid

Abscisic acid binds to receptors on the guard cell. This makes the cell permeable to K+ ions.

c. Carbon Dioxide Concentration

Increases in carbon dioxide in between the cells of spongy mesophyll closes the stomata.

d. Temperature

An increase in temperature (above 30°C) close the stomata. An increase in temperature will increase respiration which raises the CO2 concentration. With an increase in temperature there is an increase in water stress.

e. Light

 Light (blue light) opens the guard cells. It is known that K+ ion uptake of the guard cells occurs after blue light stimulates the active transport of H+ ions out of the guard cells. This forces the K+ into the guard cells through specific membrane channels.

f. Internal Clock

Stomatal openings may be controlled by an internal clock. Stomata will continue to open and close at the same time day after day.

4. Plant Adaptations

Plants which are adapted to arid environments are called xerophytes. They generally have small thick leaves, thick cuticles, and stomata on lower leave surface. The stomata can be found in crypt-like depressions which shelter pores from the wind. Some plants will shed their leaves during the dry seasons or store water during the rainy season.

Crassulacean acid metabolism is another adaptation to arid environments. Some plants open their stomata at night and close during the day. These species of plants are adapted to hot, dry climates. These plants take in CO2 during the night (converting it to malic acid/ or isocitric acid). During the day, the CO2 is released from the organic compound and used it in photosynthesis. This is known as crassulacean acid metabolism. This system allows saving in water intake.

A. UPTAKE OF MINERALS

Plants require minerals. Minerals are naturally occurring inorganic substances, usually solids with distinctive chemical compositions. Mineral ions in water are taken up as solutes by the roots and travel in the xylem. The endodermis plays a role in determining which substances enter the xylem. Mineral ions can be brought into the plant by active transport.

B. FOOD TRANSPORT

The transport of food in called translocation. Sugar and other nutrients move through the phloem.

1.   Pressure Flow Hypothesis

   Movement of sugars in the phloem is in the form of a 'source to sink' pattern. The source (where sugar is made or stored) exports the sugar and the sink (where sugar is needed, such as growing regions) imports the sugar. The source provides the nearest sink with sugar. Sugars move in this manner according to the pressure flow hypothesis. According to this hypothesis, solutes move in solutions due to differences in water potential. These differences are caused by concentration gradients of sugar. Sugar is produced by the leaf in the mesophyll. Sugar reaches the sieve tube members by symplastic or apoplastic pathways. The companion cell may help transfer the sugar. The sugar is actively transported into the phloem of the leaf. The protein pump helps. The ATP driven pump move H+ out of the cell and the difference in H+ allows the cell to store energy which increases the sugar concentration inside the phloem. This creates a hypertonic environment. An osmotic gradient is created. The water flows into the phloem from nearby xylem. There is an increase in hydrostatic pressure which produces the flow of sap out of the leaves and down the phloem.

Where the sugar is in demand in a certain tissue, it is moved out of the phloem by active transport. This creates a new osmotic gradient, and water moves from the phloem back to the xylem.

Companion cells have many mitochondria. It is believed that one of the functions of a companion cell is to produce energy for the sieve-tube cell's active transport of sugar.

IV. FACTORS THAT INFLUENCE PLANT NUTRITION

A. AVAILABILITY OF NUTRIENTS FOR PLANTS

The availability depends on soil characteristics and symbiotic fungi and bacteria.

Mineral content depends on the parent rock from which the soil was formed. In most soils, mineral content is also dependent on biological factors. Most of the mineral content stays within the system. If disturbed, the top layer is eroded and soil becomes depleted of nutrients. Another factor influencing mineral content in soil is the size of the soil particles.

pH of the soil also affects its capacity to keep minerals. If the soil is acidic, H+ replaces the positive ions that cling to the clay. These ions are leached out of the soil. Acidity also affects solubility of certain elements (calcium – more soluble and iron – less soluble).

Humus is decomposing organic material formed by bacteria and fungi which prevents clay from packing and builds crumbly soil that retains water and is porous for good aeration.

Plants require macronutrients for different functions.
1) Regulation of water balance (osmotic potential) is determined by ion concentration.
2) Magnesium is an essential part of chlorophyll.
3) Phosphorus and calcium are part of the cell membrane.

The 8 micronutrients are iron, chlorine, copper, manganese, zinc, molybdenum, boron and nickel. These are cofactors in enzyme reactions (e.g. iron is part of the cytochromes in the electron transport chain.

B. THE ROLE OF SYMBIOSIS
1. Mycorrhizae

Fungi extract nutrients (phosphates and water) from the soil and make them available to plants. This enables plants to prosper in nutrient poor soil. Some studies suggest that the fungi also screen out chemicals from toxic soils.

2. Rhizobium and Nitrogen fixing

79% of the earth's atmosphere is made up of nitrogen, but plants can't use nitrogen in this form. The triple covalent bond between the two nitrogens is a very strong bond. Plants are dependent upon two nitrogen-containing ions: ammonium (NH_4^+) and nitrate (NO_3^-).

In plants the nitrates are reduced to ammonium ions that are combined with a carbon-containing ion. These will eventually form amino acids. At the death of plants, the nitrogen containing compounds are then returned to the soil. They are then processed by soil organisms.

The main source of nitrogen loss comes from the removal of plants from the soil. If the nitrogen lost from the soil is not constantly replaced, then there will be virtually no life. The 'lost' nitrogen is replaced by nitrogen fixation. This process takes atmospheric nitrogen and incorporates it into organic nitrogen containing compounds.

Nitrogen fixing organisms are prokaryotes. Some form symbiotic (mutualistic) relationships with roots of plants. The most common nitrogen-fixing symbiotic bacterium is Rhizobium. This bacterium is found in the roots of legumes: clover, peas, beans, and alfalfa. Leguminous plants leave behind more nitrogen in the soil than do non-leguminous plants.

The roots of legumes produce a chemical that attracts bacteria produce a chemical which causes the root hair to elongate and surround the bacteria. The bacteria provide the plant with nitrogen, and the plant provides the bacteria with carbohydrates.

V. CHEMICAL REGULATION AND BEHAVIOR

A. HORMONE: CHEMICAL REGULATORS
A chemical substance that is produced in one tissue and transported to another, where is exerts one or more specific effects. Hormones integrate growth, development, and metabolic activities of various tissues of the plant.
The response to these regulators depends on the content of the hormone and the identity of the recipient (tissue).

The response is also influenced by a variety of factors in the internal environment. The main factor is other hormones.

B. CHEMICAL REGULATION IN PLANTS
1. Darwin
Darwin studied the behavior of climbing plants. He witnessed many variations of growth and attributed these to natural selection. He noticed that the grass seedlings would grow towards the light only if the tip of the cleoptile was present.

Plants have the ability to bend their tips toward the light due to unequal elongation of the lighted and dark sides of the stem.

2. Peter Boysen-Jensen and Paal
These scientists conducted experiments that furthered Darwin's observations. The cut the tip off of a grass seedling, put some gelatin on the stump and replaced the tip. The plant bent towards the light. The plant was influenced by something that could move through the gelatin.

They conducted the same experiment, but put mica between the tip and the stump. The seedling did not bend toward the light.

3. F.W. Went
In 1926, he conducted similar experiments but place tips on agar blocks. The put just the agar blocks on top of the stem. He used the block as a source of the hormone and the stem grew toward the light. Went chose the name auxin for the hormone that caused the differential growth.

4. Kenneth Thiman
In 1934 Kenneth Thiman purified auxin or indoleacetic acid (IAA).

C. TROPISMS
Growth responses of plants are curvatures of the plant towards or away from an external stimulus.

1. Positive (Negative) tropism: plant parts grow towards (away from) something.
2. Positive (Negative) phototropism: plant parts grow toward (away from) light.
3. Positive (Negative) geotropism: plant parts grow towards (away) the earth.

Nearly all specialized cell growth is caused by auxins.

D. PHOTOTROPISM
Something in the growing tip is stimulated by the light. The side that doesn't get the light has auxins which diffuse down the stem. More elongation occurs on the dark side and also the tip bends toward the light.

There are 5 types of plant hormones.
1. Auxins
2. Cytokinins
3. Ethylene gas
4. Abscisic acid
5. Gibberellins

Plant hormones are produced in minute concentrations which can have profound effects on the growth and development of plant organs. A hormone may act by altering the expression of genes affecting the activity of enzymes, or by changing properties of membranes. These actions can redirect the metabolism and development of a cell.

E. AUXINS

Indoleacetic Acid- IAA. Other compounds with functions similar to IAA have been isolated, and still others have been made in the lab. All these substances are known as auxins. The structure is similar to the amino acid tryptophane.

Auxins promote elongation of the cell. This occurs during growth. Auxin is produced by apical meristems of shoots and transported toward other parts of the plant. Auxins move in one direction from the shoot to the root. This is called polar transport. Auxins can be transported directly through the parenchyma tissue (at 10 mm per hour) or from one cell to the next.

Cellular elongation requires the loosening of the closely bound cellulose filaments of the cell wall. This loosening allows turgor pressure to expand the cells. The cytoplasm doesn't increase but the central vacuole does.

IAA activates the proton pump in the plant cell membranes that transports H+ from the cell into the cellulose cell wall. The cell wall becomes acidic. This activates a pH dependent enzyme that breaks down the cross links between the cellulose molecules. The molecules now slide past each other due to turgor pressure. The cross-links reform, and the cell wall becomes rigid.

Auxin acts on RNA transcription. The auxin stimulates growth by triggering the expression of at least 10 specific genes. Auxins also stimulate the production of rRNA, the assembly of new ribosomes, and the production of proteins different from those previously produced.

Apical Dominance and other Auxin Effects: Growth of axillary buds is inhibited by auxins from the apical meristem. This in known and apical dominance. If you cut off the stem tips, axillary buds begin to grow, and the plant becomes bushier.

Auxin stimulates the production of ethylene in cells around the axillary buds; this inhibits bud growth. In woody plants, auxins are also involved in the seasonal initiation of activity in the vascular cambium.

Auxins are also produced by young leaves, flowers, developing embryos and fruits. They promote maturation of the ovulary wall and development of fleshy roots. Auxins also can produce fruits without fertilization: seedless tomatoes, cucumbers and eggplants.

Herbicides (weed killers) such as 2, 4-d are synthetic auxins that disrupt the normal balance of plant growth. Dicots are more sensitive than are monocots to these herbicides which can, therefore, selectively remove dandelions and other broad leaf weeds from a lawn or grain field.

F. GIBBERELLINS

Are formed in young leaves around the growing tip, young seeds, and perhaps in the roots. Gibberellins produces hyperelongation of the stem.

The highest concentration of gibberellins has been found in immature seeds. During the early stages of germination (following water uptake), the embryo produces gibberellins. Once exposed to the gibberellins, cells produce enzymes that hydrolyze the starch, lipids, and proteins in the endosperm. These substances are converted to sugars, fatty acids, and amino acids used by the embryo.

G. CYTOKININS

Cytokinins were discovered in the 1940's by Johannes Van Overbeck.

1. They release axillary buds from apical dominance. Cytokinins are synthesized in roots and travel upwards through the xylem in xylem sap. As roots become more extensive, there is an increase in the level of Cytokinins which signals shoots to form more branches.
2. They work in conjunction with auxins and cause cells to divide, and can stimulate RNA and protein synthesis.
3. Cytokinins prevent the aging of leaves.

These stimulate cell division in plants. They increase the rate of protein synthesis needed for cell division. Cytokinins can cause undifferentiated cells to differentiate. They are associated with aging plants and are able to extend the life of the plant. Synthetic Cytokinins have been applied to celery and other vegetables, to extend storage life. Mechanisms for the action of Cytokinins are unkown.

H. ETHYLENE

Ethylene is the gas, which produces the smell of ripening fruit. Ethylene gas diffuses into air space between cells and may inhibit cell elongation. It initiates the ripening process, degrades cell walls and decreases chlorophyll content. Ethylene gas can initiate fruit ripening during transport.

Ethylene gas may play an important part in the emergence of seeds from the soil. However, too much ethylene gas will kill the plant, and with Abscisic acid, regulate leaf loss.

I. ABSCISIC ACID

Controls leaf separation from the stem (abscission). This is an adaptation of plants which reduces water loss during the dry seasons. It may also be a response to parasitic invasion. Abscisic acid causes the cells in the abscission zone to die and harden.

Abscisic acid may act as a growth inhibitor in seeds and may help when the plant is 'stressed' by closing stomas to decrease transpiration.

J. GRAVITROPISM

This is the plant's response to gravity. Shoots grow up and roots grow down apparently in response to auxin.

The mechanism involves settling of statoliths which are specialized plastids that contain starch grains. These plastids move to the low parts of the cells and cause the redistribution of Calcium (Ca++). This, in turn, causes a lateral movement of auxin within the root. The calcium and auxin cannot respond to gravity and must be actively transported to one side of the root.

K. THIGMOTROPISM

Specialized cells on the tendrils form tight coils around objects if touched. Cells that do not touch the object elongate. Auxins and ethylene are probably involved.

L. PHOTOPERIODISM

The response of plants to the length of periods of light and darkness.

1. Types of plants
a. Day-neutral (flower without regard to the day length)
b. Short-day (flowers only when the light period is shorter than critical length)
c. Long-day (flowers only when the light period is longer than critical length)

Short day plants require 1 hours or less of light to flower. Long day plants require 14 hours or more of light to flower. Day neutral plants are unaffected by day length. These plants will flower when a certain level of maturity has been reached.

2. Measuring the Dark

Measurements concern the length of the dark period actually controls flowering and other responses to a photoperiod. Plants require periods of uninterrupted darkness in order to flower. If the dark period is interrupted, even briefly, a plant which would otherwise flower, will not.

A plant measures the length of darkness in a photoperiod with phytochrome which is a photoreceptor that contains chromophore (light absorbing protein). Phytochromes alternate between two forms, one absorbs red light, and the other absorbs far red light. Phytochrome tells the plant when the sun rises and sets.

3. **Circadian Rhythm**
   Studies have shown that activities, such as photosynthesis, auxin production, and the rate of cell division, have daily rhythms. These rhythms continue even when all environmental conditions are kept constant. These regular day/night cycles are called circadian rhythms. Circadian rhythms are referred to as biological clocks.

   Most scientists agree that circadian rhythms originate in the organism. Evidence shows that these rhythms (biological clocks) are not exact. Different species and different individuals of the same species have slightly different clocks. Biological clocks play an important role in animal and plant physiology by synchronizing internal and external events. For example, certain plants secrete nectar only during specific times of the day or night.

4. **Resetting the Clock**
   The biological clock can be reset using modified external conditions. This is known as entrainment.

M. PLANT TOUCH RESPONSES
In the sensitive plant, the petiole drops and the leaflets fold a second or two after the leaf is touched. This is due to the sudden change in turgor pressure of specialized 'motor cells.'

In the Venus flytrap, the movement is the result of acid growth. The insect brushes against trigger hairs, and this activates enzymes that pump H+ into the epidermal cells along the outer surface of the trap hinge. The quick acidification of the cell walls causes the trap to close. The other cells on the inner surface of the hinge grow at a regular rate, and when the plant opens 10 hours later, the leaf is slightly larger.

General touching (systematic rubbing or bending) of plants stems inhibits elongation. This results in progressively shorter plants.

N. CHEMICAL COMMUNICATION AMONG PLANTS
Angiosperms can produce toxic or bad-tasting compounds. This is a defense against herbivores and insects that chew.

Some plants are apparently able to warn neighboring plants. For example, Sitka willow produces chemicals when attacked by herbivores. These chemical have been found on the leaves of other plants. Reception of the chemical by neighboring plants triggers the defense response. This can occur in plants up to 60 meters away. This was first observed in Sitka willows.

Signal-Transduction Pathways in Plant Cells: Touching plants also affects morphology. In one experiment, mechanically stimulated plants grew shorter and stockier than unstimulated plants. Somehow the touch stimulus must be transduced into an intracellular signal which is then relayed to nuclei, and thus alters the gene expression.

1. **Reception Cells**
   These detect an environmental signal or hormone, for example, specific wavelengths of light. These wavelengths stimulate certain pigments or hormones bind to specific receptors on the plasma membrane. Hormones can only target certain cells called target cells.

2. **Transduction**

This is the amplification of the stimulus and its conversion to a chemical form capable of activating the cell's responses. This critical link is a second messenger, which is found within the cell and is stimulated by the first messenger. For example, a hormone binding to the cell membrane evokes a second messenger, perhaps calcium within the cell membrane.

3. **Induction**

Induction is the bringing about of the cell's specific response to the stimulus. Some responses are rapid, others take longer and require changes in gene expression.

Unit IX
Invertebrates

I. INVERTEBRATES

Kingdom: Animalia

A. **ANIMAL CHARACTERISTICS**
1. They are heterotrophic, multicellular, and eukaryotic.
2. They are organisms that store carbohydrates as glycogen.
3. They are organisms that lack cell walls. The intracellular junctions (tight junctions, desmosomes, and gap junctions) are found only in animals.
4. These organisms have muscle and nervous tissue.
5. These organisms reproduce sexually. They have a dominant diploid organism that produces gametes, either a flagellated sperm or a large, nonmotile egg. These gametes fuse and undergo mitosis to form a hollow ball called a blastula. This blastula undergoes gastrulation; then the embryonic tissues differentiate.
6. Organisms whose life cycle may include many larval stages. Larva is a free-living sexually immature form. The larva is morphologically different from the adult. The larval form usually eats different foods and may live in different habitats. The larva will eventually undergo metamorphosis and change into the adult form.

Animals are divided between invertebrates or vertebrates, radial or bilateral symmetry, and presence or absence of coelom.

B. **SYMMETRY**

1. **Radial Symmetry**
Body parts are arranged around a central axis like spokes around the hub of a wheel. Such organisms have a top and bottom; but no front, back, left or right.

a. **Phylum: Porifera (Sponges)**

The cells of sponges are not organized into tissues Sponges exhibit primitive radial symmetry. There are four classes of sponges, based on skeletal structure. The skeleton is made up of spicules or spongin. There are many incurrent pores throughout the body and one osculum, the big hole that acts as an excurrent pore. The collar cells, choanocytes, line the spongeocoel (inner wall of the sponge) and beat the flagella to cause water movement out of the osculum. Water then filters through the pores which the sponge filters to obtain food. Amebocytes in the middle layer distribute the food to the other cells. Sponges reproduce sexually or asexually.

1. *Sexual:* Any choanocyte may change and function as a sperm, and certain amebocytes (which also secrete the skeleton) may change and function as an egg. Fertilization occurs in the middle layer of the sponge to produce a zygote, which then develops into a hollow larva with flagella. A sponge is a hermaphrodite, a single organism that produces both eggs and sperm.
2. *Asexual:* Budding and gemmules. A gemmule is an amoebocyte that is wrapped in a ball of spicules. Budding occurs when a small piece of the sponge falls off and grows into new animals.

Sponges are sessile as adults.

b. Phylum: Cnidaria (Coelenterata)
Hydra, jellyfish, corals, and sea anemones.

1) Description
The cells of a coelenterate are arranged into two tissue layers: the gastrodermis, which lines the gastrovascular cavity and arises from the embryonic endoderm, and the epidermis from the embryonic ectoderm. Coelenterates have a radial symmetry.

Coelenterates all have a simple nerve net and muscles found in the mesoglea (middle jelly), which is a collagen like material joining the epidermis and the gastrodermis.

Food is captured by tentacles that are armed with stinging cells called cnidocytes. Their digestive system has only one opening, and two-way traffic. The food enters the mouth, is digested in the gastrovascular cavity and absorbed through the endoderm. Wastes exit through the mouth.

2) Cnidarian Classes
Hydrozoa (hydra, Portuguese Man-of War), scyphozoa (cup animals- jellyfish), and Anthozoa (flower animals- anemones and coral)

3) Reproduction
Reproduction involves the polyp and medusa body forms. The polyp is the asexual stage and the medusa is the sexual stage. In the class Scyphozoa, the medusa is the dominant form. In Anthozoa only the polyp form is present and it is sexual.

Coelenterates contain gonads that produce sperm and egg. Fertilization occurs in the gastrovascular cavity to produce a zygote which forms a ciliated planula larva. Asexual reproduction comes from budding (Hydra) or production of a medusa (Obelia).

Corals are a community of polyps with a shared vascular cavity and living quarters are made of calcium carbonate. Each new generation builds over the building of previous generations to produce reefs, the largest biologically produced structures on Earth.

Portuguese Man-Of-War is not a single jellyfish, but a community of polyps with a shared gastrovascular cavity.

2) Bilateral Symmetry
Bilaterally symmetric animals have a top and a bottom, a dorsal, a ventral surface, a left and a right. Most bilateral organisms also have a distinct 'head and tail', anterior and posterior. Many of the sensing cells are collected in the anterior end, enabling the animal to assess an area prior to entering. This collection of nerve

cells is the forerunner of the brain. The concentration of nerve cells and the association of feeding structures at the anterior end is known as cephalization.

Bilateral animals are triploblastic. This means that they have three embryonic tissue layers: endoderm, mesoderm, and ectoderm. These three layers can be detected very early in the development of the bilateral animal. There are known as the 'germ layers.' Body coverings and lining of tissues and nerve tissue arise from the ectoderm. From the endoderm digestive structures arise. Muscles and the other body parts arise from the mesoderm.

Evolutionarily, this makes sense. When the sensing and nerve cells came about, they did so on the outer layer. It is more important for the outside of an organism to be sensitive to the environment. The digestive structures developed from the inner layer, the layer that surrounds the food cavity. As animals become more and more complex, the additional structures for locomotion, internal transport, excretion, and reproduction came from the new middle layers.

C. TRIPLOBLASTIC ANIMALS
The triploblastic animals can be grouped into three categories. These are determined by the presence or absence of a body cavity called the coelom.

1) Acoelomates
Simplest arrangement. The three germ layers are packed together and there is no body cavity other than the digestive cavity and there is no body cavity between he gut and the outer body wall.

2) Pseudocoelomates
There is an additional cavity between the endoderm and the mesoderm. This is called a pseudocoelom because of the location of the cavity and the fact that the cavity does not have an epithelial lining derived from the mesoderm.

3) Coelomates
These have a true coelom, a fluid filled cavity that develops within the mesoderm. Within the coelom, the digestive tract and other internal organs are lined with epithelial tissue. These tissues are known as mesenteries.

D. PHYLUM PLATYHELMINTHES: FLATWORMS
These animals have bilateral symmetry. There are acoelomate with three tissue layers which give rise to specialized organs. There are three classes of flatworm.

1. Class turbellaria: Planaria

a. Digestive system
They have a mouth, pharynx, and a branched gastrovacular cavity. There is one opening, but two-way traffic. Planarians are carnivorous. Through muscular contractions, the planaria sucks in small pieces of meat.

b. Respiration
Gas exchange is accomplished by diffusion through the skin.

c. Excretion
Water balance is regulated by flame cells that sweep excess water and nitrogenous wastes (ammonia) into tubules and out of the body through pores.

d. Nervous System
There are two main nerves with many side branches. The nerve centers (ganglia) are located in the head (encephalization), and support sensory structures such as eye spots and touch sensitive cells.

e. Locomotion

Epithelial cells are ciliated. The ventral epithelial cells secrete mucous so that planarians provide their own slime trail.

    f.   **Sexual Reproduction**
All are hermaphroditic. They have both ovaries and testes. The mating pair exchange sperm, and fertilized eggs are released through the genital pore.

    g.   **Miscellaneous**
They can reproduce asexually through regeneration, in which half of an organism regenerates the missing half.

2. Class Cestoda: Tapeworm
The head (scolex) is equipped with a ring of hooks and suckers for attachment to intestine. Te body is divided into proglottids that contain ovaries, testes, and excretory tubules. The 'ripe' proglottids (filled with eggs) break off and come out with the feces. The life cycle begins when the primary host eats the eggs and becomes infected. The eggs hatch into larvae, which burrow out and travel to muscle tissue and encyst (bladderworm). The secondary host may become infected by eating infected meat (muscle) and larvae grow to an adult form in the intestine. Adult tapeworms can be up to 20 meters in length.

3. Class Trematoda: Flukes
These are parasitic, but have a digestive system. The mouth is surrounded by a sucker, which pumps in nutrients from the host's intestine or liver. Flukes are hermaphroditic and the fertilized eggs pass out of the host with feces. Life cycle: larva is eaten by a snail (primary host). The larva develops into a sporocyst. The sporocyst leaves the snail and changes into a third larval form in the water. The larva burrows into fish muscle (secondary host). The infected fish is eaten by the final host, which the larva grows to the adult stage.

E.   **PHYLUM NEMATODA: ROUNDWORMS**
Roundworms have three tissue layers that from a pseudocoelom. This pseudocoelom functions as a hydroskeleton.

1. Circulatory System
Roundworms lack a circulatory system. Contraction of muscles move the fluid.

2. Digestive System
Roundworms have a one-way digestive system with two openings.

3. Reproduction
Both sexes are present. The female is usually larger than the males. The fertilization of the eggs is internal, and the female may deposit 100,00 fertilized eggs per day. The zygotes are resistant to harsh conditions.

Roundworms can be either free-living or parasitic.

Ascaris: This is a roundworm that lives in the intestine. The host eats the egg, the egg hatches to a larva, the larva burrows out of the intestine into the blood and travels to the heart, lungs, up the trachea, and is finally swallowed down the esophagus. The larva then grows into adulthood in the intestine.

Necator americanus (Hookworm): Te life cycle is like the ascaris, except that the egg hatches into a larva and the larva enters the human through the skin of the bare foot.

Trichinosis: This is the disease from the trichina worm. Adults in the intestine produce larva, which travel to muscles and encyst. A secondary host eats the infected meat, and the larva grows to adulthood.

Pinworms: These account for up to 50% of all parasitic infections in US children. Adult live in the intestine, and females migrate to the anus to lay eggs. The eggs are swallowed by the host, grow to adulthood, and live 3-4 weeks.

F. COELOMATES

The remaining invertebrate phyla are Coelomates. With a coelom, surrounded by lubricating coelomic fluid, the organs can bend, twist, fold back on themselves (increasing the functional surface area), and slide past one another. There are two types of coelomic animals. These groups are based on characteristic features of embryonic development. When the zygote begins to divide, the early cell division usually follows one of two patterns. In some animals (mollusks, annelids, and arthropods), the early cleavages are spiral, occurring in a plane oblique to the long axis of the egg. In the other group of Coelomates the cleavage pattern is radial, parallel to and at right angles to the axis of the egg. With both types of cleavage the embryo gradually develops to a stage known as the blastula (hollow ball of cells).

1) Protosomes

An opening, the blastopore, appears in the blastula (blastosphere). Among the coelomates with the spiral cleavage, the mouth (stoma) develops at or near the blastopore. This group of animals is called porticoes (first the mouth).

2) Dueterostomes

In the animals with the radial cleavage, the anus forms at or near the blastopore and the mouth forms secondarily elsewhere. These animals are known as dueterostomes (second the mouth). These differences are believed to have originated very early in animal evolution, before the branching that gave rise to the modern coelomate phyla.

Another difference between the two groups concerns how the actual coelom is formed. In protosomes, the coelom usually forms by a splitting of the mesoderm. This process is called schizocoelous.

In dueterostomes, the coelom is usually formed by an outpouching of the cavity of the embryonic gut. This process is called enterocoelous and is thought to have come from the schizocoelous process several times in the course of animal evolution.

G. PHYLUM ANNELIDA: SEGMENTED WORMS

Annelids are bilateral protosomes. These organisms are divided into body segments called metameres. These are separated by septa on the inside. Annelids have a segmented coelom, tubular gut, closed circulatory system, paired nephridia for the excretory system, and a centralized nervous system with specialized sensory cells.

There are three classes of Annelids.

1) Class Oligochaeta: Earthworms

The earthworm body is compartmentalized into regular segments. Most of the segments are identical. Each identical segment contains two nephridia, three pairs of nerves branching off from the central nerve chord, a portion of the digestive tract, a left and right coelomic cavity, and four pairs of bristles (setae). There are also segments that contain specialized areas of the nervous, circulatory and reproductive systems.

a. Digestive System

Mouth, pharynx (suction pump), esophagus, crop (stores food), gizzard (for grinding the food), intestine (with enzyme secreting cells and ciliated epithelial cells), and the anus.

b. Reproduction

Hermaphroditic. Mating partners join at the clitellum and exchange sperm. The sperm that is given is stored in seminal vesicles, while the sperm from the other partner is stored in the seminal receptacles.

c. Closed Circulatory System

The blood is enclosed in vessels. There is a dorsal and ventral blood vessel that is connected by five pairs of aortic arches (hearts) lying over the esophagus. The worms' movement causes the arches to 'pump' the blood.

d. Nervous System
There are two large ganglia (brains) over the pharynx connected to a ventral nerve chord. The nerve chord has a smaller ganglia in each segment.

e. Excretory System
This consists of a pair of nephridia per segment necessary to remove excess water and nitrogenous wastes. The nephridium is ciliated, collecting funnel in the coelom. There is a tubule leading to the nephiridial pore.

f. Locomotion
Setae are small lateral bristles (four per segment) that aid movement.

2) Class Polychaeta: Marine Worms
Unique features include lateral appendages (parapodia) per segment, separate genders, a free-swimming larva (trohophore), no clitellum, and a well0developed head with tentacles and eyes.

3) Class Hirudinea: Leeches
These are mostly found in fresh water in tropical regions and are mostly blood suckers. There is no head, except for a sucker around the mouth and cutting jaws. There are no setae or parapodia on segments. The leeches secrete hirudin which is an anticoagulant.

H. PHYLUM MOLLUSCA: SOFT-BODIED
These protosomes exhibit a bilateral symmetry, are unsegmented, and have a true coelom. Some of their unique features include a muscular foot, mantle, radula, and gills for breathing

1. Characteristics

a. Body Zones
1) *Head-Foot:* contains both the sensory and motor organs
2) *Visceral mass:* well developed organs of digestion, excretion, and reproduction
3) *Mantle:* specialized tissue formed from the folds of the dorsal body wall. The mantle hangs over and enfo0lds the visceral mass and secretes the shell.

b. Mantle Cavity
The mantle cavity is the space between the mantle and the visceral mass, it houses the gills. The digestive, excretory, and reproductive systems discharge into the mantle cavity. Water sweeps into the mantle cavity, passing across the surface of the gills, aerating them. Then leaves the mantle cavity carrying the excrement and gametes (in season) with it.

c. Radula
This is a movable, tooth bearing strip of chitinous material that suggests a tongue. The radula scraps food material and can be used in combat.

d. Hard Shell
The shell is made up of calcium carbonate.

e. Supply Systems

f. Circulatory Systems
These consist of a muscular pumping organ, the heart, and vessels that carry the blood to and from the heart. The heart has three chambers: two atria and one ventricle. Mollusks other than cephalopods have an open circulatory system, ie. The blood is not contained in vessels. The blood is collected from the gills, pumped through the heart, and released directly into spaces in the tissues. The blood then returns to the gills then to the heart. The blood-filled spaces are known as

the hemocoel. In mollusks, the hemacoel has almost completely replaced the coelom. The small area around the heart and cavities in the reproductive and excretor system are part of the coelom.

g. Respiration
Oxygen enters the body through the moist surfaces of the mantle and the gills. The gill is an external structure with an increased surface area where gas can diffuse.

h. Digestion
The digestive tract is extensively ciliated. Food is taken up by the cells lining the digestive glands which arise from the stomach and anterior intestine and enters the blood. Undigested material is discharged through the anus.

i. Excretion
Nitrogenous wastes produced by metabolic activities are removed by nephridia.

2) Class: Bivalvia (Clams, Mussels, Oysters)
The body is in a hinged shell which is secreted by the mantle. Adductor muscles close and open the shell. They have an open circulator system. There is no head or brain, but there are pairs of ganglia around the body. A radula is not present. Separate genders and the zygote develop into a trochophore larva, as in polychaetes.

3) Class Gastropoda (Univalves: Snails, Slugs, Abalones, Limpets, Nudibranchs)
The mantle secretes a shell. There is a well developed head with two pairs of tentacles. The first pair is for touch and the second pair has light-senstive eyes at tip. The radula scrapes food. The land snails breathe by using the mantle cavity, rich in blood vessels, as the lung. Some members are hermaphrodites (nudibranchs, sea hares, sea slugs, pteropods), but most have separate genders. Snails can host fluke parasites. The snails are asymmetrical due to torsion. Torsion is the twisting of a shell through 180° of the rest of the body relative to the head, resulting in the snail's mantle cavity and visceral mass moving to a position over the head.

4) Class: Cephalopoda (Octopus, Squid, and Nautilus)
The foot is divided into arms and /or tentacles with suckers. The nautilus has many tentacles, the octopus has eight and the squid has ten. The nautilus has an external an external shell, the squid an internal shell (pen) and the octopus no shell. Cephalopods move rapidly by jet propulsion of water from the siphon.

These organisms have a closed circulatory system with two types of hearts. The arterial heart pumps blood throughout the body and there are two gill hearts to receive blood from the body and pump it to the gills. Cephalopods have a well developed head and brain with organs for balance and an eye similar to ours. The mouth has a radula and a jawlike beak.

Unit Ten: vertebrates
5. Class: amphibia
there are 4,000 species of modern amphibians, represented by three orders:
a. Urodela
Salamanders
b. Anura
Frogs and toads
c. Apodia
Worm-like caecilians

Nearly all amphibians reproduce and develop in aquatic habitats. They have moist and highly vascularized skin. The skin is the most important organs of the repiratory exchange in spite of the presence of lungs in most. They have a

three chambered heart. Most frogs and toads are external fertilizers, but salamanders and caecilians are internal fertilizers. Most amphibians are oviparous with external fertilization. However, some are viviparous or ovovipaous.

6. Class: Reptilia
   there are 7000 species of reptiles which are represented by three important orders.
   a. **Chelonia**
      Turtles
   b. **Crocodilian**
      Crocodiles, alligators, and relatives
   c. **Quamata**
      Lizards and snakes

Reptiles are conceived, live and die on land. Since they are the first fully terrestrial group of vertebrates and therefore, have specialized organs for life on land. They female reptiles retained a cloaca, but the male has developed a penis for copulation and internal fertilization. The amniote egg is porous, leathery and complete with food and fluids(parts: yolk, allantois, chorion, and embryo).

Reptiles convert nitrogenous wastes to uric acid rather than ammonia. Ammonia is less toxic, but requires a large amount of water. The skin is dry with protective scales, reducing water loss. There are few mucous secreting glands. Most have a three and a half or four chambered heart, with 2 atria and a ventricle with a partial spetum. The crocodile has a complete spetum and a four chambered heart. Most reptiles are carnivorous. They locate food by sight, heat detecting, olfactory and hearing.

7. Class: Aves (birds)
There are 8,600 species of birds. They have a light skeleton with many hollow bones. The reptilian teeth have been replaced by a light horny beak, the neck is long and flexible, the bones of the trunk are fused together, and their breast bone is enlarged which acts as a large keel for the attachment of flight muscles. The birds tail is small, made only of four vertebrae, legs are adapted for perching and grasping. Feathers evolved from reptilian scales. The feathers are strong for their weight because of their interlocking barbs. Birds have a complicated respiratory system and lack a urinary bladder; both solid waste and liquid waste are added together. The female has only one ovary to produce eggs. Birds have a four chambered heart.

8. Class: Mammalia (mammals)
Mammals are fury or hairy animals that produce milk. There are three groups of mammals: montremes(egg laying), marsupials (pouched animals), and placentals.

Mammals use a muscular diaphragm to move air. They have a four chambered and lungs fertilization and development is usually internal(except for montremes). Females have separate urinary and reproductive tracts. Mammals may have specialized teeth. Milk is modified sweat which provides the young with high protein, high coloric nutrients.

II. Skeleton
E.   **A.Introduction**
The earth presents animals with two problems:
   1. It is quite different from place to place. Some areas are suitable for living and other places are not.
   2. The earth has gravity. Animals with a stiff skeletal system can resist the downward pull. Structures are often movable and serve as places of attachment for muscles that help animals move from place to place.

F.   **B. Types of Skeleton systems**
   1. **Hydrostatic skeleton**
      Fluid is held under pressure in a closed body compartment seen in coelenterates, flatworms, nematodes and annelids. The animals control movement by changing the shape of the body compartment with muscles.
   2. **Exoskeleton**

Hard encasement deposited on the surface of an animal. Mollusks have a shell secreted by the mantle. Arthropods have a jointed exoskeleton secreted by the epidermis. About 30-50% of the cuticle is made of chitin. Some arthropods add calcium salts to the chitin.
3. **Endoskeleton**
   Hard support elements, the bones, are buried within the soft tissue of an animal, ie. Echinoderms have a hard plate beneath the skin while vertebrates have an articulated endoskeleton.

C. Vertebrate Endoskeleton
Most vertebrates are made up of bones, except for some cartilaginous fishes, and have a bony endoskeleton with some cartilaginous structures.

1. **Functions of vertebral skeletons**
   a. Support
   b. Allows for movement via joints
   c. Forms blood cells through bone marrow
   d. Protect organs
   e. Detoxifies certain poisons which are removed from parts of the body and brought to the bones
   f. Allows for certain places for muscle attachment
   g. stores minerals

We will use the human skeleton as a representative vertebrate endoskeleton. The skeleton is divided into two components.
   Axial: skull, vertebral column, and bones of thorax
   Appendicular: limbs, pectoral, and pelvic girdles.
2. **Joints**

D. Structure of a Bone
1. **Bone parts**
   a. **Epiphysis**
      The end of the bone. Often it is covered with smooth hyaline cartilage
   b. **Diaphysis**
      The shaft of the bone that is covered with the perichondrium
   c. **Perichondrium**
      The vascularized, fibrous outer covering of the bone which provides the bone with blood vessels
   d. **Endosteum**
      The compact boe of the diaphysis
   e. **Medullary canal**
      The inner canal of the bone. This canal contains the bone marrow and the yellow marrow. The yellow marrow is the storage area for fat
2. **Bone development**
   In vertebrates, the hyaline cartilage is the forerunner of the long bones.

   a. early in fetal development, the membranous perichondrium grows around the   cartilage,
   b. The cartilage forming cells, deep in the center of the dense cartilage bed, increase in size After the cell enlargement they die and disintegrate which leaves behing the cavities of that the cells have created. Bone will form in the cavities.
   c. The first bone will start to form. This is called the primary ossification.
   d. The blood vessels from the perichondrium invade the cartilage bed. The blood first carries calcium salts and osteoblasts, the bone building cells.
   e. Osteoblasts use the calcium to form a thin bony wall surrounding open pockets of spongy bone. This lies in the center of the cartilage bed.
   f. The walls between the spaces in the center of the bed suddenly break down. This leaves a large space for the bone marrow.
   g. On the outside of the cartilage. Cells from the perichondrium lay down a collar of bone around the model. This bone is not thin, but dense and compact. As the bone accumulates, the bone gets wider. Bones lengthen at the two newborn forming centers at either end- the epiphysial plates.

        h. These plates yield to bone forming cells on either side of each plate they lay down material to make the bone gow longer, a process which stops at 18-24 years of age.

   3. Ossification continues
      The bone cells become entombed in the small hardened cavities and enter a quiet like state. They can communicate with each other through a series of capillary canals. There are web like structures called the Haversian system. This is the unit of bone. Each consists of a Haversian Canal, which contains blood vessels, surrounded by a concentric ring called the Lamellae of calcified bone. Within each ray are obsteoblasts eac cell had a minute cavity called a lacuna. Between bone cells are little canals called Canaluculi which connect with the Haversian Canals. Bone cells exchange materials by way of circulating the materials through Canaliculi. If the bone is broken, osteoblasts in the periosteum produce bone. The calcium for bone formation comes from the blood. Calium is also necessary for muscle contraction.

III. Muscular System
      Bones cannot move without muscles. Cell contraction is the changing of the
Shape of the cell. If a cell contracts in one direction, it lengthens in another direction. Some cells are designed to contract, these are muscle cells, which are found in most animals. These types of movements rely on biochemical systes involving tubulin and microtubules. Another basic cell movement depends on the protein actin found in the eukaryotic system. Actin fibers cause movement in the cytoskeleton and cell mambrane, using energy which comes from ATP.

A. Muscle groups
   There are three types of muscles
     1. Smooth muscles
       Smooth, glistening in appearance, also called involuntary muscle. Found in various internal organs such as in the walls of blood vessels and the digestive tract.
     2. Cardiac Muscle or Heart Muscle
       Has control centers of its own
     3. Skeletal Muscle
       Striated or voluntary muscle. These muscles are controlled by the somatic nervous system. They can contract much more rapidly than smooth muscle or cardiac muscle, but they cant stay contracted for long periods. Skeletal muscles are multinucleated; the nuclei lay just beneath the cell surface.

B. Muscle Anatomy
      Each muscle fiber contains a precise arrangement of protein. A whole bunch of these fibers is called a fasciculi and gives meat its stringy appearance. Blood vessels run throughout the fasciculi supplying oxygen and nutrients while getting rid of wastes and carbon dioxide. Nerves also penetrate the bundles and divide so that each fiber has a nerve. The whole mass of aligned fasciculi is the belly of the muscle. The belly is enclosed by fascia. At the end of the muscles the fascia unites to from a collagenous tissue called a tendon which fastens the muscle to the bones. When muscles contract, one end moves and one does not move much. Bones are returned to their original position by opposing actions.

In a hydrostatic skeleton, the body returns to its original position with incoming fluids.

C. Muscle Anatomy
  1.Antagonistic Muscles
     Two opposing muscle groups are called antagonistic muscles.

        a. Flexor: Biceps brachii
         Originates at two points, inserts on the radius
        b. Antagonist
         Lies on the back of the arm. It originates at three places, two on the humerus and one on the scapula

D. Muscle Fiber
  1.Each muscle fiber is surrounded by a cell membrane, sarcolemma

3. the sarcolemma receives the endings of the motor neurons at the neuromuscular junction.
4. Motor neurons send impulses from the central nervous system to muscle which causes the muscles to contract
5. Just below the sarcolemma there are a number of mitochondria, nuclei, and glycogen granules, a sarcoplasmic reticulum and T-tubules which spread the action potential ot the sarcoplasmic reticulum
6. Below these structures are rod shaped myofibrils.

Lets look at one myofibril: we see banding which is called a Z line. Between the Z lines there is the contractile unit called the sarcomere.

Toward the center is a broad region called the A band with a smaller lighter region called the H zone. The A band is made up of overlapping myofilaments. Myofilaments are filamentous protein structures of actin and myosin. The dark lines extending across the A band and running through the H zone are myosin filaments. The myosin filaments are overlapped by actin filaments which begin at the Z line and run part way through the A band. The I bands consist of actin filaments alone.

E. Muscle Contraction

When the muscle fiber is stimulated, the Z lines move together and the sarcomere is shortened. The banding changes producing a dark line where the H zone was. Actin myofilaments slide inward through the myosin. The I bands become reduced

1. **How will this happen?**
   Myosin consists of a fibrous "tail" with a globular head. The tail s where the individual myosin molecules join to form a thicker filament. The myosin head binds to an ATP molecule which can me hydrolyzed to ADP and P. the energy released by the cleaving is transferred to the myosin and changes the shape of myosin to a high energy configuration. The high energy myosin binds to a specific site of actin and forms a cross-bridge. Once attached to actin, the stored energy is released, and the myosin head relaxes to its lower energy configuration. When it relaxes, it changes the angle of the attachment of the myosin head to the fibrous myosin tail. The myosin bends inward on itself and pulls the thin filament toward the center of the sarcomere. The bond between the lower energy myosin and actin is broken when a new molecule of ATP binds to the head. The process repeats itself.

   Each of the approximately 350 heads of the myosin filament join and rejoin about 5 cross bridges per second.

   A muscle stores enough ATP for a few contractions. Although muscles store glycogen between the myofibrils, most of the energy needed for repetitive muscle contraction is stored in phosphagens. These substances can supply a phosphate group to make ATP from ADP. When at rest, the myosin binding sites on the actin molecules are blocked by topomyosin, a regulatory protein. The troponin complex, another set of regulatory proteins, positions the tropomyosin on the actin filaments.

   For a muscle cell to contract, the myosin-binding sites on the actin must be exposed. Calcium ions bind to the troponin complex which changes the shape of the complex. This changes the interaction between the troponin complex and tropomyosin. This change exposes the myosin binding sites on the actin. The membrane of the sarcoplasmic reticulum actively transports calcium from the cytoplasm into the interior of the reticulum, which is and intracellular storehouse for calcium.

2. **Steps for muscle contraction**
   a. An impulse moves down the nerve cell and through the motor neuron.
   b. The motor neuron stimulates the sarcolemma. The action potential spreads deep into the interior of the muscle cell along the infoldings of the tubules.
   c. The sarcolemma stimulates the sarcoplasmic reticulum which then releases calcium.
   d. The calcium floods the sarcomere and binds to the troponin complex. The interaction between the troponin and tropomyosin is affected. The myosin binding sites on the actin are now exposed.

e. ATP on the myosin head hydrolyzes. The energy is transferred to the myosin and changes the shape of the molecule. The energized myosin binds to a specific site on the actin and forms a cross bridge
f. The energy stored in myosin is released. Myosin relaxes to the lower energy shape. As it relaxes, the myosin bends on itself, pulling the actin filament towards the center of the sarcomere. The cross-bridge between the actin and myosin is now broken.
g. A new ATP molecule binds to the myosin head.
h. This continues until the muscle has contracted
i. The muscle returns back to its original position, when the antagonistic muscle contracts.

Rigor Mortis occurs when there is no more ATP available, and the calcium is not removed from the sarcomere. The muscle stays contracted. Rigor Mortis ends because bacteria have begun to break down the muscle filaments.

3. **Fast and slow muscles**
    Fast and slow muscles differ in the duration of twitches.
    Slow fibers have less sarcoplasmic reticula than fast fibers. Calium remains in the cytoplasm longer. The twictch lasts up to 5 times longer than the fast fiber.

    Slow twitch fibers have many mitochondria, a rich blood supply, and myoglobin(an oxygen storing protein). Myoglobin is a brownish red pigment which binds oxygen more tightly than hemoglobin. Myoglobin is found in the dark meat of poultry and fish.

4. **Osteoporosis and muscle contraction**
    Postmenopausal women do not easily absorb dietary calcium, but they need calcium for muscle contractions. The calcium is removed from the bones. Bones become brittle over time and break easily. Females need to increase calcium intake when young to prevent osteoporosis.

IV. Digestive System
Digestion is the breakdown of complex food molecules into smaller components that are used by the organism. This may occur outside of the organism as in bacteria and fungi, or the organism may have extracellular digestion. Most organisms take food into cells.

Digestion is a series of chemical reactions that use hydrolytic enzymes. The chemical digestion can be preceeded by mechanical fragmentation of food into smaller pieces. Breaking down the food mechanically increases the surface area of the food and makes the digestive enzymes more effective. Once the food is digested the organic molecules can cross the plasma and enter cells. The undigested materials are defecated.

A. **Definitions**
    1.Holotrophs
    organisms that ingest other organisms, dead or alive, whole or by the piece, or absorb organic molecules directly.
    2. Herbivores
    organisms that eat plants or algae
3. **Carnivores**
    Organisms that ingest other animals
4. **Omnivores**
    Organisms that ingest both plant/algae and animals
5. **Suspension feeders**
    Organisms that sift small food particles from the water
6. **Substrate feeders**
    Organisms that live in or on the food source
7. **Fluid Feeders**
    Organisms that suck nutrient rich fluids of the living host
8. **Bulk Feeders**
    Organisms that ingest relatively large pieces of food.

B.Comparative Digestion
   The simplest compartment for digestion is a food vacuole. These can digest food without the enzymes mixing with the cytoplasm. Protists take food in through endocytosis and then perform the intracellular digestion.

Sponge: Food particles enter the choanocytes via phagocytosis. Digestion occurs in food vacuoles. The food vacuoles are transferred to amoebocytes which distribute the food to other cells.

Gastrovascular Cavities are digestive sas with a single opening. This cavity functions in both digestion and distribution of nutrients through the body. For example, hydra catches food using cnidocytes on the tentacles, ad then stuff food into a mouth. In the gastrovascular cavity specialized cells produce digestive enzymes that break the food down, flagellated cells spread the food particles in th cavity, and particles are taken into cells by phagocytosis. Planarians also have a gastrovascular cavity with one opening. An alimentary canal is a tube with two openings: mouth and anus. Parts of the tube are specialized, ie. Some parts digest the good and other parts absorb the food. In earthworms, food is taken in by the mouth and pharynx, passes to the esopogus, the crop, the gizzard, the intestine, on to the anus. This is similar to the foraging and digestive structures of fish, amphibians, reptiles and birds.

B.Foraging and Digestive Structures in Mammals
   Teeth grow in sockets in the jaw. Usually mammals begin with temporary milk teeth that are replaced by the adult teeth. There are 4 types of teeth in mammals.

   1. **Incisor**
       Chisel shaped for cutting
   2. **Canines**
       Tearing food and defense
   3. **Premolars**
       Ginding food
   4. **Molars**
       Grinding food. In herbivores molars are large and flat.
   Humans have teeth that are not specialized for any particular type of diet.

   D. Human digestive system is a good representative of the Mammalian system

1.Oral cavity
           the lips are essential in eating.
           a. Close lips to swallow
           b. Help food keep inside the mouth
2. Tongue
           a. Moves food into position for chewing
           b. Tells us when our food can be swallowed
           c. Prevents us from swallowing
           d. Contains chemoreceptors which can distinguish 4 different types of taste: salt, sour, and bitter. These receptors are in a specific concentration on specific sites of the tongue. The stimulation of the taste buds can also enhance saliva flow.

3.Three pairs of Salivary Glands
           a. **Parotids**
               Located in the front and below the ears at the angle of the jaw.
           b. **Submaxillaries**
               Found below the angle of the jaw
           c. **Sublinguals**
               Found below the tongue.
               Saliva: 95% water, ions, lubricating mucus, and starch splitting enzyme amylase which starts digestion and digests the starch caught between the teeth. Dissolved in the saliva is a slippery glycoprotein called mucin. Mucin protects the mouth from abrasions and lubricates the food. Saliva also contains buffers, which help prevent dental cavities by neutralizing acid in the mouth, and antibacterial agents.

4. Pharynx

Near the rear of the oral cavity and forms a common passageway to the naval cavity. Below the tongue the pharynx divides into the larynx and laryngopharynx. When you swallow the top of the larynx moves so that the air passageway is blocked by a cartilaginous flap called epiglottis. This ensures that the bolus stays out of the respiratory system.

5. Esophogus

Moistens the food and mves it to the stomach and is made up of smooth muscle.
The esophagus serves two functions
      a. Secretes mucus into the lumen and cavity of the digestive tract.
      b. Moves food along- compressing food inta a bolus-muscles contract behind the food and push it along.

6. Stomach

Located on the left side of the abdominal cavity just below the diaphragm. This temporarily stores and helps digest the food.

    a. food in the stomach
      the stomach stretches easily and any reistance to the stretching will cause cramps. The stomach is closed off at either end by wo sphincters. The pyloric sphincter which is the bottom sphincter that opens to the small intestine. The cardiac sphincter is the top that opnes up into the esophagus. Food is churned without being pushed into the esophagus or intestine. Ulcers occur when the digestive system digests its own stomach or small intestine. The vomit center in the brain allows for the cardiac sphincter to relax, the pyloric sphincter to tighten, and the stomach to contract.

      A complex layering of muscles allows for the twisting action and wringing and shortening of the stomach that grinds up the food.
      After being ground up, the pyloric sphincter relaxes a bit and the food enters the small intestine.

      About every 20 seconds the stomach contents are mixe by the churning of the smooth muscles. When the stomach is empty, the stomach churns and hunger pangs are felt. After food and gastric juices mix, acid chyme is produced. The pyloric sphincter opens and squirts some chyme into the small intestine. It takes 2-6 hours for the stomach to empty after a meal.

    b. Chemistry of the stomach
      The stomach is lined mucosa, mucus secreting tissue, the tubular glands, which secrete gastric juices. Chief cells secrete hydrochloric acid which activates pepsinogen to be converted to pepsin. Pepsin hydrolyzes proteins and works well in the low ph generated by the HCL. Other glands secrete water mucus, and rennin, which digests milk and gastric lipases. A low ph in the stomach, kills bacteria.

      Gastric secretions are controlled by the nervous system and hormones. When we see and smell foods, the brain stimulates the stomach to secrete gastric juices. Certain substances will cause the stomach wall to realease a hormone called gastrin. Gastrin travels through the circulatory system to the stomach, causing the stomach to secrete more gastric juices.

   7. **Small Intestine**
     Food in liquid form enters the small intestine. The small intestine is about 20 feet long and is broken up into three regions, duodenum, jejunum, and ileum. It is lined with mucin and adapted for absorption of food through a highly molded inner surface. Each fold is called a villus.

    a.Functions
         1) Chemical digestion
         2) Absorption
    b. Enzyme Producing Organs
      These secrete the enzymes into the small intestine.
         1) *Liver:* The liver secretes bile into the duodenum. Bile is a fat emulsifier. Bile is stored in the gall bladder and reached the duodenum of the small intestine via the bile duct. Where it is joined by basic fluids from the pancreatic duct. Bile reduces the size of fat globules so

lipases, enzymes that break down lipids, can break them down. If the bile duct is blocked, one becomes jaundiced because bile ends up in the blood stream.

2) *Pancreas:* The pancreas is a glandular organ that lies in the first turn of the small intestine. The pancreas secretes bicarbonate which neutralized acid. The pancreas also secretes enzymes that brea down carbohydrates, proteins, fats, and nucleic acid. These enzymes from the pancreas carry out much of the digestive process. The acid of the chyme activates the stomach to produce secretin, a hormone that stimulates the pancreas to release bicarbonate.

The digestion of starch, begun in the mouth, is continued in the small intestine by the addition of pancreatic amylase, which hydrolyzes starch into the disaccharide maltose. Maltase will break down maltose into glucose monomers.

Proteins are broken down by trypsin and chymotrypsin. These break down the polypeptides into the smaller polypeptides. Carboxypeptidases split one amino acid at a time off the carboxyl end while the aminopeptidases work in the opposite direction. These enzymes are secreted by the pancreas as inactive zymogens. Enterokinase activates zymogens in the small intestine.

Nucleases hydrolyze DNA and RNA

All this occurs in the duodenum of the small intestine. The two remaining regions are specialized for absorption.

c. Absorption in the Small Intestine
Each villus is covered with epithelial cells that contain microvilli. These projections increase the surface area of the small intestine. Within each villus is a capillary bed and a lacteal. The nutrients enter directly into the blood stream from the small intestine.

The small intestine is capable of vigorous movement which mizes food and enzymes together. This movement also helps with absorption.

Nutrients are absorbed across the epithelial layer into the capillaries or lacteals. Sometimes the transport is passive while other times it is active. Amino acids, vitamins, glucose, are pumped against the gradient by the epithelial membranes. The absorption of some nutrients appears to be soupled with the active transport of sodium across the membrane. The sodium is actively transported out of the cell, nutrients are co-transported.

8. **Large Intestine**
The small intestine joins the large intestine on the right side of the body. Here, the cecum forms a pouch which ha a finger like projection called the appendix. There is a one way valve at the junction of the large and small intestine called the ileocecal valve which insures that there is no backflow into the small intestine.

The large intestine consists of several parts: cecum, ascending colon, transeverse colon, descending colon, sigmoid colon, rectum, anal canal, and anus. The fun tions of the large intestine include the absorption of water and minerals into the blood, preparation of feces, and the housing of bacteria which produce vitamin K, biotin, folic acid, and methane. Approximately 2/3 of fecal matter is dead bacteria. The large intestine secretes mucus to lubricate for easier export. The rectal valves support the feces until defecation. The wastes go through the anal sphincter, under voluntary control and out the anus. It takes 12-24 hours for material to travel the length of the large intestine.

E. Digestion in Herbivores: Ruminants
These organisms must digest cellulose. However, mammals don't produce the necessary enzymes. In order to digest the cellulose, mammals must have large flat teeth for grinding cellulose. Cellulose must be broken down to release plant nutrients. Once broken down the food goes through the esophagus to a four chambered stomach of such

ruminant herbivores such as cattle, deer, giraffes, antelopes, and buffalo. The stomachs harbor protozoans and bacteria that break down cellulose.

F. Chemistry of Digestion

Chemical digestion and absorption: Carbohydrates are broken down into simple sugars. Fats are broken down into fatty acids and glycerol. DNA and RNA are broken down into free nucleotides. Proteins are broken down into various amino acids.

1. **Carbohydrate digestion**

   Starch digestion begins in the mouth with amylase that is found in the salivea. The breakdown of carbohyrdrates is stalled in the stomach because the acidity and resumes in the small intestine where amylase from the pancreas converts all starch into maltose. Maltose is broken down by maltase into glucose which is absorbed. Sucrose, which is glucose and fructose, is broken down by sucrase. Lactose, milk sugar, is broken down in the gut by lactase. Lactase is absent in most blacks and Asians and in some whites preventing them from breaking down lactose.

2. **Fat digestion**

   Fats reach the small intestine with little chemical change. Even though the stomach secretes a lipase. Bile separates fats into tiny droplets that are broken down further by lipases into fatty acids and glycerol. These cross the membrane and reform in the villi. Longer chans of fatty acids, more than 12 carbons, enter the lymphatic vessels of the villi. Fatty acids with fewer than 12 carbons go into the capillaries and are carried to the liver. The ones in the lymph system follow the lymphatic system to the thoracic duct near the heart and enter the blood stream. If there is too much fat in the blood after the meal, the blood will appear milky.

3. **Protein digestion**

   Proteins are the most complex food molecule and their digestion is complex. Pepsinogen, secreted by the chief cells is changed by hydrochloric acid into pepsin. Pepsin is a nonspecific endopeptidase and hydrolyzes proteins into smaller peptides. Specific enzymes will break pepitides down further until individual amino acids are left. These amino acids are absorbed into the blood stream and sent to the liver. In the liver, the amino acids are used for eneg and to build proteins.

4. **Nucleic Acids**

   Almost everything we eat contains some nucleic acids. Nucleases produced in the pancreas break nucleic acid bonds. They break down the nucleic acids into small units of either single bases or small chains.

G. Integration and Control of the Digestive Process

The realease of digestive enzymes must be precisely timed. They are controlled mechanically, neurally, and hormonally.

For example, the thought of chocolate stimulates saliva flow. The saliva flow can also be stimulated by chewing. Neural and mechanial stimulants can stimulate saliva flow. Gastric secretions can be stimulated by the presence of food. The neural message is sent along the vagus nerve from the brain to th stomach lining. Food in the stomach stimulates sensory neurons in the stomach and a hormone gastrin is released from stomach to the blood.

H. Nutrition

1. **Carbohydrates**

   Carbohydrates are the most common source of energy used in cellular respiration. Blood glucose must remain constant. Glucose is stored in the muscles as glycogen and used for energy. If not used, carbohydrates are stored as fat.

2. **Fats**

   Unsaturated fats are necessary for cell membrane synthesis. Fats are sources of energy and insulators. Fats also serve as a source for vitamins A, D, E, and K

3. **Proteins**

Proteins can be stored in the liver and in musce tissue. There is a constant turnover of body protein. Amino acids can build proteins, form nitrogenous bases, can be oxidized for energy, and can be converted into fats and carbohydrates. When amino acids are used, they leave behind a nitrogenous waste which is poisonous and must be removed. Humans can produce 12 of the 20 amino acids. There are 8 amino acids that humans must obtain from food. Brain development requires proteins.

4. **Vitamins and Minerals**
Vitamins: function in common enzymatic reactions as co-enzymes. There are two types of vitamins: fat soluble and water soluble

5. **Mineral**
Simple inorganic ions. They may be used in the formation of gross structures, such as bones or may become an active part of functional molecules. Some are necessary for enymatic actions.

I. Food as Fuel
The energy content of food is measured in calories
The energy content of:
    Fat=9 kcal/ 1 gram
    Protein= 4 kcal/1 gram
    Carbohydrates= 4 kcal/1 gram
Several processes must occur continually in higher anmals alive, for example, breathing and heart beating. The number of kcal a resting animal needs at a given time is called a basal metabolism rate, or BMR

V. Respirtation
A. **Introduction**
Exchange of carbon dioxide and oxygen between an animal and the environment.

1. Animals
    a. require a continuos supple of oxygen for aerobic respiration
    b. must expel carbon dioxide
    c. must have a wet respiratory surface

the exchange of gases requires structures with two basic charchteristics
    1. Permeable surface area of sufficient size
    2. moist surface area since gases cant normally cross dry membranes

B. **Gas exchange Comparisons**
    1. **Protists**
    Gases are exchanged by diffusion
    2. **Sponges to annelids**
    Gases are exchanged by diffusion
    3. **Mollusks and enchinoderms**
    Gases are exchanged through gills
    4. **Arthropoda**
    Gases are exchanged through trachea, book lungs, or gills

Some organisms, for example, earthworms and frogs, use their entire outer skin as the respiratory organ. The skin needs to be moist, so they live in water or in damp places.

C. **Gills**
Other organisms use a localized region of the body that is golded or branched, which enlarges the area of the respiratory surface for gas exchange. The expanded respiratory surface for aquatic animals, external and bathed, are gills. A detterent in having water as a respiratory medium is that the concentration of oxygen in the water is lower than in the air; the dissolved oxygen concentratin in water is about .4% compared to about 20% in air. The warmer and saltier the water, the less dissolved oxygen it holds. Gills must be efficient in obtaining oxygen from the water. A process helps is ventilation, increased flow of the respirtory medium

over the respiratory surface. Lobsters and crayfish use tiny appendages to beat a current of water over the gills. If ventilation didn't ovvur, water around the gills would stagnate and become quickly depleted of oxygen.

The arrangement of capillaries in the gills increases gas exchange. Blood flows opposite to the direction in which water passes over the gills, a countercurrent exchange. With countercurrent exchange, gills can remove 80% if the oxygen in the water. Gill baskets are found in tunicates and lancelets. Tunicates hava na open circulatory system; their blood lacks hemoglobin. Gill baskets are highly branched structures with enormous surface area, but they probably don't fuction in gas exchange. Instead they may strain sea water. Fish have a combination of respiratory and circulatory system. There is a thin walled, finely divided out-pocketing with extensive capillary beds through which blood flows, bringing carbon dioxide and carrying oxygen away. These structures are gills.

Gills in Fishes: In fish, gills have a solely respiratory function. There are five pairs of gills found on most fish. Gills are rows of fingers like rods from which feather filaments arise either side. Each supporting rod hoiuses an artery that sends capillaries into each filament. Oxygen and carbon dioxide can pass across the walls of the capillaries easily. Oxygenated blood passes back to the supporting rod and joins to form a dorsal aorta which branches off to the body for distribution.

  Gills are composed if rows of supportive gills arches along with blood vessels and
Gill filaments form these arches. Gill rakers are stiff fingers-like protrusions from gill arches. These keep swallowed foood from passing over the gills. All active aquatic animals must keep water flowing constantly over the respiratory surfaces. Sharks swim constantly with their mouths open for the most part. Fish keep water moving by moving mouth muscles. Gills are closed off to the outside by the opeculum. The fish closes its mouth and swallows, the operculum opens and closes the watere flows out over its gills.

D.   Trachea: Insects
Air is a different medium than water. There is an increase in oxygen and carbon dioxide concentration, and oxygen diffuses much quicker than in water. The respiratory surface, which must be large and moist, always loses water through evaporation. A solution to this problem is to have a respiratory surface that has many folds in the interior of the body.

Trachea are tiny air tubes throughout the insect's body. The tiniest tubules extend to almost every cell, where the gas is exchanged by diffusion across a moist membrane. The opening into the trachea is a spiracle. Air can enter the trachea through diffusion or rhythmic body movements.

E.   Lungs: Adaptations for Terrestrial Vertebrates
Lungs are folded within the body and are restricted to one location. Since they are centrally located, a circulatory system must carry oxygen to all cells. Lungs contain a dense net of capillaries. Lungs consist of an inpocketing, branching tube that ends in a multitude of tiny air sacs called alveoli, where the blood and the air are separated by a thin moist membrane. By muscular control of its breathing apparatus and valves of its mouth and pharynx, an animal can control the amount of air that passes through the lungs.

1. **First Lungs: Amphibians**
Nearly all have lungs and exchange gases in two ways: through bag like lungs and through their moist, highly vascularized skin. These animals represent the transition from aquatic to terrestrial animals. The larval froms of amphibians breathe with gills, which are strictly aquatic structures. A metamorphosis occurs, the lungs expand, and gills are absorbed into their bodies. The adult amphibians then use the lungs and skin to obtain oxygen.

2. **Reptiles**
The reptile skin is impervious to air, so reptiles are strictly lung breathers. The trachea is subdivided into smaller passages that enter numerous membranous compartments. This increase the surface area of gas exchange membrane. The breathing movements fo pertiles occurs when the muscles around the entire body cavity contract and relax.

3. **Birds**
A one way, countercurrent circulation of air occurs in the lung. There is not much mixing of old air and new air. Birds breathe through mouth and nostrils but incoming and out going air are

separated within the respiratory cavity. The repiratory system is the most complex of all vertebrates. Inhaled air passes in wide bronchi through the lungs and into air sacs, which can be surrounded by gonads, and into the cavities of some bones. When the bird is not flying, muscles on the thorax and abdomen respire for breathing movements. In flight, the rapide beating of wings is all that is required for air movements.

F. Anatomy of the Human Respiratory System
The human respiratory system is typical of all mammals.

1. Air Flow
The air first passes through the nasal passages, important for filtering, warming, and moistening the air before it enters the lungs. The nostril hairs act as initial filters. The nasal cavity is lined with a mucous membrane. This thin layer of mucus is constantly being swept downwards towards the throat by ciliary action. The nose contrains many capillary bed s which warm the air before it enter the lungs. The nasal cavity is separated from the mouth by a hard plate, which is a bony shelf at the roof of the mouth that ends in a soft muscular region called the soft palate. The air moves from the nasal passages to the pharynx to the larynx and into the trachea. The laryngeal opening contains the vocal mechanisms. Below it is the trachea. The trachea is a tube that is composed of C shaped rings of stiff hyaline cartilage that holds the passage open. The trachea branches into the right and left primary bronchi in the chest. The bronchi branch again into bronchioles to from the respiratory tree. The trachea and other bronchiole structures have a lining similar to that of the nasal passages. The air is thus cleared of dust and debris.

2. Human Lung
Bronchioles are the smallest branches of the respiratory and end in grape-like clusters of air spaces called aveoli. Each of the alveolus is enclosed in a dense capillary bed. The atmosphere is only one membrane away from the blood. The alveoli provide an enormous surface area. The total surface area of the 300 million alveoli in our lungs is equal to 750 square feet, can could cover a tennis court. Lungs are in a triangular shape. The right lung has three lobes while the left lung ahs two lobes because of the space that the heart takes up. Two bag like membranes enclose the lungs. The inner pleura is attached to the spongy surface of the lung. The outer pleura froms the tough lining of the pleural cavity which houses the lungs. The pleural cavity is bounded by the muscular shelf, the diaphragm. Only mammals have diaphragms.

3. Gaseous Exchange and respiration Control
Breathing involves intercostals muscles and the diaphragm. The relaxed diaphragm protrudes into the pleural cavity. Inhalation is accomplished by contracting the diaphragm and contraction of the intercostals. The change increases the volume of the pleural cavity, creaeting a partial vacuum. The pressure of the atmosphere forces air down into the lungs, causing them in inflate. Exhalation is produced by the relaxation of the rib cage and diaphragm.
The volume or air an animal inhales and exhales with each breath is called a tidal volume. On average, humans have a tidal volume of 500 mL. The maximum volume of air that can be inhaled and exhaled during forced breathing is called vital capacity, in humans 4,000 to 5,000 mL. Lungs actually hold more air than their vital capacity. It is impossible to completely remove all air from the lungs. The air left behind is called the residual volume.

4. Partial Pressure
The amount of one particular gas in a system can be described in terms of partial pressure Air is about 21% oxygen. The partial pressure of oxygen at sea level is .21 atm and the partial pressure of carbon dioxide is .23 atm. The concept of partial pressure is important in understanding how gas is exchanged. Gases move form a region of higher partial pressure to a region of lower partial pressure. Blood arriving to the lungs has a lower P02 and a higher PCO2. The oxygen from the lungs diffuses into the blood and the carbon dioxide from the blood loosely diffuses into the lungs.

5. Exchange of Gases
The exchange takes place on the moist inner surfaces of the alveoli through simple diffusion because of differences in partial pressure. The blood enters the lung from the heart. There is low partial pressure of oxygen while the partial pressure of carbon dioxide is high. Some of the carbon dioxide is in the form of bicarbonate ions, some as dissolved carbon dioxide and some carbon dioxide loosely bound to hemoglobin.

The alveoli produce the enzyme carbonic anhydrase which converts the HCO3 to carbon dioxide. This conversion increases the partial pressure of carbon dioxide. The blood and air are in near contact on the opposite sides of the thin alveolar membrane. Near equilibrium occurs when molecules of oxygen go into the blood and carbon dioxide goes out. The equilibrated air is exhaled and fresh air is inhaled. The blood flow is continuous; oxygenated blood moves away from the lungs nd deoxygenated blood moves toward the lungs.

6. **Respiratory Pigments: Transportation of oxygen**
Oxygen is not very soluble in water. Most animals use respiratory pigments to carry oxygen. Respiratory pigments are proteins containing a metal atom. Hemoglobin, abbreviated Hb, is the pigment of most vertebrates. The protein contains iron which binds to the oxygen. Hemocyanin, which can be found in horse shoe crabs, has a copper atom. Hemoxyanin causes the blood to be blue and is dissolved in the plasma, not on the blood cell. Hemoglobin is highly specialized to associate and disassociate from oxygen. A molecule of hemoglobin contains four heme groups. Each heme group contains an iron atom. In hemoglobin there are four iron atoms in all. This allows the heme groups to bind reversibly to four molecules of oxygen. The binding of a oxygen to one subunit causes a slight shape

7. **Carbon dioxide**
Seven percent of the carbon dioxide released by cells is transported as carbon dioxide dissolved in plasma. Twenty three percent of the carbon dioxide binds to the amino groups of the amino groups of hemoglobin. The combination of carbon dioxide and Hb is called carbamino Hb.
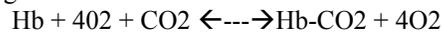
   Hb + 4O2 + CO2 $\longleftrightarrow$ Hb-CO2 + 4O2
   70% of the carbon dioxide is transported as bicarbonate ions.
   Enzyme: carbonic anhydrase
   CO2 + H2O $\longleftrightarrow$ H2CO3 $\longleftrightarrow$ HCO3 + H
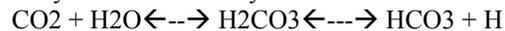
The release of H+ makes the blood more acidic. The higher the acidity affects the dissociation of Hb, inducing it to unload oxygen.
The control of respiration: The major respiration control centers are in the pons, a small sphere at the back of the brain which tapers into the spinal cord. The medulla also contains control centers. The best understood center is called the rhythmicity center which has two circuits of opposing neurons: one for inspiration and one for expiration. This coordination produces rhythm of breathing.

8. **Breathing Sequence**
   a. The inspiratory circuit activates muscles for inhalation and inhibits the expiratory circuit.
   b. The lungs fill, activating stretch receptors which fire the signal to inhibit inspiratory circuit which ceases to inhibit the expiratory circuit.
   c. The expiratory circuit activates, inhibiting the inspiration center and exhalation occurs.
   d. When the lungs are emptied, inhibition of the inspiration circuit ceases and the inspiration circuit activates.

Respiration centers respond to level of CO2 in the body. The body also responds to an increase in acidity level created when the CO2 forms H2CO3 which dissociates.

9. **Hyperventilation**
The oxygen sensor is the carotid body which is a group of nerves in the carotid artery (in the neck). This carotid body monitors the partial pressure of oxygen moving toward the brain. If there is too much oxygen, the carotid body constricts the carotid artery which constricts the amout of oxygen to the brain. When one hyperventilates, the mechanism overreacts to the high level of oxygen in the body. The carotid body constricts the carotid artery so much that the brain is starved of oxygen and one passes out.

VI. Circulation
A. Comparative Circulatory systems
1. **Gastrovascular Cavities**
A sac like body consisting of a body two cells thick encloses a central gastrovascular cavity. The cavity serves two functions-digestion and distribution of substances. The fluid inside the cavity is continuous with the water outside through a single opening, so both inner and outer layers of tissues are bathed in fluid. Some organisms have their body cavities lined with flagellated cells that stir and distribute the food.

2. **Open circulatory system**
In an open circulatory system the blood is free to percolate directly through the tissue. There are no blood vessels. The general fluid is called hemolymph. The exchange of material between the fluid and body cells occurs as the hemolymph oozes through sinuses, the spaces surrounding the organs. Hemolymph is circulated by body movements that squeeze the sinuses and by the contraction of the heart and dorsal vessel. The heart pumps the hemolymph through the vessels which opens into a series of interconnected system of sinuses. Arthropods and most mollusks have such systems.

3. **Closed circulatory System**
In a closed circulatory system the blood is enclosed within blood vessels. Annelids and squids have closed circulatory systems.

B. **Circulation in vertebrates**
All verterbrates have a closed circulatory with an efficient and centrally located heart

1. **Atrium**
Thin walled heart chamber that empties into the ventrilcle
2. **Ventricle**
Thick walled heart chamber that pumps blood from the heart into the arteries.
3. **Artieries**
Round and thick walled with smooth muscles and connective tissue. Arteries carry blood away from the heart. The largest artery is the aorta.
4. **Arterioles**
Small arteries
5. **Capillaries**
Thin walled vessels that branch from the arterioles. Capillarie are te functional units of the circulatory system. Capillaries are the areas of exchange, can be selectively opened, and increase internal temperature of the surface when hot. In the body, the main artery branches into arterioles which divide into a greater number of capillary beds. It is in these capillary beds, which are only one cell thick, that oxygen, carbon dioxide, nutrients, and wastes are exchanged. Capillaries join to form vennules which join into veins and enter the heart.
6. **Vennules**
Receive the blood from the capillaries. The blood then flows into larger veins and back to the heart.
7. **Veins**
Thin walled and flattened. They lie near the surface of the skin and carry the blood back to the heart. Veins in mammals have a one way valve that prevents back flow.

C. **Circulation in Fish**
Most fish have a two chambered

Pg. 157
Red blood cells lack nuclei when mature. They also lack mitochondria and
Generate ATP anaerobically. Each red blood cell contains 250 million
Molecules of hemoglobin.

Erythrocytes are formed in the red marrow of the bones- ribs, vertebrate, breastbone, and pelvis. Within the bone marrow are pluripotentstem cells that can divide into any type of blood cell. If tissues are not receiving enough

oxygen, the kidney secretes a hormone cally erythropoietein which stimulates production of erythrocytes in the bone marrow. If tissues have too much oxygen erythropoietein is reduced, and erthrocyte production slows.

d.White blood cells or Leukocytes
   There are 5 types of white blood cells, monocytes, neutrophils, basophils, eosinophils, and lymphocytes. Monocytes and neutrophils fight infections through phagocytosis. Lymphocytes give rise to cells that produce antibodies. Leukocytes in the blood are in transit to sites of infection. All of these are produced by the stem cells. Lymphocytes mature after leaving the marrow in the spleen, thymus, tonsils, adenoids, and lymph nodes.

e.Platelets
   These are numerous tiny structures which lack nuclei, are cell fragments, and are active in blood clotting. Clots can form anywhere. If a clot occurs inside the blood vessels it is termed atherosclerosis. Hidden clots can break of and clog arteries which in turn can cause heart attacks and strokes.

f.Clotting
   Prothrombin and fibrinogen are required
   1. A blood vessel is damaged
   2. Platelets and damaged cells release thromboplastin, an enzyme.
   3. Prothrombin + Thromboplastin + Calcium--→ thrombin
   4. Thrombin + Fibrinogen--→ Fibrin
   5. Fibrin along with cofactors and damaged platelets forma network that solidifies becoming a clot and stopping the bleeding.
   6. The clot contracts pulling the wound together. This prevents bleedin and encourages healing

12. Lymphatic system: the second circulatory system
      the lymphatic system drains tissue spaces and cavities of fluid that has leaked out of the capillaries because of the high hydrostatic pressure and returns fluids t the blood stream through ducts which enter the sublavian vein. It is a system consisting of a large number of nodes and thin walled ducts.

The fluid in the lymphatic system is moved along by the squeezing action of muscles. There are vlves in the ducts to prevent backflow of fluid. The lymph fluid is a water substance.

Lymph nodes are lymph glands that are scattered through the body. They are concentrated in the neck, armpits, and groin areas. Lymph nodes can contain lymphocytes. Foreign materials, bacteria, viral particles, are swept into nodes and are attacked by the lymphocytes.
The main function of the lymphatic system is to remove foreign material or invading microorganisms. The lymph nodes enlarge during illness. The spleen and tonsils are part of the lymphatic system.

13. Cardiovascular Disease
      Atherosclerosis: plaques develop on the inner walls of the arteries which narrowing the diameter of the vessels. These plaques can be infiltrated by calcium deposits which in arteriosclerosis or hardening of the arteries. Hypertension: high blood pressure which promotes atherosclerosis, increasing the chance of heart attacks and strokes. One cause is the increase in concentration of LDL, low density lipoproteins. These are plasma particles made of thousands of cholesterol molecules and other lipids bound to a protein. High density lipoproteins reduce the deposits of cholesterol in ateries.

VII. Thermoregulation

A. Feedback loops
      A stimulus produces a reaction that ultimately reduces the stimulus. For example, a baby is hungry and cries. When baby gets fed, it stops crying. The stimulus for the baby is hunger. The baby's response is to cry. The parental stimulus is the baby's cry. The parent response is to feed the baby. Now assume that the baby cried because of a deep rash. If the parents got up and tried to feed it, the baby would cry louder and the parent would try harder to feed. This is a positive feedback loop. The stimulus evokes a response that further increases the stimulus. Negative feedback is very stable in nature. Positive feedback is untable and uncommon in nature. It is often associated with illness.

Another non-biological example of negative feedback is the home thermostat. Biological homeostatic systems have limits. Many different organisms can regulate their body temperature but over a wider range than others.

B. **Thermoregulation**

Chemical reactions are influenced by temperature. Animals must develop a life style that permits survival over a range of internal temperatures or must develop ways to keep the temperatures constant. Ectotherms are cold blooded organisms that absorb heat from surroundings. Endotherms are warm blooded organisms that maintain a consistent internal temperature. They derive heat from metabolism.

Why thermoregulation

Animals are subjected to changing environmental temperatures. There are two ways to deal with this.
   a. some organisms go into a metabolic torpor where biochemical processes slow down and they become sluggish or immobile.
   b. Organisms can take measures to conserve metabolic heat and retain it for the parts that need it the most.

Thermoregulation involves mechanisms that cause heat loss, as well as heat gain. In fact physiological damage created by too much excessive heat is often permanent. Damage caused by low temperatures is often temporary, except in extreme cases.

Heat is transferred between organisms and the environment.
   1. Conduction
       Conduction is a direct transfer of heat between the environment and body surfaces. Ehat is always conducted from a body of higher temperature to one of lower temperature.
   2. Convection
       Convection is the flow of air or liquid past the surface of a body
   3. Radiation
       Radiation is the transfer of heat between objects that are not in direct contact. Heat is transferred as electromagnetic waves.
   4. Evaporation
       Evaporation is the loss of heat from the surface of a liquid that is losing some of its molecules.

C. **Thermoregulation in Animals**
   1. **Invertebrates**
       Invertebrates have little control over body temperature. They adjust their temperature through behavioral or physiological mechanisms. However, some larger flying insects can generate internal heat, and in the winters moths have counter current exchange. Honey bees maintain a special social organization that keeps them warm in the winter and cool in the summer.
2. **Fish**

   a. How tuna swim fast
       Tuna have a specialized circulatory arrangement. In a slow moving fish, major vessels are centrally located, with branches serving the propulsion muscles and outer portions of the body. This kind of system tends to cool the blood, preventing heat from accumulating in swimming muscles.

       In a tuna, major arteries and veins are always paired and parallel, as are peripheral branches. This fosters counter current exchange.

   b. Counter current exchange
       When arteries and veins run closely parallel carrying blood, in opposite directions, the blood is of different temperatures. Venous blood is cold, while arterial blood is warm. The arterial blood gives up heat to the returning venous blood. Also in some swimming muscles there is a rich supply of blood, this network of blood vessels is called the rete mirabile (wonderful net). Counter current heat exchange helps keep the swimming muscles warm.

   c. Regulating Behaviorally
       Fish move to a temperature zone that is appropriate for the species.

3. **Amphibians**

The optimal temperature for amphibians varies from 7-25°C. They produce little heat and lose heat rapidly through evaporation. Behavioral adaptations enable them to maintain body temperature.

4. **Reptiles**

Reptiles regulate temperature depending on where they live. Reptiles in temperate
Regulate body temperature much better than the reptiles in the tropics. Heating and
cooling are achieved through orientation to the sun's rays. They gain body heat
by basking and lose heat by avoiding the sun.

Reptiles can also improve behavioral thermoregulation by changing color. The
Horny toad is actually a horned lizard. When the body temperature is low, the skin
Darkens, increasing the absorption of sunlight.

5. **Marine Mammals**

The optimal body temperature for a marine mammal is around 36-38°C. The metabolism of a marine mammal is not much higher than land mammals that conserve
Heat more effectively. Marine mammals have insulation in the form of blubber with counter current exchange in tail and flippers. When they migrate to a warmer environment, the blood vessels of the skin dilate.

6. **Birds**

Birds have an average body temperature of 40°C. They have no sweat glands, but they can pant to promote evaporative heat loss. Feathers provide great insulation, but birds must warm their legs. Through the legs they lose a large amount of heat. Warm blood from the body core must flow to cells of the extremities. Counter current heat exchange reduces heat loss. Arteries carrying warm blood down the legs are in close contact with veins carrying blood in the opposite direction. The heat from the arterial blood is transferred to the vein. Blood in the veins becomes warmer as it moves up the legs, as the veins come into contact with warmer arteries.

Birds and Mammals conserve heat by a number of methods: In winter, birds puff up and mammal's hair stands up on end (piloerection). These actions trap insulating air under the hair and feathers. Shivering is a method of heat production. Other animals store layers of fat or may huddle together.

D. TERRESTRIAL MAMMALS: THERMOREGULATION

1. **Production of Heat**

Metabolism generates heat that warms the body. Fur and fat help retain the heat. The rate of heat production can be increased in two ways.

a. Contraction of muscles by moving and shivering increases heat production.
b. Action of certain hormones such as epinephrine and thyroxine may increase cellular respiration rates.

Some mammals have brown fat, which is a tissue located in the neck between the shoulders. Brown fat is specialized for rapid heat production.

2. **Maintaining A Constant Body Temperature: Four Methods**

a. Change the rate of metabolic heat production.
b. Adjust the rate of heat exchange with the environment.

G. **1) Vasodilation occurs when the superficial blood vessels dilate; this** increases the blood flow to the body surface. The heat is transferred

to the environment by conduction, convection, and radiation. Body temperature decreases.

H. **2) Vasoconstriction occurs when the superficial blood vessels constrict and the blood flow decreases. The body temperature increases.**

For mammals, large ears are a way to get rid of heat. Fur/hair is a way of retaining heat.

c. Evaporative heat loss is loss of water from the respiratory tract surface and across the skin. Panting and sweating increase evaporation.
d. *Behavior:* Many animals bask in the sun when it is cool and
hide/migrate when it is hot.

3. **Thermostat (How the Body Measures Temperature)**

a. The brain is constantly monitoring the temperature of the blood flowing through it. Temperature monitoring of the brain is done by the hypothalamus, which behaves like an ordinary thermostat. It can distinguish differences as small as 0.01°C. The hypothalamus has two thermoregulatory areas.
   1) The heating center controls vasoconstriction of superficial vessels, erection of fur, and shivering.
   2) The cooling center controls vasodilation, sweating, and panting.
b. Sensory neurons on the skin are sensitive to temperature. Some of the temperature receptors, called Ruffin Organs (warm receptors), increase the activity when temperature increases. Others are called Bulbs of Krause (cold receptors) and increase their activity when their temperature decreases. Warm receptors stimulate the cooling center of the hypothalamus and the cold receptors stimulate the heating center.

If the temperature is too cold, then the hypothalamus increases the rate of heat production. It stimulates the adrenal medulla to release nonepinephrine, which increases the metabolic activity of cells thus creating heat. The hypothalamus also stimulates the thyroid by stimulating the anterior pituitary to release TSH (thyroid stimulating hormone). This causes the thyroid to increase its own secretions, increasing metabolic activity to increase body temperature.

The hypothalamus actually measures the heat by measuring related chemical changes in the blood.

4. **Temperature Acclimation**
Temperature Acclimation means adjusting to a new environmental temperature over a period of time. Physiological acclimation to a new temperature has several aspects.

   a. Cells may increase the production of certain enzymes.
   b. They may produce the same enzyme but at a different temperature optima.
   c. The cell membrane may change the properties of saturated and unsaturated lipids.

5. **Torpor**
This is a state in which metabolism decreases and the heart and respiratory system slows down.

   a. Hibernation
   Hibernation allows an animal to withstand long periods of cold temperatures and decreased food supply.

   b. Aestivation
   Aestivation allows an animal to survive elevated temperatures and diminished water supply.

   c. Diurnation
   Diurnation is similar to hibernation and aestivation but for shorter periods.

VIII. EXCRETORY SYSTEM
A. OSMOREGULATION AND EXCRETION
Excretion is the removal of metabolic wastes from the body. In other words, the removal of nitrogen wastes that result from the breakdown of amino acids. Osmoregulation is the maintenance of proper waste and ion balance. Terrestrial animals lose water by urinating, sweating, defecating, and breathing.

Aquatic Animals can also lose water across the body surface. All animals have one general problem; cells cannot survive a net water gain or loss.

B. NITROGENOUS WASTE
Proteins are broken down into individual amino acids before the can pass into the blood stream. Amino acids can be made into proteins, converted into carbohydrates or fatty acids or used as fuel in respiration. Some changes produce left over fragments of nitrogen compounds that can be poisonous.

The amine group NH_2 is removed from the amino acid as NH_3 (ammonia). In water the ammonia forms ammonium ions (NH_4^+). Molecules of ammonia are highly toxic and must be changed into a less toxic substance or excreted quickly.

Some animals release ammonia, while others convert it to less toxic waste: urea or uric acid.

   1.   Ammonia
Most aquatic animals excrete ammonia.

   2.   Urea
Mammals and adult amphibians excrete urea.

- Urea is produced in the liver when ammonia is combined with carbon dioxide. The circulatory system carries the urea to the kidney.
- Urea allows the animal to excrete less water, release waste, and is 100,000 times less toxic than ammonia.
- *Uric Acid:* land snails, insects, birds, and reptiles excrete urine acid, a semi solid. By excreting uric acid, an animal reabsorbs nearly all water.

C. OSMOTIC ENIVRONMENT

If two solutions are isosmotic, they are equal in osmolarity. When two solutions are different, the one with the greater concentration of solutes is hyperosmotic and the more dilute solution is hypoosmotic. Water will move from the hypoosmotic solution to the hyperosmotic solution through a semipermeable membrane, one that does not permit the passage of solutes.

Each kind of environment presents its own osmoregulatory problems for animals. Organisms that are isotonic with the aqueous surroundings do not need to adjust their internal osmolarity. They are osmoconformers. Animals that are not isosmotic with the environment are osmoregulators. These organisms must regulate and adjust their internal osmolarity.

Definitions:

   1.   Euryhaline
Animals that can survive radical fluctuations in osmolarity (e.g. Brine Shrimp)

   2.   Stenohaline
Organisms that cannot survive radical changes in osmolarity.

Anhydrobiosis is a dormant state that some animals maintain when habitats dry up.

D. MARINE ENVIRONMENT

To survive in this environment organisms must solve two problems.

   1.   Seawater is a hypertonic medium. Thus marine mammals tend to lose water by osmosis.
   2.   Seawater has more salts in it than do the cells. The presence of solutes creates an osmotic gradient- with the lower concentration toward the inside. Soluble ions will tend to enter the organism.

Animals that live in the deep sea always come into contact with the same osmotic gradient. The animals that live near the bays and estuaries come into contact with an environment that experiences changes in salinity. Most marine invertebrates are osmoconformers. The fish in Class Agnatha are isoosmotic. Members of the Class Chondrichthyes must maintain an internal salt concentration that is relatively low compared to the outside environment. Sharks pump salt out of the body through a rectal gland in the anus. The shark, however, has an osmolarity close to that of seawater by retaining a large amount of organic solute in the form of urea. Prior to eating shark, you must soak it in fresh water to get rid of the urea. Sharks produce another organic compound, trimethylamine oxide (TMAO) which helps protect proteins from the effects of urea. As a result, sharks are slightly hyperosmotic to seawater. They balance this by not drinking and urinating frequently.
Bony fish continually drink seawater. The salt is removed by the gills. Nitrogenous wastes in the form of ammonia and salt are excreted across the gill membranes.

E. THE FRESH WATER ENVIRONMENT

Since fresh water organisms are hyperosmtic to fresh water, the tend to take in water through osmosis, the cells can swell and rupture, so these organisms must keep excess water out. Also fresh water doesn't supply the necessary ions that fish need. Organisms must spend energy to take these ions and pump them across the membrane of the skin. Nitrogenous wastes are flushed out in the form of ammonia into the available water.

The protist paramecium has a contractile vacuole that pumps out water. Many fresh water animals, including fish, remove excess water by excreting excess amounts of dilute urine. With this they experience a slight loss of salts. This salt concentration is replenished by eating plants and animals that have a higher salt concentration than the water. The gills can also pump sodium and chloride ions from the external environment into the blood.

The excretory systems of fish and amphibians are highly developed. As amphibians become more terrestrial with maturity, changes occur in the excretory process. The tadpole excretes nitrogen in the form of ammonia and adult frogs shift to the production of ammonia.

F. THE TERRESTRIAL ENVIRONMENT
The threat of dessication is the problem. The solutions to this problem are high intake of water, a highly efficient water conserving excretory system, water tight skin, and behavioral solutions.

All organisms use specialized epithelia called transport epithelia to regulate the transport of salt and water.

Transport epithelium consists of a single sheet of cells facing the external environment or some pathway that leads to the external environment. The cells of the epithelia are joined together by impermeable tight junctions. This ensures that solutes must pass through the cell membranes. Transport epithelia vary in their permeability to water and salt as well as the types and numbers of membrane proteins used in active transport. For example, gills of fresh water fish pump salt in and the gills of saltwater fish pump salt out. The epithelia found in the nasal glands of marine birds, which drink sea water, excrete excess salt via the nasal salt glands. Sharks have their epithelia in the rectum.

Transport epithelia are dedicated to osmoregulation. In terrestrial vertebrates, they are located in the kidney.

Terrestrial Vertebrates: These animals always need to replace the water that has been lost to the air. The most important way to conserve water is through the specialized kidney. Reptiles and birds save water by also producing uric acid.

Mammals produce primarily urea, which requires a constant water supply for its elimination.

G. COMPARTIVE EXCRETORY SYSTEM

1. Flame Cells: Platyhelminthes
This is the simplest excretory system. It regulates the contents of fluid directly. Tubes capped by flame cells have a tuft of cilia which beat and move fluid to openings in the tubular system. These openings, called nephridiopores, open to the environment.

2. Metanephridia: Earthworms
Internal openings collect body fluid that drains to the outside world through a nephridophore. Excretory tubules are closely associated with the circulatory system. Nephrostomes collect body fluid into the tubules. As the fluid moves along the tubules, salts are pumped out to the tubule and into the blood. The urine exits through the nephridophore.

3. Malpighian Tubules: Insects
These tubules remove nitrogenous wastes from the blood by opening into the digestive system and dangling in the fluid of the body cavity. The transport epithelia move salts and nitrogenous wastes into the tubule which leads to the digestive system and out the anus.

4. Vertebrate Kidney
The excretory tubules are concentrated in the kidneys, a pair of bean shaped organs. Blood is cycled through the kidney which removes nitrogenous wastes and adjusts the concentration of salts in the blood.

H. THE HUMAN EXCRETORY SYSTEM
1. **Kidney Parts**
   a. The renal artery brings blood to the kidney.
   b. The renal vein takes blood form the kidney.
   c. Urine is the waste fluid formed in the kidney.

      d.   The ureter carries waste from the kidneys.
      e.   The urinary bladder temporarily stores the urine.
      f.   The urethra carries the urine from the bladder out of the body.

The human system includes kidneys, ureters, urethra, and bladder. Each kidney receives blood through a renal artery. The blood entering through the artery is under high pressure. The excretory system removes excess water, salts and nitrogenous wastes. The volume and content of urea depends on the quantity of water taken in. The kidney is regulated actively by the hormones of the hypothalamus and adrenal glands.

The kidney can be broken down into three regions:

    1) cortex
    2) medulla
    3) pyramids

The cortex consists of the filtering units of the kidney, the nephrons, and related blood vessels. Each nephron consists of a spherical capsule and a long tubule that forms a very long loop that goes into the medulla and returns to the cortex.
Groups of nephrons empty into a common collecting duct that extends into the medulla. They are joined by other ducts to form the pyramids.
The nephrons are the functional units of the kidney. There are one million nephrons/kidney. 1,100 liters to 2,000 liters of blood flows through the kidney every day. The nephrons process 180 liters of filtrate leaving 1.5 liters of urine excreted per day.
Begin at the Bowman's Capsule, which is a hollow bulb or cup that surrounds a ball of capillaries from the renal artery, called the glomerulus, here the blood is force filtered. Water passes into the Bowman's Capsule containing glucose, amino acids, small proteins and vitamins.
A long tubule emerges from the capsule. The first region is the Proximal Convoluted Tubule whish then forms a long hairpin bend called the Loop of Henle. It is in this loop and in the collecting ducts that most of the water is reabsorbed into the blood.
After the loop, the Distil Convoluted Tubule and the collecting tubules. This carries the urine down to the sac like urinary bladder. The bladder is capable of moderate stretching. When full, stretch receptors on the bladder signal that it is time to empty the bladder.
When the muscles of the urinary bladder contract, the urine is forced out of the body through the urethra.

   3. **How a Nephron Works**
        a.   Filtration
Blood pressure forces fluid from capillaries into the Bowman's Capsule. The capillaries, which are porous, and podocytes (specializedcalles in the Bowman's Capsule) function as filters where small molecules and water filter into the capsule and large molecules do not.

        b.   Secretion
As the filtrate travels along the renal tubule, some molecules are joined by substances and are transported across the transport epithelia from the surrounding interstitial fluid. The proximal and distal tubules are the most common sites of secretion. This is a selective process involving passive and active transport.

    1) *Secretion:* Out of the body.
    2) *Reabsorption:* Back into the body.
    3) *Filtration:* What will be excreted from the body.

   4. **Movement through the Renal Tubule**
        a.   Proximal Convoluted Tubule
The wall is made up of transport epithelia. The epithelia adjusts the volume and make-up of this filtrate by secretion and reabsorption.

A constant pH is maintained by the secretion of H^+. Drugs and poisons are secreted into the filtrate. Nutrients (glucose and amino acids) are actively transported into the interstitial fluid. Potassium, water and other salts are reabsorbed. 70% of the water and 75% of the salt is reabsorbed.

The proximal tubule is composed of microvilli which increase the surface area for reabsorption. As salt is moved out by active transport, water moves out by osmosis.

b.   Descending Limb of Henle

Water continues to be reabsorbed. The transport epitheliem is permeable to water but not to other solutes. The interstitial fluid surrounding the tubule is hyperosmotic. As the water leaves, the salt concentration increases.

c.   Ascending Limb of Henle

Transport epithelium is permeable to sodium chloride but not to water. There are two regions of the ascending loop.

1)   Thin Segment; near the loop tip (bottom).
2)   Thick Segment: near the top.

As the filtrate moves up through the loop, sodium chloride diffuses out. The loss of sodium chloride contributes to the high osmolarity of the interstitial fluid. In the thick segment, sodium chloride is actively transported (Cl- is actively transported out, Na^+ follows in the negative charge). The filtrate becomes more dilute.

The Distal Convoluted Tubule also plays an important role in secretion and absorption of substances. K^+ is secreted into the filtrate and Na^+ is reabsorbed. pH is regulated by secreting H^+ and reabsorbing HCO_3^-.

d.   Collecting Tubule
Carries filtrate to the medulla and renal pelvis. The transport epithelium is permeable to water but not to salt. Water is reabsosrbed and the urine is concentrated. At the end of the duct (inner medulla) the transport epithelium is now permeable to water but not urea, some of it diffuses out into the interstital fluid which contributes to the high osmolarity of the interstitial fluid near the descending limb of the Loop of Henle.

5.   **Regulation of the Kidney**
Antidiuretic Hormone (ADH) is produced by hypothalamus and stored in the pituitary gland. There are osmoreceptors in the hypothalamus which monitors the blood. When the solute concentration of the blood rises to a certain point, the pituitary gland releases ADH. This increase in concentrationis caused by excessive water loss.
ADH reaches the kidney and targets the distal convoluted tubules and the collecting ducts. ADH increases the permeability of the transport epithelium to water which increases water reabsorption.

Alcohol inhibits ADH which causes excessive water loss in urine.

Juxtaglomerular apparatus (JGA) is located where the blood vessel meets the glomerulus. When Na^+ in blood is too low and thus blood pressure is low, JGA releases an enzyme renin into the blood. Renin activates ANGIOTENSIN, a plasma protein. Angiotensin changes into the active form of angiotensin II. This hormone increases the sodium concentration which raises the blood pressure. This increases filtration.

Angiotensin II also stimulates the adrenal gland to release aldosterone. Alosterone acts on the Distil Convoluted Tubule which stimulates the reabsorption of sodium out of the tubules. This increases the blood volume and blood pressure.

Atrial natriuretic protein (ANP) opposes renin-angiotensin-aldosterone. The wall of the atrium releases ANP in response to an increase in blood volume and pressure; the hormone inhibits the release of renin from the JGA and releases the release of aldosterone.

IX. ENDOCRINE SYSTEM

Animals coordinate activities of specialized parts via the nervous and endocrine systems. The endocrine system uses chemical messengers that travel to specific organs. These chemicals are called hormones.

Note: Exocrine Glands produce a variety of substances, such as, sweat, mucus, and enzymes. These substances move through ducts. Endocrine Glands produce a variety of substances, but move these substances without ducts and so are often referred to as ductless glands.

A. HORMONES
Hormones are chemical messengers that are formed by endocrine glands in one part of the body and travel to other parts of the body and cause chemical changes.

There are more than 50 known hormones. They are regulatory devices that make the body behave in a coordinated fashion and can affect behavior. Only certain types of cells, target cells, are affected by a particular hormone.

Each hormone has a specific protein shape that is recognized by the hormone's target cells. The first step in a hormone's action is the binding of the hormone to a hormone receptor. A hormone receptor is a protein on or in the cell membrane. Once bound, the target cell responds to the hormone signal. The effects of hormones are often countered by opposing, or antagonistic, hormones. For example, insulin and glucagons. Insulin removes glucose from the blood and glucagon adds glucose to the blood.

There are three groups of hormones.
1. Steroids have the usual four ring structure. Each ring may have different side groups. Steroids are derived from cholesterol. Common steroids are the sex hormones progesterone, testosterone, and estrogen. Other steroids are aldosterone, coritcosterone, and cortisol.
2. Peptides are composed of amino acid chains. Two of the simplest are the antidiuretic hormone (ADH) and oxytocin which are made up of 9 amino acids. Insulin has 51 amino acids.
3. Modified Amino Acids: There are only a few of these, epinephrine and nonepinephrine. Most frequently the modified amino acid is tyrosine.

B. Variations On Hormones: Other Chemical Messengers
Phermones are chemical signals that work like hormones except they are communication signals between animals of the same species. Phermones attract mates, mark territories, and alarm organisms. Phermones are small volatile molecules that disperse easily into the environment and are active in small amounts.

Local Regulators are chemical messengers that affect target cells near their point of secretion.

Growth Factors are proteins that must be present in order for cells to grow and develop normally. Target cells of the growth factors also have receptors on the cell membrane. Some oncogenes have membrane proteins that mimic growth factor receptors.

Prostaglandins are modified fatty acids that act as local regulators. There are 16 different discovered prostaglandins. They are active in the female reproductive system. They are also local regulators in the defense system, for example, fever, inflammation and pain intensity are caused by prostaglandins. Aspirin inhibits the formation of prostaglandins.

C. How Hormones Work
Hormones act in low concentrations and can affect different target cells within an organism. However, how a hormone triggers specific changes in target cells can be broken down into one of two methods:
1. Steroid hormones enter the nucleus and influence the expression of the cells' genes.
2. Most non-steroid hormones attach to the cell surface and through a second messenger affect the cell. Both of these methods are called signal transduction pathways.

D. Steroid Hormones
Steroids pass through the target cell membrane and enter the nucleus. A steroid hormone will bind to a receptor protein recognizes specific DNA regions. These receptor proteins are probably transcription of

specific genes by attaching to an enhancer sequence of DNA. Steroids can initiate transcription and produce mRNA; eventually a protein is produced.

E. Peptide Hormones

Peptide hormones are unable to pass through the cell membrane. These bind to hormone receptors of the target cell. This binding will cause a variety of biochemical reactions through a second messenger. There are two types of second messengers: cAMP (cyclic AMP) and Inositol Triphosphate.

F. The Second Messenger

Cyclic AMP is so important it is called the second messenger. The hormones are the first messengers. They bring the message to the target cells. Within the cell, the actual response of the cell is triggered by cAMP.

For example: Epinephrine is released from the adrenal medulla and carried by the blood to a target cell, such as the liver. The liver has a receptor site on the cell membrane. Epinephrine fixes onto the membrane and activates the enzyme adenyl cyclase through the G protein which is provided by GTP. When the enzyme is activated it converts ATP to cAMP. cAMP stimulates the activity of glycogen phosphorylase which hydrolyzes glycogen. cAMP activates a cAMP-dependent protein inase which transfers a phosphate group from ATP to a protein. This stimulates another kinase which adds a phosphate group to glycogen phosphorylase which hydrolyzes glycogen. cAMP starts this enzyme cascade. One benefit from an enzyme cascade is that it amplifies the response of the hormone. The number of activated products increases at each step.

G. Inositol Triphosphate

Many chemical messengers induce responses in target cells by increasing the cytoplasmic concentration of Ca^{++}. The second messenger that intermediates between hormonal signal and the increase in Ca^{++} is inositol triphosphate (IP_3).

H. Invertebrate Hormones

All invertebrate have hormones that function in maintaining homeostasis. Invertebrate hormones regulate water balance, help with reproduction, regulate growth, and signal when to molt.

I. Endocrine System in Vertebrates

The evolution of the hormones and the nervous system is important in adjusting the animals to the environment. The endocrine system is essentially the same in all mammals.

In the endocrine system more than a dozen tissues secrete hormones. The changes occur when the hormone encounters the target area. Hormones are degradable, they do their jobs and disappear. Some hormones directly affect tissues, and others like tropic hormones affect other endocrine glands.

J. The Endocrine Glands
1. Pituitary

This is called the 'Master Gland" because it influences other glands. The hormones from the pituitary activate other glands. It is a tiny structure (12-13 mm in diameter), about the size of a kidney bean. If you want to find out where it is point your finger into your ear, between your eyes, where the two lines intersect, will be your pituitary.

The gland lies in a pocket of bone and attaches to a stalk which emerges from the base of the brain just below the hypothalamus.

The pituitary is divided into the anterior (front) and the posterior lobes. The anterior lobe is primarily glandular and secretes seven important hormones: Adrenocorticotrophic hormone (ACTH), Growth hormone (GH), Prolactin (PRL), Follicle Stimulating Hormone (FSH), Lutenizing Hormone (LH), Thyroid Stimulating Hormone (TSH), Melanocyte Stimulating (MSH). The posterior lobe is really part of the brain (it is directly connected to the brain); its blood circulation is separated from the anterior lobe. The posterior does not manufacture hormones, but it stores two hormones, oxytocin and ADH, that are made in the hypothalamus.

2. **Hypothalamus**
The hypothalamus manufactures hormones and releasing factors which control the release of hormones from the anterior pituitary. The hypothalamus plays a role in integrating the endocrine and nervous systems. The hormone releasing cells are specialized neurons that are different from both the secretory cells of the endocrine system and other neurons. These cells are neurosecretory cells. They receive impulses from other neurons and secrete hormones as a response. There are two sets of secretory cells that:
   a. Produce releasing hormones for the anterior pituitary.
      Two releasing hormones:
      1) Thyrotrophic hormone releasing factor (TRH), which releases the thyrotrophic hormone.
      2) Lutenizing hormone releasing factor (LRH), which releases lutenizing hormone and follicle stimulating hormone.
   b. Produce hormones for the posterior pituitary.

K. Anterior Pituitary (Adenohypophysis) Hormones

1. **ACTH (adrenocorticotrophic hormone)**
Targets the outer layer of cells in the adrenal gland. When these cells are stimulates, the adrenal cortex secretes a battery of hormones, most of them steroids. As the levels rise, the increased levels of the released hormones inhibit the ACTH production. ACTH regulates the metabolism of fats.

2. **GH (growth hormone)**
A protein consists of almost 200 amino acids. GH stimulates growth, the production of other growth factors, stimulates the liver to produce a hormone somatonedins which stimulates bone and cartilage to grow, and assists amino acids across the cell membrane. This increases the acceleration protein synthesis, decreases carbohydrate utilization, increases blood glucose and stimulates the release of insulin. Proper levels are needed for proper growth. Increased levels cause giantism. Decreased levels cause midgets to form. We can clone GH in E. Coli. A sudden increase in GH causes acromegaly or growth surges in restricted areas.

3. **Thyroid Stimulating Hormone (TSH)**
Stimulates the thyroid to release thyroxin, triodothyronine, and calcitonin. These regulate the metabolic rate of the body and calcium ion levels of the blood.

4. **Follicle Stimulating Hormone (FSH) and Lutenizing Hormone (LH)**
Gonadotropins, which stimulate the activity of male and female gonads. Both are glycoproteins.

5. **Melanocyte Stimulating Hormone (MSH)**
Regulates the activity of pigment containing cells present in some vertebrates.

6. **Endorphins**
Similar to ACTH and MSH are endorphins. Endorphins are the bosy's opiate which inhibits the perception of pain. Heroin and other opiates are mimic endorphins. The 'runner's high' is caused by the release of endorphins to counteract the pain.

7. **Prolactin**
Promotes milk production in mammals. Similar to the growth factor, it regulates fat metabolism and reproduction in birds, and delays metamorphosis in amphibians.

L. Posterior Pituitary (Neurohypophysis) Hormones
Oxytocin and ADH are stored here. ADH is released when the osmotic pressure of blood is down. This causes retention of fluids in the blood. The increased fluid levels increases the osmotic blood pressure inside the blood vessels. Oxytocin is stimulated by the stimulation of the nipples and sexual intercourse. Oxytocin stimulates prolactin which stimulates milk secretion; it also stimulated the uterus to contract

M. Thyroid Gland

1. This is shaped like a bow tie with two lobes, located in the ventral urface of the trachea. The thyroid is located in front and slightly below the larynx. It weighs about 30 grams. The thyroid produces throxine (T_4), and triiodothyronine (T_3). T_3 is usually more active, although both have the same effects on the target cells. The thyroid plays a huge role in the development and maturation of vertebrates.

   An overactive thyroid causes hyperthyroidism with the following symptoms: nervousness, hyperactivity, insomnia, weight loss. An underactive thyroid causes hypothyroidism which has the opposite symptoms. A goiter is an enlargement of the thyroid gland; the thyroid cells deficient in iodine. Cretins are people that have lacked thyroxine since birth. Mental and physical retardation are a result of the low level of thyroxine.

   Thyroxine is controlled by the thyroid stimulating hormone of the anterior pituitary gland. TSH is influenced by a releasing factor from the hypothalamus.

   Calcitonin is a thyroid protein which regulates blood calcium concentration.

N. Parathyroid Gland and Parathormone

Parathyroids are four pea sized bodies embedded in the thyroid.
Parathyroid hormone (PTH) is produced by the parathyroid. Made up of the 81 amino acids, PTH increases calcium concentration. Low amounts of PTH gives muscle concentration. Calcitonin decreases the calcium concentration. Low amounts of PTH gives muscle convulsions which can lead to death. PTH targets three know tissues: intestine, kidneys, and bone cells.

1. Intestines

PTH increases absorption of calcium into the blood.

2. Kidney

PTH inhibits the secretion of calcium into the body.

3. Bone

PTH increases the activity of osteoblasts which dissolves calcium phosphate; the calcium ions are them released into the blood.

O. The Pancreas an the Islets of Langerhans

The pancreas is an exocrine gland and manufactures digestive enzymes for the intestine.

Scattered throughout the pancreas are groups of true endocrine cells that secrete products directly into the blood stream. These cells are called the Islets of Langerhans. TheIslets are made up of two types of cells.
1. *Alpha*: Alpha cells produce glucagons
2. *Beta*: Beta cells produce insulin

Glucagon stimulates liver to break down glycogen into glucose, which is released when blood sugar is low. Glucagon increases the conversion of amino acids and fatty acids to sugar. Insulin has the opposite effect. When there is high blood sugar, insulin stimulates the liver to remove glucose from the blood. It slows liver breakdown of glycogen and inhibits the conversion of amino acids and fatty acids to sugar.

If you have low blood sugar, then you are hypoglycemic. If you have high blod sugar, then your are a diabetic. There are two types of diabetes. Type I diabetes mellitus (insulin dependent/juvenile onset) is caused by an autoimmune disorder where the immune system attacks pancreatic cells. Such diabetes require a daily injection of insulin. Type II diabetes mellitus (adult onset/insulin independent) is caused by either target cells responding to less insulin or the production of less insulin. This form of diabetes is treated through a restrictive diet.

P.   **Adrenal Glands**
The adrenal glands are closely associated with the kidney. There are two glands in one. There is an outer layer called the cortex and an inner layer called the medulla.

1.   **Adrenal Cortex**
The adrenal cortex can be stimulated by stress. ACTH stimulates the adrenal cortex to synthesize and secrete a family of steroids called corticosteroids. Increased levels of these steroids suppress the release of ACTH. There are two types of corticosteroids.

A. Mineralocorticoids
Mineralocorticoids (such as aldosterone) target cells on the renal tube of the kidney. This increases the recovery of sodium and increases the excretion of potassium and hydrogen ions into the urine. Aldosterone works with ADH to keep fluids of the body relatively constant.
B. Glucocorticoids
Glucocorticoids (such as cortisol) are partly responsible for elevating glucose metabolism. They also increase protein and fat metabolism. Glucocorticoids have n important role in the sexual development of an individual. The adrenal cortex makes the same hormones as the testes and ovaries, and these produce the secondary sex characteristics.

2.   **Adrenal Medulla**
Produces epinephrine and norephinephrine. These are calecholamines, which are synthesized from the amino acid tyrosine. These hormones increase the level of energy sources and increase the rate and stroke of the heartbeat. They also cause smooth muscles of some blood vessels to constrict and others to relax, which prevents blood from going to the skin, gut and kidney, and increases blood flow to the heart, brain and skeletal muscles.

Q. **Ovaries and Testes**
The ovary produces the two hormones estrogen and progesterone.
The testes produce androgens; the main one is testosterone
They are important in reproductive functions and also stimulates the lengthehing of long bones.

P. Pineal Body
The pineal body is located above the brain stem and secretes melatonin (a modified   amino acid) which, along with MSH, controls the skin pigmentation in vertebrates.

R.   **Thymus**
At puberty the thymus begins to diminish and almost disappears by adulthood. The thymus secretes thymosin which stimulates the development and differentiation of T lymphocytes.

Hormones are also produced in the uterus and stomach lining.
X.   IMMUNE SYSTEM
A. HOMEOSTASIS
Tendency of the body to maintain a constant internal environment in the face of insults from the external environment. This includes invasion from the outside.

B.   NON-SPECIFIC DEFENSES
1.   **External Barrier**
Skin and mucus membranes cover the animalís body. Skin usually cannot be penetrated by bacteria or viruses, although a small abrasion may allow a way for foreign substances to invade. The pH of the skin, due to the presence of sweat and oil, ranges from 3-5. the low pH will kill most foreign bacteria. Saliva and tears wash away bacteria and contain antimicrobial proteins, for example, lysozyme which attacks the cell wall of bacteria. Mucus membranes that line the respiratory, digestive, and excretory tracts prevent harmful microbes from entering the body. Foreign substances stick to the mucus. The lining of the trachea is ciliated epithelium which sweeps the particles into the mucus and digestive tract.

2.   **Phagocytosis**

All animals have in common one very effective line of defense ameboid that engulf and eat any foreign particle including microorganisms. Some are fixed in places such as the spleen or lymph nodes. These cells engulf any foreign substance that passes through. Others roam freely; these cells are called phagocytes.

a. **Neutrophils**
   Make up 66-70% of our white blood cells. They are attracted to body parts via a chemical signal. Neurophils can leave the blood and enter infected tissue via ameboid movement and destroy invaders. As they destroy invaders, neutrophils tend to self-destruct. Neutrophils live for only a few days.

b. **Monocytes**
   Make up 5% of our white blood cells. They provide a more effective phagocytic defense. After they mature, monocytes circulate for a few hours in the blood and migrate into tissues to develop into macrophages.

c. **Macrophages**
   Are the largest phagocytic cells and live a long time. The macrophage pseudopods grab invaders; the invaders are pulled into the macrophage and destroyed by digestive enzymes and reactive oxygen. Some bacteria evade macrophages; a bacterial capsule can prevent the bacteria form being pulled into the macrophage and some cell walls resist digestive enzyme. Some macrophages reside permanently in organs and tissues, such as alveoli, the liver and the lymph nodes.

d. **Esinophils**
   Make up 1.5% of white blood cells. They phagocytize and contain detructive enzymes within the cytoplasm. Esinophils defend against large parasites, such as worms, by positioning themselves against the external wall of the worm and discharging enzymes from the cytoplasm.

e. **Natrual Killer Cells**
   They attack the bodies own infected cells. Natural killer cells can also attack cells that are precancerous. They attack the outer cell membrane; then the cell opens up and lyses.

3. **Nonspecific Response: Inflamation**
   Physical damage to tissue (e.g. a scratch) allows microbes to invade and triggers an inflamitory response.

   a. The small blood vessels in the area of the injury dialate; this increases the blood flow to the injured area causing the redness and heat of the injury.
   b. The blood vessels become more permeable and fluids from the blood move into neiboring tissues. This action causes swelling (edema).

   Both of these actions are started by chemical signals. Histamine is a chemical signal which is contained in a circulatory white blood cell called a basophil and in cells called mast cells found in the connective tissue. If these cells are injured, they release histamine which triggers local vasodilation and increases capillary permeability. White blood cells and damaged tissues release prostaglandins and other substances to promote blood flow to the injured area. The vasodilation and increased blood flow also brings platelets and other clotting factors to the injured area. The clotting process begins the repair of the body and helps block further invasion of microbes.
   Within an hour after injury, phagocytes will migrate from the blood to the injured area. These phagocytes move via chemotaxis. Neutrophils arrive first followed by the monocytes that chane into macrophages. Macrophages not only devour invaders but also clean up the tissue remains and the neurtophils that have self destructed. Pus is mostly ded cells and fluid leaked from the capillaries. The pus is slowly absorbed by the body.
   The bodyís reaction to an infection may be more systematic:
   The injured cells emit molecules that stimulate the bone marrow to release more neutrophils. The pathogen toxins may start a fever which causes white blood cells to realease pyrogens that set the bodyís thermostat at a higher temperature. This also helps with defense.
4. **The body?s nonspecific defenses**
   a. 1st line of defense
      skin, mucus membranes

   b. 2nd line of defense

phagocytes, natural killer cells, antimicrobial proteins, and

inflammatory response

C. **Immune system basics**
   1. **Specific defenses: basics**
   Third line of defense is the immune system. This specific system is different than the nonspecific system by having four features.

      a. **Specificity**
      Specificity is the ability of the immune system to recognize ane eliminate particular microorganisms and foreign molecules. An antigen is any foreign substance that elicits and immune response. An antibody is a specific protein mad by lymphocytes against foreign substances.

      Each antigen has a specific molecular shape and stimulates a specific antibody.

      b. **Diversity**
      Diversity results from the immune systemís ability to respond to millions of types of invaders. Each invader is recognized by their antigen markers. The immune system can do this because of the large variety of lymphocytes.

      c. **Self/ noself recogniton**
      Self/nonself recognition occurs because of the immune systemís ability to differentiate between the bodyís molecules and foreign substances. Immune system failure leads to autoimmune responses.

      d. **Memory**
      Memory is the immune systemís ability to remember antigens and react more quickly upon subsequent exposures.

   2. **Active/ Passive immunity**
   Active immunity is the immunity gained by recovery form an infectious disease.

   This can be acquired naturally or artificially through vaccinations. Vaccines may be inactive bacterial toxins, killed microbes or living but weaker microbes.

   Vaccines create a memory in the immune system for a quicker response on subsequent exposures. Passive immunity occurs when the antibodies are acquired by an individual.

   3. **Natural passive immunity**
      a. mother passing antibodies through the placenta to the fetus
      b. mother passing antibodies to child when nursing
   4. **Artificial Passive immunity**
   Injecting antibodies, such as gamma globulin shots.

   5. **Humoral/ cell-mediated immunity**
   Humoral immunity is the production of antibodies that are secreted by lymphocytes and circulate as soluble proteins in blood plasma and lymph. These proteins defend against toxins, free bacteria and free viruses. Cell mediated immunity is the immunity that depends on the direct action of cells.

   This immunity defends against bacteria infected cells, viral infected cells, fungi, protozoans, worms, and cancer cells.

   6. **B and T cells**
   Lymphocytes are responsible for humoral and cell-mediated immunity. There

   are two types of lymphocytes: B and T cells

      a. B cells carry out humoral immunity
      b. T cells are responsible for cell-mediated responses Lymphocytes originate from the stem cels in the bone marrow. All cells look alike initially. The cells later differentiate depending on where they mature. T cells mature in the thmus. B cells mature in the bone marrow. Mature B and
   T cells are most concentrated in the lymph nodes, spleen, and other lymphatic organs. They are both equipped with speicifc antigen receptors on their cell membranes. The b cells receptor is an antibody bound

to the cell membrane. When an antigen binds to the receptor, it activates the lymphocyte to divide and produce a population of effector cells. Tehse cells do the actual defending.

B cells give rise to plasma cells which secrete antibodies. T cells give rise to cytotoxic t cells which destroy infected or cancer cells, or helper t cells, which help B cells.

7. **Antigen-Antibody specificity: molecular basis**

   a. antigens

   antigens are proteins or large polysaccharides. Most of these particles are the outer components of viral coats, and te capsules and cel wall of bacteria. Foreign cells, pollen and other foreign substances often have antigens on their surface. Antibodies recognize only a portion of the antigen, this portion is the epitope. A single antigen can have several epitopes eliciting many different antibodies to be produced against it.

   b. Antibodies

   Antibodies make up a class of proteins called immunoglobins which have at least two identical sites that bind to the epitope of the specific antigen. A basic antibody has four polypeptide chains, two light and two heavy, joined together to form a Y shaped molecule. Both the light and heavy chains have a constant region. The amino acid sequences in the constant region vary little among the antibodies of a class. At the tip of the Y shaped molecule, the variable region can be foud in both the heavy and light chains. This region varies extensively from antibody to antibody and is the antigen binding sites. The association between antigen-antibody binding site is analogous to the enzymeís substrate association.

   The antigen binding site is responsible for an antibodyís recognition factor. The stem of the antibody molecule is responsible for the antibodyís effector function which is to inactivate or destroy the antigen. In mammals there are 5 types of constant regions that correspond to the 5 classes of immunoglobins: IgG, IgM, IgA, IgD, and IgE. Each class of antibodies is characterized by a type of constant region that enables the antibody to perform certain defense functions.

8. **Antibody: specificity and diversity**

   Each lymphocyte recognizes and responds to only one antigenic epitope. The immune systemís ability to defend against an almost unlimited variety of antigens depends on the diversity of antigen-specific lymphocytes. Each lymphocyteís specificity for an antigen is predetermined during embryonic development, before an encounter with an antigen. The lymphocyte displays the antigen receptor on its cell membrane. If an antigen does come into contact with the lymophocyte, the lymphocyte is activated and initiates an immune response. The seleced cells divide and develop into a large number of identical effector cells. These clones combat the antigen that caused the response. Tehis is called the clonal section Since bacterial proteins have many epitopes, several cell lines can be clones at once.

9. **Immunological Memory**

   Clonal selection is the primary immune response. Between exposure to the antigen and the production of cloned effector cells is a time lag of ten days. If the body is exposed to the same antigen at a later time, the response time is between three to five days. This is the secondary immune response. The ëmemoryí ability of the immune system is based on memory cells. During the primary response, the memory cells are not active. These cells survive long periods of time and divide quickly when exposed to the same antigen again. Self tolerance is the lack of the immune systemís response to ones own body cells. During embryonic development, any lymphocytes with receptors for molecules found in the body are destroyed.

   The marker for ëselfí is the major histocompatibility complex (MHC). These molecules are glycoproteins embedded in the cell membrane. A large family of genes consisting of 20 MHC genes with at least 50 alleles for each gene makes it almost impossible for two people (except identical twins) to have the same MHC.

   There are two classes of MHCs.

   1)Class I MHC are located on all nucleated cells.
   2)Class II MHC are restricted to macrophages and B lymphocytes. These play an important role in how cells of the immune system interact.

10. **Humoral Response: Activation of B Cells**

a. Binding of an antigen to specific receptors on the B cell surface.
b. Involving the helper T cells and Macrophages.

After a macrophage engulfs a pathogen by phagocytosis, pieces of the pathogen are displayed on the surface of the macrophage. In this stage, the macrophage is called the antigen-presenting cell (APC). The antigen fragments are found in the class II MHC. A helper T cellís receptors recognize this combination of MHC and antigen. Contact between the T cell and the APC activates the T cell. The T cells divide and form clones of helper T cells. These helper T cells selectively stimulate B cells that have encountered the same antigen. The T cell binds to a B cell that is displaying antigen fragments bound to the class II MHC on the cell surface. The B cell is then stimulated to develop into a plasma cell and produce antibodies.

Most antigens stimulate this response and are known as t-dependent antigens. The antibodies cannot be produced without the T cells. There are t-dependent antigens that initiate a humoral immune response without involving macrophages or T cells. These antigens are usually long chains of repeating units, such a polysaccharides or protein subunits which are usually found in bacterial capsules and bacterial flagella. Usually, the numerous subunits of such antigens bind to a number of the antigen receptors in on the B cell surface, providing enough stimulus for the B cells to work without the T cells. The T-independent antigen response is weaker than the T-dependent response,

Once activated a B cell gives rise to clones of plasma cells and each cell can secrete up to 2,000 antibodies per second for the four to five day life span of the cell.

11. **Antibodies: How they work**

Antibodies donít usually destroy an invader directly. Here are the ways an antibody works:

a. Neutralization

The antibody blocks certain site on an antigen to make it ineffective, for example, antibodies bind to viral attachment sites then viruses canít attach to cells. Eventually phagocytosis will engulf the invaders.

b. Agglutination

Clumping. This is possible because each antibody has at least two

different binding sites

c. Precipitation

Antibodies cross link antigen molecules (not cells) to form precipitates that are eaten by phagocytes.

d. Complement

A group of proteins that act cooperatively with elements of the nonspecific and specific defense systems. Antibodies often combine with complement proteins, the antibodies activate the complement to produce lesions in the cell membrane of a foreign cell. Lysis of the foreign cell is the result.

12. **Monoclonal Antibodies**

Monoclonal cells are all descendants of a single cell and produce identical antibodies. New technologies rely on this method to produce specific antibodies inexpensively. One product of monoclonal antibody technology is a hybridoma. This is a hybrid cell formed from a cancer cell (myeloma) and a B cell. Antibodies can be produced indefinitely.

13. **Cell-Mediated Response**

This response battles pathogens that have already entered cells. The key components are T lymphocytes which are lymphocytes that mature in the thymus and migrate to the lymphoid organs like the lymph nodes and spleen. T cells cannot be activated by free antigens. T cells only respond to the antigenic epitopes displayed on the surfaces of the bodyís own cells. These bound antigens are recognized by T cell receptors. T cells respond to the MHC-antigen complex or the macrophage. The T cells with the correct receptors divide to form clones of effector cells specialized to fight the pathogen. There are two main types of T cells called into action: Helper T cells (TH) and Cytotoxic T cells (TC).

     a. TH Cells
1) help activate B cells to produce antibodies.
2) help activate other types of T cells to start the cell mediated response to antigens. This ability depends on chemical signals called cytokines. A cytokine is a molecule secreted by one cell as a regulator of neighboring cells. Binding of the TH cell to APC (antigen presenting cells) macrophagescauses the macrophages to release a cytokine called interleukin 1. Interleukin 1 signals the TH to release interleukin 2. Interleukin 2 stimulates TH cells to grow and divide which increases the supply of TH cells and interleukin 2. The interleukin 2 and other cytokines also activate B cells and stimlate TC cells.

     b. TC Cells
Cytotoxic T cells are the only T cells that kill other cells. Host cells infected by viruses or other intracellular pathogens display antigens and class I MHC. (TH cells look at class II MHC and antigen complexes). When TC cells bind with an infected cell, they release perforinwhich is a protein that forms an open lesion in the infected cellís membrane. The cell loses cytoplasm through the lesion, the cell lyses, pathogens are released, and antibodies bind to the pathogens. Cytotoxic T cells also defend against cancer cells. Natural killer cells do not respond to antigens although they kill cells in the same manner.

     c. TS Cells
A third type of T lymphocytes is the suppressor t cell (TS) ñ not well understood. TS cells probably turn off the immune system.

D. Complement System
     About 20 different complement proteins circulate in the blood in inactive form.These must be achieved through a series of reactions.

     The activation of the complement system is called the classical pathway.

1. The pathway is initiated when antibodies bind to the invader.
2. A complement protein bridges the gap between two adjacent antibody molecules. The antibodies and complement activate complement produces a small lesion in the pathogen membrane.
3. The complement produces a small lesion in the pathogen membrane.
4. The cell lyses.

     The alternative pathway doesnít require antibodies and the targets arenít specific so no membrane attack complex is formed. Substances found in many bacteria, yeast, viruses, virus-infected cells, and protozoans can activate complement proteins to form a complex. Through the alternative pathway, complements can also contribute to inflammation. Complement proteins bind to histamine containing cells and histamine is released. This alarms the body to a local injury. Several complex proteins attract phagocytes to the infected area.
In opsonization, complemenat proteins attach to foreign cells and stimulate phagocytes to ingest cells. In immune adherence, complement, antibodies and phagocytes work together. An invader is coated with antibodies and complement proteins and adheres to a surface where phagocytes eat them.

E. Applications
     1. Blood groups
If given the wrong blood type, the transfused cells would be destroyed through the cell mediated response.

     2. Tissue grafts and Transplants
MHC is responsible for tissue rejection. A foreign MHC causes TC cells to be activated. To avoid this, tissues must be matched and suppressor drugs given.

F. Immune System Disorders
     An autoimmune response occurs when the immune system attacks the bodyís own cells.

1) Rheumatoid arthritis: attacks joints.
2) Insulin dependent diabetes: attacks insulin cells in pancreas.
3) Rheumatic fever: attacks heart muscle/valves.
4) Graves disease: attacks thyroid. Too much thyroid hormone is produced.

Allergies are the hypersensitivity to environmental antigens and often involve IgE. For example, IgE recognizes allergen (pollen) and attaches to the allergen. IgE is already attached to a mast cell at the stem. Once attached to the allergen the mast cell disintegrates releasing histamine. Histamine causes the dilation of small blood vessels, runny nose, sneezing, and smooth muscle contractions which causes difficulty in breathing. Anaphylactic shock is a severe allergic reaction.

Immunodeficiency is the deficiency in hormonal or cell mediated immunity, for example, HIV and AIDS.

XI. Reproduction

A. Definition

Reproduction is the creation of new life from preexisting life. There are two types of reproduction: asexual and sexual. In asexual reproduction, a single individual produces genetically identical offspring. In sexual reproduction, two individuals produce offspring that are a combination of genes inherited from both parents.

B. Asexual Reproduction

Many invertebrates can reproduce asexually by fission, the splitting off of one individual from an existing one or separating into two of more individuals of equal size.

In budding, a new individual grows out from the body of the original. Fragmentation is the breaking of the body into several pieces. Each piece will grow into a new individual.

Regeneration is the result from an injury and may result in two individuals;
for
example, planaria and echinoderms.

C. Sexual Reproduction

In sexual reproduction, there is fusion of two haploid gametes that form a diploid zygote. Usually the female gamete (ovum) is large and nonmotile while the male gamete (spermatozoa) is small, flagellated, and motile. Sexual reproduction increases genetic variation among offspring.

D. Cycles

Most animals show a periodicity of reproduction which allows animals to conserve resources and allows a time when conditions favor the survival of offspring. These cycles are controlled by a combination of hormonal and seasonal cues.

E. Patterns

Females can produce two types of eggs, one is fertilized and the other type of egg can develop without being fertilized, parthenogenesis. In parthenogenesis the adult is usually haploid, as in daphinia, ants, bees, and wasps. Among vertebrates, some fish, and amphibians and lizards, the adults are diploid.

In hermaphroditism each individual has both male and female reproductive parts.

Most hermaphrodites must mate with another individual. Sequential hermaphroditism occurs when an individual changes gender during its life. Some species are protogynous and are female first; others are protandrous and are male first.

F. Fertilization and Developmet

1. Fertilization

a. External fertilization
Occurs when eggs are released by the female and fertilized

by the male in a moist or aquatic environment.

b. Internal fertilization
Occurs when sperm is deposited in the female tract as close to the egg as possible. This requires cooperative behavior that makes copulation possible.

2. Protection of the embryo

In external fertilization, a large number of zygotes are produced.

Initially, a large portion of the zygotes are killed by predators. In internal fertilization, the number of zygotes is fewer. Eggs protect the embryo and parental care protect the young. Some animals retain the embryo which develops in the female reproductive tract.

Animals that practice sexual reproduction have a basic problem in getting the eggs and sperm together. Solutions involve precise timing.

For example, the Caribbean fireworm-1î long. Found in the West Indies. On the 5th night after August full moon, they crawl out of burrows and swim to the surface. They reach the surface after sunset, but an hour before the moon rises. The worms become phophorescent. Males and Females blink at different rates and swim to each other. Then they burst, releasing eggs and sperm into the water. Internal fertilization evolved as a result of selection for males that could get the sperm closer to the egg. Males eventually developed various structures and behavioral patterns that placed the sperm inside the female.

Copulation is the process of getting the sperm inside the female. Oviparity is when development of the embryo occurs externally (e.g. in eggs).

G. **Comparative Reproduction**

I some fish, the fertilized eggs remain in the uterus until they are mature. The eggs hatch inside the female. The female then gives birth to live young. This is ovoviviparity.

Vivipariy occurs when the young develop in the uterus.

Fish are usuallyoviparious and lay hundreds upon thousands of eggs; some are ovoviviparous; for example, sharks have leathery eggs that develop and hatch internally.

Amphibians are usually oviparious with external fertilization. Reproduction in the terrestrial environment presents several problems. For example, getting the sperm to the egg and preventing the dessication of both the sperm and the embryo.

Reptiles and birds hace internal fertilization and are mostly oviparious. However, a few snakes are ovoviviparous. Reproductive systems in reptiles are similar to those of fish and amphibians. But male reptiles have well developed but hidden copulatory organs. Turtles have one penis, and lizards and snakes have two penises (hemipenes) which can be averted (turned inside out like the fingers on a rubber glove). Reptiles and birds produce fewer eggs than fish and amphibians. Reptiles have less parental care of young and lay more eggs than birds.

H. **Mammals**

Mammals are almost all vivparious. Most vivparios animals have placentas. Through the placenta the embryo receives oxygen and nourishment and discharges waste and carbon dioxide.

1. **Monotremes**

Includes the duck-billed platypus and the spiny anteater. Monotremes lay eggs like birds and reptiles, but have fur and produce milk.

2. **Marsupials**

In marsupials, like the opossum and kangaroo, the young develop in the uterus, but a true placenta is lacking. The immature young leave the uterus and squirm out of the vagina; then they crawl into the mother?s open pouch and attach to a nipple. There are two nipples in a female kangaroo, one big and one small. When the baby grows, it changes from the small to the large nipple.

3. **Placentals**

Humans are the primary example (see below). Through the placenta the embryo receives oxygen and nourishment and discharges waste and carbon dioxide.

I. Placentals: Human Reproduction

1. **Male Reproductive System**

a. **External Genitalia**
   Penis, and testes held in the scrotum.

1) Before birth the testes descend from the abdomen, up over the pubic bone and down into the cooler scrotum. The sperm will develop at about 2°C below the body temperature. When cold, muscles contract and draw the testes towards the body. Testes produce sperm and sex hormones.

They are oval bodies consisting of two highly coiled tubules which store sperm. The semniforous tubules are the other set of tubules. They are highly coiled with connective tissue, interstitial cells that produce testosterone and other androgens, blood vessels and nerves.

2) The spermatic cord for the epidiymis contains the vas deferens (tube for sperm transport) along with blood vessels and nerves of the testes. The spermatic cords, one from each testis, travels up over the pubic bones and into the body cavity. They go up over the bladder and the two vas deferentia join together on the underside of the bladder. There they are joined by a seminal vessicle duct. The seminal vesicle duct. The seminal vesicle produces a a volume (about 60% of total volume) of ejaculate (semen) which contain nutritive fructose, amino acids, and proteins which allow the semen to clump in the uterus. This makes the semen easier to move when the uterine contracts. Semen also contains buffering materials and prostaglandins which signal the uterus to contract.

3) The vas derens (ejaculatory duct) is joined when the urethra, near where it leaves the bladder. Surrounding this junction is the prostrate gland. The prostrate increases the pH of the semsn with secretions. The increase in pH does two things: activates the sperm and protects the sperm from the acid environment of the female reproductive tract. Below the prostrate, the urethra receives ducts from the bulbourethral gland (Cowpers gland) which adds mucus to the semen and may lubricate the semen. The semen then leaves the urethra.

b. **Erectile Tissue**

1) The mammal penis consists of special tissue with erectile capability. In some mammals the erection may be due to the spaces of the penis filling with blood or may be brought about by pulling the penis out from where it usually rests and is already stiffened by cartilage and bone (the baculum). In human males, the penis is an erectile shaft tipped by an enlarged region, the glans penis. A vertical slit at the tip of the opening is the urethra.

2) The penis consists of three cylinders of spongy tissue. Two are paired and called the corpora cavernosa. The third is called the corpus spongium During sexual excitement, blood flow into the spongy tissue increases, and the venous flow back to the body is restricted. The penis fills with blood and becomes erect. The tough sheath of connective tissue that surrounds the penis resists expansion and allows the penis to become firm.

c. **Sperm production/Spermatogenesis**

1) Each ejaculation of a human male contains about 400 million sperm cells. Sperm are produced in the walls of the semniferous tubules. Cells inthe outermost region continually divide by mitosis. Some of these cells, those that will produce sperm, start meiotic divisions.

2) Some of the outer cells of the semniforous tubules, called spermatogenia, are larger than the surrounding cells. When one of these cells enters meiosis, it is called a primary spermatocyte **In** meiosis I the homologous chromosomes separate and the two cells become the secondary spermatocytes. Meiosis II follows and forms four spermatids. Each spermatid undergoes the necessary reorganization to form a spermatozoa. The spermatozoa at this time are nourished by Sertoli cells. In the spermatozoa, the chromatin will be condensed into a small sperm head. The cytoplasm will differentiate into a mid section and tail piece.

3) An acrosome, a cap like structure on the tip of the head, arises from the lysosomes. Behind the head are a large number of mitochondria which produce ATP for movement of the tail. Mature sperm are swept by cilia and stored in the epididymis. If the sperm are not stored, they will be incapable of fertilizing an ovum.

2. **Female Reproduction**

a. **External Genitalia**

1) Collectively known as the vulva: Mons Veneris- the fatty tissue over the fatty arch. Below the mons veneris if the large outer folds, the labia majora (major lips), which cover a number of sensitive structures. Inside the labia majora are the labia minora (minor lips). These are joined together at the upper poriton to form a roof over a small prominence, the clitoris. The clitoris is a highly sensitive structure that is made of spongy erectile tissue and is homologous to the penis. The clitoris doesn?t enfold the urethra but gets erect and firm when stimulated. It can also produce an orgasm but does not ejaculate. There are two openings below the labia minora. The first is the urethral meatus, the urethral opening. The second is the introitus, the vaginal opening. In virgins, the vaginal opening may be partially blocked by a membrane called the hymen.

    b. Internal Genitalia
1) The vagina is a distendable, muscular tube about 7-8 cm long when relaxed. The functions of the vagina are to receive the erect penis and act as a birth passage during delivery. The vaginal walls provide a moist, firm surface for the penis, yet can expand to accommodate the passage of a fetus.
2) Vestibular glands (glands of Bartholin) are located beneath the surface of the lower margin of the vaginal openingand provide mucus secretions. The glands actively secrete when the female is sexually aroused.
3) The vagina usually has bacteria which are responsible for the acidic environment. The acidity prevents the growth of harmful bacteria and yeasts. In addition to the vagina there are the uterus, oviducts (fallopian tubes) and the ovaries.
4) The uterus is about 7 cm long and 4-5 cm wide in a female that has never been pregnant. The uterus begins at the upper end of the vagina. The opening is surrounded by a ring of firm tissue called the cervix. The uterus is a hollow pear shaped organ and most mammals have a bifurcated uterus. The single uterus, found in humans and promates, is specialized for species that usually give birth to only one child at a time.
    a) The walls of the uterus consists of three specialized layers.
The inner layer is the versatile mucosa which produces soft, highly vascularized endometruim. This layer receives and supports the zygote. Below the inner layer is the middly layer which is highly vascularized smooth muxsle that can expand. The outer most layer is composed of connective tissue which is continuous with the broad ligament which forms on either side of the uterus. This supports the uterus, ovaries and oviducts.

    b) Oviducts emerge from each side of the upper end of the uterus and outward a few inches and downwards. The ovidusts terminate in fimbriae which are finger like structures, but there is no cirect connection between the oviduct and the ovaries. Eggs are shed into the body cavity and picked up by the motile, ciliated fimbriae.
5) The ovaries are located in the center of the broad ligament and are additionally supported by the ovarian ligament. They are oval shaped and have two main regions: the outer cortex and the inner medulla.
6) The outer cortex contains the germinal epithelium. Egg cells, that are arrested after prophase I of meiosis, reside here. There are 200,000 potential eggs in the ovaries. Once ovulation occurs the egg is expelled from the follicle; the remaining follicular tissue grows within the ovary to form a solid mess called the Corpus Luteum.
7) Mammary Glands are not part of the female reproductive tract, yet are still important in reproduction. The secretory apparatus is made up of a series of alveoli. small sacs of specialized spithelial tissue that secretes milk. The alveoli drain into a series of dusts that open at the nipple. Deposits of fatty tissues form most of the mass of the mammary gland of a nonlactating female.

  c. Oogenesis: Development of the ova
Eggs remain in the ovary after prophase I prior to birth. After
Release meiosis I occurs with unequal cell division. After they are
fertilized, eggs undergo the second meiotic division.

3.   Hormonal Control of Human Reproduction
Reproduction is under hormonal control. The primary sites of human reproductive hormonal control are the pituitary gland, gonads and placenta. These are under the influence of the hypothalamus. The hypothalamus initiates the release of hormones, and monitors the hormone level in the blood. When directed by the hypothalamus, the pituitary secretes prolactin and gonadotropin.

Prolactin stimulates milk production.
Gonadotropin stimulates growth or activity in the gonads and is responsible for the growth during puberty and the development of the secondary sex characteristics. It also stimulates sex hormone production and is responsible for initiating the development of sperm and egg.

Two specific hormones of the pituitary are Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH) or Interstitial Cell Stimulating Hormone (ICSH). These hormones target the ovaries in females and the testes in males.

a. **Male Hormonal Action**

FSH targets the sperm producing seminiferous tubules. FSH acts with ICSH to induce the testes to produce the sex hormones called androgens, specifically testosterone.
Testosterone is produced in the seminiferous tubules. The production of androgens may increase or decrease with the increase or decrease of sexual activity. Androgens are vital for the development of maleness. Development of gonads and secondary sex characteristics requires testosterone. The sex drive is influenced by testosterone. High levels of testosterone inhibits ICSH. The ICSH level is detected by the hypothalamus which tells tha pituitary to slow ICSH and decrease the production of testosterone.

b. **Female Hormonal Action**

At puberty (9-12 years of age) events are initiated by the rise of Pituitary gonadotropin, FSH, which acts on ovaries.

The ovaries respond by producing estrogens. Estrogens influence the growth of breasts and nipples, and broadening of the hips. Estrogen along with adrenocorticotrophic hormone (ACTH) influences the growth of the uterus, vaginal lining, labia, clitoris,and appearance of pubic hair; however, too much ACTH can cause beard growth. Puberty is marked by the ovarian or menstrual cycle. The gonadotropin and ovarian hormones increase and decrease with regularity. The menstrual cycle is analogous to estrous cycles in other vertebrates.

A mature ovum is released from one of the two ovaries every 28 days. Ovulation is at mid cycle (14th day).

1) **First Half: Follicular /Menstrual Flow phase**

During the first 3-4 days, the uterine lining is being shed, this is menstruation. In the proliferative phase the pituitary releases more FSH. The FSH targets the immature ova in the germinal epithelium of the ovary.
The cells surrounding several immature ova will grow, this forms follicles. The hormones produced by the largest follicle inhibit other follicles From forming. The hormonal supproession of follicles limits the number of embryos. Hormonal birth control pills are based on this action.

One follicle grows steady for the first 14 days. The cluster of cells form a fluid cavity and enlarges to protrude like a blister from the ovary. During the 14th day the ovum bursts from the ovary and begin its journey down the oviduct. As the follicle grows, it secretes increasing amounts of estrogen. This stimulates the uterine lining to undergo cell division and build a highly cascularized, dense layer of cells called the endometrium. The cervix is stimulated by the estrogen and secretes an alkaline mucus which changes the acod environment to one that is more hospitable to sperm. If the egg is fertilized in the oviduct, it will descend into a suitable environment.

As the 14th day approaches there is a rising blood estrogen level that triggers the pituitary to inhibit FSH secretions and increase the production of LH. LH targets the enlarged fluid filled follicle. Under LH the fluid content increases and the follicle ruptures. There is a slight temperature increase (1°F).

2) **Following ovulation: Proliferative/ovulatory phase begins**

In the ovary the vacated follicle forms a new structure, the corpus lutem. This is responsible for continuing estrogen secretions and initiates the rise of progesterone. The progesterone helps make the final preparations in the uterus for receiving the eggs.

Progesterone and estrogen increase for six days following ovulation. During this time the endometrium of the uterus reaches its greatest development.

The tiny embryo will settle into this tissue, secreting with enzymes that will enable the embryo to settle into the fluid-filled spaces and continue development; this may cause some bleeding. Uterus is receptive until day 25-26. Unless the embryo is snugly implanted and puts out its own placental hormones, the endometrium will be sloughed away and menstruation will begin.

3) Luteal/Secretory phase

Progesterone and estrogen production decreases. The high blood hormone levels at day 21 are monitored by the hypothalamus, which ceases to stimulate LH production. LH decreases and causes the corpus luteum to recede which causes the estrogen and progesterone level to drop. These hormones are responsible for maintaining the edometrium.

4) How does the cycle start over?

The FSH is slowed by high estrogen. When estrogen level drops the inhibitory effect ceases. If pregnancy occurs, then the embryonic tissue puts out LH and progesterone. At the end of the pregnancy, no more progesterone and LH are produced, the uterus contracts and labor begins.

J. HUMAN SEXUAL BEHAVIOR

Human sexual act is clinically organized. The act is divided into four phases in the male and female: excitement, plateau, orgasm, and resolution.

1. **Excitement**

The female's initial events of a sexual response in a woman are a faster heart beat, faster breathing, increase in blood pressure, accompanied by firming of the nipples and reddening of skin around the genitals, face, breasts and abdomen. The clitoris swells, and there is general moistening of the labia majora.

In the male, similar events in the circulatory and respiratory systems happen rapidly. There is vasocongestion in the penis and elevation of the scrotum. Lubricating fluid may appear on the top of the penis.

2. **Plateau**

The plateau is where copulation begins.

In the female, the events of the excitement phase continue and are accompanied by pelvic thrusts. The swollen clitoris withdraws into its hood rather suddenly at this time; it is sensitive to the touch. The labia becomes swollen, uterus may elevate and the facial muscles relax.

In males, the excitement increases steadily. The glans reaches its greatest size and rigidity. The testes increase in size and elevate in the scrotum

3. **Orgasm (Climax)**

The orgasm, or climax, involves complex, involuntary muscle contractions and pleasurable sensations. In the female, the muscles around the vagina to the uterus contract. The cervix is pulled upward and draws the semen upward. The contractions continue every .8 seconds. In the male, ejaculation of semen occurs as powerful striated muscles at the base of the penis contract every .8 seconds.

4. **Resolution (After the orgasm)**

The male loses erection and the female can be aroused again.

K. CONEPTION/PREGNANCY/BIRTH

Conception is the fertilization of the egg.
Pregnancy/Gestation is the condition of carrying one or more developing embryos in the uterus.
Some gestation periods: Humans- 266days, rats- 21 days, dogs- 60 days, cows- 270 days, and elephants- 600 days from conception.

Human gestation can be divided into trimesters of about three months each.

1. **First Trimester**
   There are radical changes for both the mother and the baby. The egg is fertilized. Cleavage (cell division) of the zygote begins after 24 hours. The trip down the oviduct to the uterus takes 3-5 days. One week after fertilization, the embryo is a hollow ball of cells called the BLASTOCYST which implants in the endometrium. The endometrium grows over the blastocyst, and the tissues that grow out of the embryo mingle with the endometrium to form the placenta.
   Organogenesis, which is the development of the baby organs, occurs. At the fourth week, the embryo's heart beats. At the eighth week, all structures of the adult are present in some form. The embryo is now called a fetus. The fetus is only 5 or 6 cm long.

   Changes in the mother: A hormone, human chorionic gonadotropin (HCG), acts like LH and keeps progesterone and estrogen levels high. If progesterone decreases, menstruation begins. The levels of HCG are so high that some is excreted in the urine and can be detected with a pregnancy test. The increased levels of progesterone causes formation of mucus plug in the cervix, growth of maternal part of the placenta, enlargement of the uterus, cessation of ovulation and menstrual cycle, and the rapid enlargement of the breasts.

2. **Second Trimester**
   In the second trimester the fetus grows rapidly to about 30 cm long and is quite active. The hormone levels stabilize as HCG declines and the corpus luteum breaks down. The placenta secretes own progesterone, and the uterus grows.

3. **Third Trimester**
   The third trimester there is rapid growth of fetus to 3-3.5 kg and 50 cm in length. The fetal activity decreases as the fetus takes up more space. The mother's abdominal organs are compressed and displaced, leading to frequent urination, digestive blockage, and strain of the back muscles.

4. **Birth: Parturition**
   A series of strong, rhythmic contractions of the uterus (labor) pushes the baby out. Prostaglandins from the uterus, oxytocin from the posterior pituitary and nerves regulates labor contractions.

   The first stage of labor is the opening or dilation of the cervix. Complete dilation completes the first stage. The second stage of labor is the actual birth. The third stage is the expulsion of the placenta.

   Lactation occurs after birth. Progesterone decreases and prolactin is secreted which stimulates milk production after 2-3 days.

5. **Some Contraceptives**
   a. Rhythm method
   b. Barrier methods
      • Condom
      • Female condom
      • Cervical cap
      • Diaphragm
      • Foams, jelly (spermicide)
   c. IUD: prevents implantation of blastocyst in the endometrium
   d. Coitus Interruptus
   e. Birth Control Pill/ Morning after pill
   f. Norplant

XII. DEVELOPMENT: PROGRESSIVE CHANGES OF FORM AND FUNCTION
A. STAGES
   There are three stages to embryonic development: cell division, differentiation (the specialization of cells), and morphogenesis (the movement of cells and tissues to convert the cell mass of the early embryo into a three dimensional form of a juvenile). Each egg cell at the time of fertilization consists of a haploid nucleus which is surrounded by a region of cytoplasmic substance that contains yolky material. The cell membrane plays and important role in fertilization.

B. THREE TYPES OF EGGS (DIFFERENTIATED BY THE YOLK QUANTITY AND DISTRIBUTION

1. **Birds and Reptiles**
   These have the largest yolks; an ostrich egg is the largest. Amphibians also have a relatively large yolk mass. If the yolk is on one side of the egg, it is called teloecithal. If the yolk is evenly distributed in the egg, it is called mesolecithal.

2. **Placental Mammals**
   Placental mammals produce eggs whose yolk is evenly distributed. The eggs are barely visible and only supply the embryo with nutritive materials for a brief period of time. A few days after fertilization, implantation occurs in the uterine wall. These eggs are called centrolecithal because the egg is contained in a central yolky region entirely surrounded by a thin layer of cytoplasm.

3. **Arthropods**
   Arthropods have a central yolky region that is surrounded by a thin layer of cytoplasm. These eggs are centrolecithal. The cell membrane is a supplemental transparent substance that surrounds the cell. Mammalian eggs have a dense cell covering that is held together by a jelly like substance.

C. FERTILIZATION

Soon after the sperm touches the egg surface, the arcosome releases a hydrolytic enzyme that enables the arcosome to penetrate the jelly coat. The arcosome is coated with bindin, a protein that binds to specific receptor molecules in the vitelline layer, which is just outside the plasma membrane of the egg. The plasma membrane of the sperm fuses with the plasma membrane of the egg.

The outer membrane of the egg undergoes several changes.
1. It produces a barrier to prevent other sperm from entering.
2. The egg cytoplasm around the sperm head engulfs the sperm. The head and neck region detach from the midpiece.

After fusion of the plasma membranes, the nucleus of the sperm enters the cytoplasm of the egg. The union of the gamete membranes opens ion channels that allow sodium (Na+) to flow into the egg cell, changing the membrane potential. The membrane depolarizes and prevents other sperm cells from fusing with the cell membrane. This is called the fast block to polyspermy.

The egg then responds to fertilization with a cortical reaction. The union of the sperm and egg causes calcium to be released in the cytoplasm, secreted from the ER in the egg. The increased concentration of calcium causes vesicles in the cortex, the outer zone of the cytoplasm in the egg, to fuse with the cell membrane. The vesicles release the contents through exocitosis into the perivitelline space between the cell membrane and the vitelline layer. The secreted substances loosen the adhesive material between the cell membrane and the vitelline layer. The resulting space swells by osmosis. With the swelling, the vitelline layer forms a hardened fertilization membrane. This membrane can prevent other sperm from entering. The formation of this membrane happens about a minute after fertilization, after the voltage moves across the membrane and the membrane has returned to normal. The development of the fertilization membrane is slow block to polyspermy.

D. EGG ACTIVATION

The in crease in the cytoplasmic concentration of calcium also initiates membrane changes within the egg. Prior to fertilization, the metabolism of the egg is slow. A few minutes after fertilization, cellular respiration and protein synthesis rates increase. The egg is activated. Calcium starts the expulsion of H+ from the egg and pH changes from 6.8 to 7.3 in the cytoplasm. This change in pH may be responsible for the metabolic changes in the egg. Fertilization and activation are two separate functions. Eggs can be artificially activated (by calcium injection or temperature shock) which can lead to the egg developing by parthenogenesis. Eggs with the nucleus removed can be activated and proteins will be produced. This means that eggs must have mRNA stockpiled prior to fertilization. Soon the sperm nuclear membrane breaks down and releases the

chromosomes into the egg cytoplasm. The sperm nuclear substances begin to migrate to the egg nucleus. The sperm and egg haploid nuclei migrate through the thick cytoplasm to form a tight union. The new cell is called a zygote.

E. FUTURE OF THE ZYGOTE

The zygote is one cell containing a full set of chromosomes, some cytoplasm, organelles and some food. From this cell an organism will be formed with its specialized tissues. As cells divide from 1 to 2 to 4 to 8 to 16, and so on, the cells reposition themselves. Tissues interact, grow around and into each other, fusing, spreading and shifting until a recognizable organism is produced. The key stages are Cleavage and the formation of the blastula, Gastrulation, and Organogenesis. The zygote diveds shortly after fertilization this is the first of many divisions. Each division is preceded by DNA replication. These divisions produce balls of cells. The embryo doesn't grow during this stage. The cytoplasm of the one large cell is divided up into cells called blastomeres. The cells do not go through the G1 and G2 stages of the cell cycle. The small cells increase the surface area to volume ratio. The second cleveage usually occurs more rapidly after the first. The cells will continue to divide and will take on the appearance of a hollow ball composed of small rounded cells.

Animal eggs have a definite polarity: the animal pole and the vegetal pole. The hemispheres of the zygotes are named after their poles. The animal hemisphere has melanin granules in the cortex and is gray in color. The vegetal hemesphere contains the yellow yolk. The first two cleavages are vertical and two cells in both the animal and vegetal poles are formed. The third division is horizontal, this creates an embryo with four cells in the animal and vegetal pole. During this time differences in dueterosome and protosomes development appear. In deuterosomes the animal pole is aligned directly with vegetal cells. In protosomes the animal cells are lined up with the grooves of the vegetal cells. Continued cell division produces a blastula with a blastocoel forming in the center.

F. GASTRULATION

Gastrulation is the rearrangement of cells in the blastula. The result of gastrulation is that some of the cells at or near the surface of the hollow blastula move to a new , more interior location, thus forming a gastrula. We'll look at gastrulation in a sea urchin and a frog.

1. **Sea Urchin**
   The blastula of the sea urchin is one cell thick. Gastrulation starts at the vegetal pole, and the cells slightly flatten to form a plate that invaginates or buckles inward. Cells near the plate separate from the blastula wall and enter the blastocoel as migratory mesenchyme cells. The buckled plate now forms into a narrower pouch called the archenteron, the primitive gut. The opening of the archenteron forms across the blastocoel. The embryo is now a gastrula with three primary germ layers. From outside to inside the three layers are the ectoderm, the mesoderm (from the migrating mesenchyme cells), and the endoderm. From these three layers all of the organs will develop.

2. **Frog Cell**
   The blastula is more than one cell thick. The vegetal cells are full with yolk. The first sign of gastrulation is a small crease, formed by bottle cells, on the blastula. These cells will burrow inwards, producing an invagination which is the dorsal tip of the blastopore. The involution happens when the cells on the surface of the embryo roll over the edge of the dorsal lip (into the interior of the embryo) and continue to migrate on the roof of the blastocoel. The dorsal lip will increase in size and form a circle which is then filled with a yolk plug. With the moving of cells, the blastocoel is nearly filled with cells. Now organs begin to form.

G. ORGANOGENESIS

Organs form from the primary germ layers. He first organs to form are the neural tube and notochord. The notochord forms just above the archenterons from the dorsal mesoderm, and the neural tube forms above the developing notochord as a plate of dorsal ectoderm. The neural plate coils itself into a tube and will become the brain and spinal chord, the central nervous system. Along the embryo's anterior-posterior axis, the notochord elongates. The notochord serves as the model which mesodermal cells will use to form the vertebrae. Strips of mesodermal cells, called

somites, are arranged on both sides of the notochord and will form the vertebrae and muscles of the axial skeleton. Next to somites are mesoderm cells that will become the lining of the coelom.

Ectoderm will become the external covering and associated glands, the inner ear, and the eye lens. Mesoderm will become the notochord, lining of the coelom, muscles, skeleton, gonads, kidneys and most of the circulatory system. Endoderm will become the lining of the digestive tract and gives rise to the outpockets of the archenteron- liver, pancreas, lungs. The ectoderm also forms the neural crest. These cells migrate to various parts of the embryo forming pigment cells in skin, forming some muscles of the skull, teeth, medulla of the adrenal glands, and peripheral components of the nervous system.

H. COMPARATIVE EMBRYOLOGY OF BIRDS AND MAMMALS

1. **Birds**
   The yolk is the egg cell swollen with food. The egg cell is surrounded by a protein rich solution (egg whites) which provides additional nutrients for the embryo. The cleavage of the fertilized egg happens outside the yolk. The animal pole of the egg will divide to form a blastodsc. Cleavage continues and the blastodisc cells are sorted, a blastocoel and blastula are formed somewhat differently than in frogs. Gastrulation in birds also involves cells moving from the surface to an interior location. The embryo forms a flattened gastrula called a primitive streak. The bird now has three germ layers from which organogenesis proceeds.

I. MAMMALIAN DEVELOPMENT

In the oviduct, the eggs are fertilized and the earliest stages of development occur. The egg moves down to the uterus and cleavage is relatively slow in mammals and the blastomeres are roughly of equal size. After five days, the embryo has 100 cells and the embryo is a blastocyst. At one end of the blastocyst is a group of cells called the inner cell mass that will provide some extraembryonic membranes. The outer epithelium is called the trophoblast. The trophoblast will form the fetal part of the placenta.

The embryo reaches the uterus as a blastocyst and ready to implant. The trophblast secretes enzymes that allow the blastcyst to implant into the uterine lining. Capillaries in the endometrium have worn away leaving a blood pool the surrounds the blastocyst. The trophoblast extends fingerlike projections into the maternal tissue, and from this the placenta will form. The inner cell mass will form a flat embryonic disc which will develop into the embryo. Once the blastula forms, gatrulation occurs with the inward movement of the cells from the upper layer through a primitive streak. Gastrulation will form the mesoderm and the endoderm. The chorion develops from the trophoblast and surrounds the embryo. The amnion encloses the embryo in a fluid filled cavity. The yolk sac has no yolk but produces blood cells which later migrate into the embryo. The allantosis is incorporated into the umbilical cord and organogenesis begins.

J. HOW ORGANS DEVELOP

1. **Two Basic Concepts**
   a. The organization of the cytoplasm of the unfertilized egg causes regional differences in the early embryo development of many animal species.
   b. A cell of an embryo can affect cytoplasmic changes that will affect the gene expression of neighboring cells. Chemical signals or membrane interactions can cause these changes.

2. **Factors in Development**
   a. Polarity of the Embryo
   Bilateral animals have an anterior/posterior axis, dorsal/ventral axis, and a right and left side. These are established at fertilization.

   b. Localized Cytoplasmic Determinants
   Organization of the egg cytoplasm has an impact and influence on early animal development. If the cytoplasmic substances are not evenly distributed in the egg, the blastomeres will differ in cytoplasmic components. These substances in the blastomeres are the cytoplasmic determinants

that determine the developmental fates of the different parts of the embryo by controlling gene expression.

c. Mosaic and Regulative Development

Depending on when the blastomeres lose their totipotency, the ability of a cell to retain the potential to form all parts of the animal; will determine if the development can be described as mosaic or regulative.

Mosaic: cells develop earlier, each cell rigidly produces specific parts of the embryo.

Regulative: cells are totipotent longer and their fates can be altered in animal development. Fate Maps and Analysis of Cell Lineages: For cells that are defined early in development, we should be able to determine which part of the embryo will be derived from each region of the blastula. This can be done now.

d. Morphogenetic Movements

Movement of the cells and changes in cell shape are important in animal development. These involve three properties of cells: Extension, Contraction, and Adhesion.

Extension and contraction usually involve the reorganization of the cytoskeleton, for example, the formation of the neural tube and neural plate, invaginations and evaginations. Ameboid movements are also important in gastrulationand neural crest dispersal. The extra cellular matrix helps guide cells in their movements. This matrix includes adhesive substances and films that direct cells on a route. For example, fibroectins help cells adhere to a surface as they migrate. Intracellular glue holds certain cells together as tissues and organs are shaped.

e. Induction

The ability of one cell group to influence the development of another group of cells is called induction. For example, some cells produce activin, which is a chemical signal that causes cells to move inward through the dorsal lip.

f. Differentiation

As tissues and organs form, cells begin to specialize. The beginning of cell differentiation is the appearance of tissues producing specific proteins. During differentiation cells become specialists, producing certain proteins.

g. Genomic Equivalence

All cells have the same genes but differentiate in both structure and function.

h. Determination

Before differentiation, the cell may be constrained to a particular course in development; the cell is determined. Determination appears to be a serial process. As cells develop, their options seem to narrow. The determination involves the control of the genome by the cytoplasm of the cell. Cytoplasmic cues can begin to determine cells as early as the first cleavage in mosaic cells.

i. Pattern Formation

The shaping of an animal and its individual parts involves pattern formation. This involves the forming of a body form with the specialized organs and tissues.

Homeotic Genes control the overall body plan of an animal. They control the fate of a group of cells. There are segments of DNA that have an identical sequence of 60 amino acids called homeodomains. These bond to specific DNA sequences. They activate or repress transcription by binding to enhancer regions of DNA. These sequences have been conserved in evolution and are almost identical across a wide variety of organisms.

Positional Development: genes that regulate the development must respond to some kind of positional information, this indicates a cell's location and relative positions to other cells.

Cells must receive and interpret environmental cues that vary from one location to another. One possibility is a chemical signal called a morphogen, that varies in concentration along a gradient.

XII.   NERVOUS SYSTEM
The nervous system allows animals to monitor both the outer and inner world.

A. FUNCTIONS
The nervous system has three overlapping functions:

1. **Sensory input**
Conduction of signals from sensory cells to the integration center of the nervous system.

2. **Integration**
Interpretation of information, carried out by the central nervous system – the brain and spinal cord.

3. **Motor output**
Muscles and other glands.

The peripheral nervous system connects the central nervous system (CNS) to the rest of the body.

B. NERVOUS SYSTEM: CELLS
There are two main cells of the nervous system: neurons and supporting cells.

1. **Neurons**
Neurons are nerve cells. A group of neurons travel along the same canals and form white fibers called nerves. These cells are the functional unit of the nervous system. They can react to environmental stimuli in specific ways. The nerves that are involved with detection of environmemtal stimuli are called receptors; some detect major, non-specific stimuli while others detect specific stimuli.

Stimulation results in the neuron's being activated. The message is carried to the spinal cord and then on to the brain. Once the message is in the central nervous system the message is decoded, by other neurons.

Neurons come in an array of sizes. All have a dendrite region. This area receives stimuli from either the environment or another neuron. The dendrites may or may not extend from the cell body. The signal moves from the dendrite to the cell body. The cell body contains the nucleus and most of the cell organelles. Clusters of cell bodies in the brain are called nuclei, and a cluster of cell bodies outside the brain is called a ganglion.

The axon is the trunk of the neuron. It mat be very long (in humans, up to 3 feet long), and transmits impulses away from the cell body. The axons of many vertebrae neurons are enclosed by a chain of supporting cells called schwann cells (in the peripheral nervous system) that form an insulating layer called the myelin sheath.

Neural impulses are transmitted both chemically and electrically. This can happen because the cell membrane has the ability to pump out certain molecules that have an electrical charge and allow other particles in.

There is a great diversity of neuron shapes and functions. There are three types of neurons:
a.   Sensory neurons communicate information about the external and internal environment.
b.   Motor neurons convey impulses from the CNS to effector cells.
c.   Interneurons which integrate sensory input and motor output.

2. **Supporting Cells**
   Supporting cells outnumber the neurons 10-50 times. These cells are essential for the structure integrity of the nervous system and the normal functioning of neurons.

   In the CNS, the supporting cells are glial cells. There are several types of glial cells.
   a. Astrocytes encircle the capillaries in thebrain and contribute to the blood- brain barrier. The barrier restricts the passages of most substances into the brain.
   b. Oligodendrocytes form insulating myelin sheaths in many cells of the CNS. In the peripheral nervous system, Schwann cells are the supporting cells that form the myelin sheath. These cells grow around the axons in a way that they form concentric layers. The lipid sheaths provide electric insulation of the axon.

C. RESTING NEURON: NEURAL IMPULSE
The signal transmitted along the length of the neuron is an electrical signal that depends on the flow of the ions across the cell membrane.

All neurons have a charge difference across the cell membrane. The inside of the cell is more negative than the outside of the cell. The differences can be measured by electrodes. This voltage measured across the membrane is the membrane potential. And ranges from –50mV to –100mV. The outside of the cell is called zero, so the negative sign is in reference to the outside of the cell. Or a resting neuron, the membrane potential is about –70mV. This is the resting potential.

Because of the selectively permeable membrane, there is a difference in the ionic composition between the intracellular and extracellular fluids, called membrane potential. Both the intra and the extracellular fluid contain ions. The principle cation (+ charge) outside the cell is Na+ with a small amount of K+. Inside of the cell the main cation is K+ with a small amount of Na+. The main anion (- charge) outside the cell id chloride (Cl-). There is some Cl- inside the cell; however, inside the cell is a class of negatively charged substances that can be treated as a single group.

The ions cannot diffuse across the membrane. They must move through the ion channels or be carried by transport proteins. These channels are selective for particular ions. Cells usually have greater permeability to K+ than to Na+, suggesting that the cell has more potassium channels than sodium channels.

There is a large concentration gradient of K+ out of the cell and the cell is very permeable to K+; hence there is a net flux of K+ out of the cell. As K+ leaves the cell, it shifts the positive charge from inside to the outside of the cell. Because the large group of negatively charged molecules (proteins, amino acids, sulfate, and phosphates) cannot leave the cell, the interior of the cell becomes more negative than the outside. The increasing negativity of the inside attracts the K+. If K+ were the only cation moving, then the potential of the inside when the K+ efflux equaled the K+ influx would be –85mV. This is the equilibrium potential. However, Na+ ions are also present and some move into the cell making it less negative. This makes the resting potential –70Mv. If left unchecked the concentration gradient of Na+ and K+ would disappear, but another type of cell membrane protein called the sodium potassium pump. This pump uses ATP to actively transport sodium out of the cell and potassium in the cell.

D. ACTION POTENTIAL
Neurons have proteins in their membranes called gated channels. These proteins let the cell change its membrane potential in response to stimuli that the neuron receives. If the stimulus opens up a potassium channel, the membrane potential will be more negative as K+ exits, this is hyperpolarization. If the sodium channels open and allows an influx of sodium, the membrane potential will be less negative, this is depolarization. The voltage changes caused by this are called graded potentials. A large stimulus will open more channels and produce a larger change in permeability.

In a neuron a graded potential can only occur until a level of depolarization called the threshold is reached. If a cell is depolarized to the threshold an action potential results. The threshold potential is 15-20 mV more positive than the resting potential and varies for different neurons.

The action potential is an all or none event. Once the threshold is met, an action potential is triggered. When that happens, there is a depolarizing phase; the membrane actually reverses polarity. The interior of the cell is now positive which is followed by a repolarizing stage when the resting potential is reestablished. There may be a stage in which a neuron is reestablishing its resting potential and the inside is more negative than usual. This is called the undershoot and is corrected quickly.

The action potential comes about because of voltage-gated channels which open and close in response to membrane potential. The two types of channels which contribute to the action potential are the sodium and potassium channels. The voltage-gated sodium channels have two gates that are voltage sensitive. The activation gate responds to depolarization by quickly opening. The inactivation gate responds to depolarization by slowly closing. At resting, the inactivation gate is open and the activation gate is closed. When the cell is depolarized, the activation gate quickly opens and the sodium rushes into the cell, thereby depolarizing the cell. More sodium gates open causing more depolarization (positive feedback). The opening and depolarizing happens until all the sodium channels are open.

When the cell repolarizes, the sodium-channel inactivation gate has closed. The voltage sensitive potassium channels open in response to depolarization which allows the K+ to flow quickly out of the cell. This helps restore the internal negativity of the resting neuron. If a second stimulus tries to stimulate the cell during repolarization, the cell will not respond. This is called the refractory period.

How do neurons distinguish strong stimuli from weaker ones? Strong stimuli result in a greater frequency of action potentials.

E. MOVEMENT OF THE ACTION POTENTIAL

A neuron is stimulated at its dendrites of the cell body, and the action potential travels along the axon to the end of the cell. An action potential that occurs at one end of the cell assures that the next region of the cell will be depolarized above the threshold which triggers a new action potential at that position. This will cause the next region to be depolarized and so on.

Speed of the Action Potential: One feature that affects the speed of the action potential is the diameter of the axon. The larger the diameter the faster the speed of transmission.

Another way to increase the action potential speed is b the use of myelinated axons. The myelin sheaths have small gaps called the nodes of ranvier between neighboring schwann cells. The voltage sensitive ion channels are concentrated in these node regions. The flow of ions can only occur at these regions. The action potential jumps from node to node, thus skipping the insulated regions. This is saltatory conduction which is a faster transmission of the impulse.

Review: If there is sufficient stimulus (above the threshold), then the neuron changes.
1) At any dendrite that receives a stimulus, the sodium pump drops briefly, less than a millesecond.
2) The Na+ rushes into the negatively charged interior.
3) The polarity of the inside of the cell changes from –70mV to +30mV which is a total of +100mV change. The cell is depolarized. This process of depolarization is called the action potential.
4) Depolarization moves along the entire length of the neuron in a wave like action. Following depolarization, an immediate eflux of K+ occurs through the membrane. The K+ outflow is followed by the Na+ pump restoration, this moves the Na+ out of the cell and the K+ back into the cell.
5) Too much K+ and Na+ are moved outside the neuron for a brief time. This is called the hyperpolarized state. During this state the neuron cannot respond to any stimulus.

F. SYNAPSE AND THE SYNAPTIC JUNCTION

The synapse is the space between cells of the nervous system. The transmitting cell is called the presynaptic cell and the cell receiving the stimulus is the postsynaptic cells. There are two types of synapses: electrical and chemical.

1. **Electrical Synapses**
    These allow the action potentials to spread directly from the presynaptic to the postsynaptic cell. These cells are connected by gap junctions. These channels allow the local ion currents of an action potential to flow between the neurons. These cells allow the impulse to travel from neuron to neuron without delay and no loss of signal strength. These are not as common as the chemical synapse.

2. **Chemical Synapses**
    Chemical synapses have a narrow cleft or gap that separates the presynaptic and postsynaptic cells. A series of events at the synapse converts the electrical signal of an action potential to a chemical signal and back to an electrical signal in the postsynaptic cell. On the presynaptic cell there is a swelling at the end of a branch called the synaptic terminal. Within the synaptic terminal are numerous sacs called synaptic vesicles that contain thousands of neurotransmitter molecules. When an action potential arrives at the synaptic terminal and depolarizes the presynaptic membrane, the vesicles move to the membrane that faces the cleft. Once depolarized Ca2+ moves into the cell through voltage channels, the sudden increase of calcium ions stimulates the synaptic vesicles to fuse with the presynaptic membrane and spill the neurotransmitter into the cleft by exocytosis. The neurotransmitter travels a short way to the postsynaptic membrane.

    The specific receptors that extend from the cell membrane on the postsynaptic membrane receives the neurotransmitters. These receptors are connected with selective ion channels that open and close controlling which ions exit and enter the cell. When a receptor binds to a neurotransmitter, it opens the ion channel that allows K+, Na+ and Cl- to cross the membrane.

Enzymes quickly break down the neurotransmitter into smaller components that are recycled by the presnaptic cells. The chemical synapses allow for signals to travel one way. The synaptic cells can also integrate information made of excitatory signals.

3. Neuron Integration at a Cellular Level
A neuron may receive information from many different neurons. Some messages will be inhibitory and others will be excitatory. How a neuron reacts depends on the ability to integrate the positive and negative signals. At an excitatory synapse, the neurotransmitter receptors control gated channels that allow Na^+ to enter and K^+ to leave. There is a net flow of positive charges into the cell which depolarizes the cell. This is an excitatory postsynaptical potential (EPSP). At an inhibitory synapse, the neurotransmitter molecules causes the cell to become hyperpolarised by making the membrane more permeable to K^+, which rushes out or Cl^-, which moves in. This makes it more difficult for the threshold to be reached. This is called the inhibitory postsynaptical potential.

A single EPSP at one synapse is usually not strong enough to trigger an action potential. Usually, several synapses acting at the same tie on the same postsynaptic cell can induce a cell to depolarize. The additive effect of postsynaptic potentials is called summation.

4. Two Types of Summation

a. **Temporal summation**
    This occurs when chemical transmissions from one or more synaptic terminals occur so close together in time that each potential particularly depolarizes the membrane before the voltage returns to the resting potential after the prior stimulation.

b. **Spatial Summation**
    This occurs when several different synaptic terminals, usually belonging to different presynaptic neurons, stimulate the postsynaptic cell at the same time.

G. NEUROTRANSMITTERS AND RECEPTORS

1. **Criteria**
    For a compound to be recognized as a neurotransmitter, it must meet three criteria.

a. The presynaptic cell must contain the specific compound, which will affect the membrane potential of the postsynaptic cell, in synaptic vesicles and when properly stimulated, discharge the substance.
b. The compound should be a EPSP or IPSP hen artificially injected into the synapse.
c. The substance must be removed quickly from the synapse by either enzymes or the cell.

2. **Types of Neurotransmitters**
   a. Acetylcholine (ACh) is a common neurotransmitter. ACh is released at the neuromuscular junctions, exciting the motor cells. At other times, ACh can be inhibitory. The effect depends on the receptors found on thee postsynaptic membranes.

   b. Biogenic amines are neurotransmitters derived from amino acids. Chatecholamies are produces from the amino acid tyrosine and include epinephrine (in the CNS), norrepinephrine (in the atonomic nerves), and dopamine (in the brain).

   c. Neuropeptids are short chains of amino acids that can serve as neurotransmitters. Endorphin are neuropeptides which decreases perception of pain.

H. NEURAL CIRCUITS AND CLUSTERS
There are three major patterns of neurons which are usually grouped together as a circuit.
1. Convergent circuit in which many neurons converge on one neuron.
2. Divergent circuit in which one neuron stimulates many neurons.
3. Reverberating neuron is a circuit of neurons n which a signal returns to its original source.

Nerve cells are not evenly distributed, they are arranged in groups called ganglia. A ganglion occurring in the brain is called a nucleus. The ganglia allow the coordination of activities without involving the whole system.

I. INVERTEBRATE NERVOUS SYSTEM
The simples system can be found in the phylum cnidarians. These organisms have a loosely organized net of nerves with no central control. Echinoderms have nerves that branch from the central nerve ring around the oral disk. This system coordinates the movements of the arms. Bilateral animals have a concentration of organs around the anterior end, a trend called cephalization. Enlargement of the anterior ganglia would lead to the first brain. Invertebrates show increasing cephalization from flatworms to annelids to arthropods.

J. VERTEBRATE NERVOUS SYSTEM
It is derived into different parts, the Central Nervous System (CNS) which processes information and the Peripheral Nervous System (PNS) which caries the information.

1. The Peripheral Nervous System
Consists of two separate groups of cells

a. In the sensory division, are afferent cells which bring information into the central nervous system.
b. In the motor division, are efferent cells which carry signals to the muscle cells. The motor nervous system has two divisions with separate functions.

   1) The Somatic Nervous System carries signals to skeletal muscle following a response to external stimuli. This system is voluntary but a substantial portion of the skeletal muscle movement is actually determined by a reflexes (a reflex is an automatic reaction to a stimulus).
   2) The Autonomic Nervous System regulates the internal environment by controlling smooth and cardiac muscles, the organs of the gastrointestinal tract, the cardio vascular system, the excretory system, and thee endocrine system. The control is usually involuntary. There are two divisions of the autonomic nervous system. When the two go to the same organ, they are antagonistic to each other.

      a) The sympathetic which increases the energy expenditure and prepares an individual for action.

b) The parasympathetic which gains and conserves energy.

2. Central Nervous System: CNS
It forms the bridge between the sensory and motor functions of the peripheral nervous system. There are two main divisions: the spinal cord, which is inside vertebral column, and the brain, which is on top of the spinal cord and is the center for integration of homeostasis, perception, movement, intellect, ad emotions.

The CNS is covered by meninges. These are three layers of protective connective tissue.

Neurons in the CNS are located in bundles. The myelin sheath gives them a white appearance which is called white matter / inner region. The outer region is the gray matter which are thee pathways going to the cell body.

There are ventricles which are fluid filled spaces in the brain that connect with the narrow central canal of the spinal cord. The spaces are filled with cerebrospinal fluid, which the brain forms by filtering the blood. The cerebrospinal fluid absorbs shock, cushions the brain, and carries nutrients, hormones, and white blood cells to different parts of the brain. The cerebrospinal fluid flows through the ventricles and central canal and empties back into the veins.

a. **Spinal Cord**
The Spinal Cord has two main functions.
1) Integrates simple responses to certain stimuli
2) Carries information to and from thee brain.

The spinal integration is usually a reflex, as sensory nerve carries information up to the spinal cord where it connects with a motor neuron.

b. **Brain**
The brain is an over development of one end of the nervous system.

1) Development of the Brain
Advanced planarians have a longitudinal, bilaterally symmetrical body plan composed of two nerve cords. A concentration of neurons, called a ganglion, in the head region. The ganglion can be seen as a precursor to a brain.

Annelids have a large ganglion which is surrounded by the esophagus in the head of the worm. Each segment has a pair of fused ganglia.

Arthropods have a brain that is composed of ganglia above and below the esophagus. Each brain part has a specific role.

Echinoderms have a nerve ring around the mouth. Five nerves tracks in some groups the nerve trunks consist of specialized neuroectoderm. However, there are no ganglionic masses of nerve tissue.

2) Brains of Vertebrates
There are three parts of any vertebrate brain: The forebrain is the cerebrum. The midbrain senses the visual and olfactory stimuli. The hind brain controls the involuntary actions.

Chondrichthyes: Sharks have a small cerebrum. If it is removed, the shark shows little or no change in behavior. A large part of the brain is devoted to smell.

Osteichthyes: Bony fish brains are more differentiated. If the cerebrum is removed, it causes alterations in their behavior.

3) The Human Brain

The forebrain contains the two cerebral hemispheres and the internal structures which include the thalamus and hypothalamus. The mid brain is between the forebrain and hind brain. The hind brain is made up of the medulla, cerebellum and pons. The medulla controls the mechanical processes, such as breathing and heart beat. The cerebellum controls balance, equilibrium, and coordination. The pons is the portion of the brain stem, above the medulla that connects the cerebellum to the cerebral cortex. The thalamus is a great relay station. It consists of densely packed clusters of neurons and connects different parts of the brain. The thalamus contains the reticular system which is an area of interconnected neurons which may activate the appropriate parts of the brain. The hypothalamus is small and densely packed with cells. It is important in regulating the internal environment as well as general aspects of behavior. The hypothalamus controls heart rate, blood pressure , and body temperature. It helps regulate pituitary glands, and controls basic drives such as hunger, thirst and rage. The cerebrum is the center of intelligence. The more the cerebrum convolutes, the more the surface area of the cerebrum increases. The two hemispheres are equal in potential, but not identical. The primary route of communication between the right and let cerebral hemispheres is the corpus callosum. If this is cut, the halves cannot communicate.

XIV. THE SENSES

Sensations are nerve impulses that are conveyed as action potentials along sensory neurons to the brain. Once the brain is aware of the sensations, they are perceptions.

A. FUNCTION OF SENSORY RECEPTORS
Receptors are structures which transmit information about the changing external and internal environment. Receptors are modified neurons that can occur singly or in groups along with other cell types within sensory organs: eyes, ears, etc. the basic function of receptor cells is to change the stimuli into action potentials and carry those action potentials throughout the nervous system. There are five functions that are common to all receptor cells: Reception, Transduction, Amplification, Transmission, and Integration.

1. **Reception**
    Reception is the ability of the cell to recognize stimuli. Each receptor has a region suited to absorbing a particular type of stimulus.

2. **Transduction**
    Transduction is thee conversion of stimulus energy into electrochemical activity of the nerve impulse. The stimulus changes the permeability of the receptor cell, this changes the membrane potential which causes an action potential.

3. **Amplification**
    The stimulus needs to be amplified so it can be carried by the nervous system. The amplification of the signal may occur in the sense organ or as part of transduction.

4. **Transmission**
    The action potential must be transmitted to the nervous system. The initial response of the receptor to the stimulus is called the receptor potential which is a graded change in membrane potential.

5. **Integration**
    Integration is the processing of information. One type of integration by the receptor cell is sensory adaptation. Sensory adaptation is a decrease in sensitivity during continued stimulation. Receptors are selective in the information they send to the DNS. Integration of sensory information occurs at all levels within the nervous system.

B. TYPES OF RECEPTORS

1. **Thermoreceptors**

Many vertebrates have specific heat receptors. There are two types of receptors which may be responsible for the registering of heat and cold. Ruffin's end organs may be heat receptors and the bulbs of Krause may be the cold receptors.

2. **Mechanoreceptors**
   There are two types of contact receptors: pressure and touch. The pressure receptors are located deep in the skin and utilize three nerve endings: Heavy pressure is picked up by Pacinial Corpuscles and light pressure is picked up by Meissners" Corposcles. Merkel's Disks are also close to the surface and may be light touch detectors. In most mammals, touch sensitivity seems to be great around hairy areas. In primates, touch is greatest around the lips, eyes, and fingertips. Muscle spindle contains modified muscle fibers attached to a sensory neuron which runs parallel to the muscle. When the muscle is stretched, the neuron is stretched and the neuron is depolarized. The signal moves to the spinal cord. Hair cells are mechanoreceptors which are used to detect motion and can be found in the vertebrate ear, lateral line of fishes, and amphibians. These "hairs" are either specialized cilia or microvilli. When the cilia are bent the cell membrane is stretched which increases the cell permeability to sodium and potassium ions. The specificity allows hair cells to respond to the direction, strength, and speed or the motion.

3. **Hearing and Balance Receptors**
   Both senses involve mechanoreceptors that trigger action potentials when the hairs are bent. The sound receptors of most species of vertebrates are located in the inner ear. Land vertebrates have an auditory canal and one to three middle ear bones that transmit vibrations to the tympanic membrane or ear drum. The tympanic vibrations go to the inner ear which stimulate auditory receptors which then carry the impulses to the brain.
   In mammals, the auditory apparatus differs in three basic ways from other animals.
   a. There is an external ear or external pinna. In most mammals this can move to maximize sound input. The external ear collects sound waves that move down the auditory canal to the tympanic membrane.
   b. The middle ear has three bones: the hammer (malleus), the anvil (incus), the stirrup (stapes). These bones move an oval window beneath the stapes. The middle ear also opens up into the Eustachain Tube.
   c. The movement of the oval window moves fluid in the cochlea. The cochlea is a structure that is coiled like a snail shell. Frequency discrimination in the cochlea is possible by the neurons attached to hair cells. The sensory "hairs" of the hair cells are actually modified cilia. The cochlea has two chambers separated by the cochlear duct. The cochlear duct is filled with endolymph and has the organ of corti which contain the receptor cells in the ear. These receptor cells are actually hair cells that project into the cochlear canal.

4. **Process of Hearing**
   Vibrating objects create sound waves in the air. These waves cause the tympanic membrane to vibrate with the same frequency as the wave (frequency is the number of vibrations per second). The tree bones in the middle ear amplify and transmit these frequencies into the oval window. The vibrations of the oval window produce pressure wave in the fluid within the cochlea. The cochlea changes the energy of the vibrating fluid into action potentials. The vibration oval window creates a wave in the fluid which moves around the cochlea through the tympanic canal, stopping at the round window (end of the canal) and dissipates. The wave hits the organ of Corti and stimulates the hair cells. The stimulation makes the cells more permeable to sodium, resulting in depolarization and an action potential. Volume is determined by the amplitude of the sound wave. The greater the amplitude the more vigorous the vibrations of the fluid in the cochlea. Pitch is determined by the frequency of the sound wave. A shorter frequency has a higher pitch. Each region of the organ of Corti is activated by particular frequencies.

5. **Balance and Equilibrium**
   Part of the inner ear consists of the semicircular canals. Behind the oval window is a vestibule with two chambers: utricle and saccule. The utricle opens up into three semicircular canals.

   The semicircular canals allow for the body to sense motion. Fluid moves in the canals. The semicircular canals are arranged in three planes of space to detect rotation of the head. Hair cells in the utricle and

saccule respond to changes in the head position. Motion sickness occurs when the ears sense motion but the eyes do not.

6. **Vision Receptors**

Light receptors are sensitive to a particular part of the electromagnetic spectrum, 430 nm to 750 nm. Visual receptors contain pigments which absorb certain kinds of light energy and transform the energy to a neural stimulus. There are two types of receptors: rods, which are sensitive to all wavelengths of the visible light, and cones, which respond only to specific colors. There are three types of cones: red sensitive, green sensitive, and blue sensitive. The ranges of sensitivity overlap, and our perceptions of multitude of colors derive from the balance of stimulation of the three populations of cones.

   a. **Eye Structure**

   The conjunctiva is the transparent membrane that covers the font of the eye except for the cornea and the lines the inside of the eyelid. The cornea is the transparent covering over the pupil that lets light in. The pupil is the opening that lets light into the eye. The iris is the colored part off the eye. The lens focuses the image onto the retina. Ciliary Muscles stretch the lens. The retina contains the photoreceptor nerves. The vitreous humor is the transparent jelly in the eye which holds the eye shape. The optic nerve transmits the impulse to the brain. Everyone has a blind spot where the optic nerve enters the retina. There are no photoreceptors at that spot.

   The choroids layer is dark and pigmented. It prevents light from reflecting in the eye. The fovea is an area on the retina that contains the highest concentration of rods and cones. The sclerotic layer surrounds the eye except for the conjunctiva and the cornea.

   b. **Seeing in Vertebrates**

   Light enters through thee pupil and is focused by the lens onto the retina, a sensitive layer of pigment at the back of the eye. The mammalian retina is made of two types of photoreceptors: rods and cones.

   c. **Signal Transduction in the Eye**

   In the eye, there are 125 million rod cells and 6 million cone cells which accounts for 70% of all receptors in your body. Rods and cones have different functions in vision. Rods are more sensitive to light bud do not distinguish colors, we see at night but in black and white. Cones are cells that need more light to be stimulated, but they can detect color. In humans, rods are found in the greatest density at the lateral regions of the retina and are absent in the middle (fovea). The cones greatest density is in the middle of the fovea. The light absorbing molecule is retinal, which is synthesized from vitamin A. the retinal is combined with opsin, which is a membrane protein. Rods have rhodopsin, which is their own type of opsin which is bonded to retinal. The rhodopsin absorbs the light, the retinal changes shape and separates from the rhodopsin. The is referred to as bleaching. In the dark, retinal rejoins with opsin. When you walk into a dark room from a bright environment, you are almost blind because there is not enough light to stimulate the cones and the rods need time to become functional again after being bleached.

   Color vision is a result of three subclasses of cones each with its own type of opsin attached retinal, called photopsin. The red cones, green cones, and blue cones all have their own type of phototpsin.

   Other types of cells are needed in the retina in order for the transduction of light energy into an action potential. Light hyperpolarizes the membrane which decreases the permeability to sodium ions. The photoreceptors release less neurotransmitters in the light than in the dark. The axons of the rods and cones synapse with bipolar cells which synapse with ganglion cells and with horizontal and amacrine cells. These cells help integrate the information before it goes to the brain.

   d. **Visual integration**

   Signals rom the rods and cones may travel either vertically or laterally.

Vertically: The signal goes from the receptors to the bipolar cells to the ganglion cells.
Laterally: The horizontal cells carry signals from one rod or cone to other receptor cells to several bipolar cells. Amacrine cells spread the information from one bipolar cell to several ganglion cells. When a rod or cone are stimulated a horizontal cell which stimulates nearby receptors but inhibits distant receptors and bipolar cells which is lateral inhibition. This sharpens the image. Axons from the ganglionic cells form the optic nerve that sends the sensations from the eyes to the brain. The optic nerve from the two eyes meet at the optic chiama near the center of the base of the cerebral cortex. The optic chiasma is organized so that the right side of the brain receives image from the left eye. The information is sent to the visual cortex.

7. **Chemoreceptors: Chemical detection in vertebrates**
    a. **Smell: Olfaction**
       Olfaction in vertebrates is usually accomplished by moving chemical laden water or air into a canal or sack that contains the chemical receptors. The chemicals. The chemicals cant be detected until they go into solution. The nasal passages of all vertebrates are moistened by mucus; this is where the olfactory receptors lie. In land vertebrates the best sense of smell is found among mammals, especially carnivores and rodents. Carnivores often find their meals by smell. Rodents discriminate among themselves on the basis of families and they may recognize each other by smell. Olfaction is poor in primates.
       Olfactory receptor cells line the upper portion of the nasal cavity and they send impulses along the axons to the olfactory bulb of the brain. The receptive ends of the cells contain vilia that extends into the layer of mucus. When a substance diffuses into the region, it binds to a specific receptor on the olfactory hairs and depolarizes.

    b. **Taste: Sustation**
       The sense of taste is neurologically very similar to the sense of smell. In land dwelling animals, taste receptors are confined to the mouth area. There are four basic tastes: sweet, sour, salty, and bitter. In humans, these are located in specific areas of the tongue; sweet on the tip, sour on the sides, bitter on the back and all parts of the tongue are sensitive to salt. Studies suggest that the cells of any taste bud can respond to three or even four tastes but they are more sensitive to some than others.
       If both salt and sweet fire at the same time, how does the brain distinguish between the two tastes? Each taste has its own neural code, producing different firing patterns in the receptors. Some animals have an affinity for tastes, while others don't. For example, cats do not have taste buds for sweets, while guinea pigs do. The differences among arumal tastes correlates with their diets. For example, cats are flesh eaters; they would have little use for sweets. Humans are omnivores and eat almost anything.

8. **Pain receptors**
   Almost all animal experience pain, although we cannot say what perceptions they actually associate with the stimulation of their pain receptors. Pain is detected by a class of dendrites called nociceptors. Different groups of pain receptors respond to excess heat, pressure or specific classes of chemicals released from damaged/ inflamed tissues. Prostoglandins sensitize the receptors.

Unit XI
Ecology
Ecology: study of the relationship of living things and their environments.
Review: A population is a group of organisms of the same species that live in the same area or are interbreeding and sharing genetic information.

I.   **Population Dynamics.**
      A. Properties of Populations

The individual of a population is transitory, but the population endures. Properties of populations include growth patterns, morality patterns, age structure, density and dispersion. In the absence of net immigration or emigration, the growth rate increase is equal to the birth rate minus the death rate. The growth rate can be positive can be positive or negative. This property of a population per capita rate of increase is symbolized by the letter r. if the population increases at a constant rate, it shows an exponential curve. This can be described by the differential equation.

$$DN/dt = rN$$

R= per capita increase N=# of individuals present, t= time period. This type of growth is sometimes called logarithmic or log growth, presumably because the graph of log N vs. t is a straight line.

The exponential growth curve is shown by microorganisms in the lab, and also by the initial stages of an algal bloom. In nature, short term exponential growth occurs when opportunistic species invade an area and use abundant local resources. Weeds and some insects are examples of opportunists.

c. Limiting factors: carrying capacity

For many populations, the number of individuals in an area is determined by the environment. A given environment can support only a limited number of individuals. Population size hovers around this number which is known as the caryin capacity.

In the environment it may vary seasonally. A simple way of showing the effect of the carrying capacity is through the following equation often called the logistic equation.

$$Dn/dt = rN (k-n)$$

R=capita increase and it is multiplied by the number of individuals present N at any one time. K=carrying capacity, the number of individuals the environment can support over a specified amount of time.

The (k-n)/ K is a negative feedback term. If N is small, (k-n)/K and the curve, if graphed, is almost an exponential curve. As N increases, then the value of (k-n)/k decreases and the growth curve slows. When n=K, growth stops. If the number of organisms, N, becomes grater than K, growth is negative. Eventually the population stabilizes. The model of population growth, represented by the s-shaped or sigmoid curve is called the logistic.

2. Survivorship Patterns

Mortality also affects population size. There are three basic survivorship patterns. These patterns often show up in combination in a population.

   d. type I
      Most organisms die at the later stages in life
   e. type II
      Mortality rate is the same for all ages
.c. type III
      Most organisms die in the early stages of life

3. Age structure

Mortality patterns affect age structure of a population. Age structure is the number of individuals of different ages in the population. A cohort is the individuals in a population of the same age. A plot of cohort survivorship for the population yields the age4 of the population.

4. Density and Dispersion

Population: Density, the number of individuals per unit area or volume.
Dispersion: The pattern of distribution of the organisms within the two or three dimensional space.

There are three basid cispersion patterns.

a. Random
   The spacing between individuals is irregular; individuals are spaced independently of one another.

b. Clumped

Individuals associate in patches. The presence of on individual increases the chance of finding another individual.

    c. Regular
    Individuals are evenly spaced within an area.

A number of factors, biotic and abiotic, may affect the spatial distribution of a population. Dispersion patterns often rely upon the distribution of essential resources. These dispersion patterns are not fixed and can change either seasonally or in different parts of the life cycles.

Dispersion patterns may also depend upon the scale of observation. A local scale (a few square meters) that shows a random distribution may reveal a clumped distribution of a larger scale.

B. THE REGULATION OF POPULATION SIZE
Two influences on population size are limiting factors and population cycles.

1. Limiting Factors
Specific limiting factors affect the size and density of a population. The most important factors are the organism's tolerance to factors such as light, temperature, available water, salinity, nesting space, and availability of required nutrients. If any requirement is in short supply, or any environmental factor is too extreme, growth of the population may not be possible.

2. Density-dependent and Density-independent factors
Density Dependent Factors cause changes to the birth or death rate as the population density changes, usually causing an increase in the death rate as population density increases. For example, a depleted food supply may increase competition which increases the mortality rate. Also predators may be attracted to an area with a higher concentration of prey.

Density Independent Factors are those that affect the birth rate or death rate regardless of the population size. For example, environmental disturbance such as a flood will cause a similar death rate in a large or small population.

3. Population Cycles
Population fluctuations that peak regularly over the course of years are an indication of the complexity of population dynamics and are not well understood by population ecologists.

C. LIFE HISTORY PATTERNS
This is a variable property of populations.
There are two extreme alternatives: r- selected (prodigal) and k- selected (prudent).

1. Early or Late Reproduction
Breeding early or late can affect population growth.
A short life expectancy strategy is to reproduce early.
A long life expectancy strategy is to put energy into growing fist and then reproducing.

2. The Asexual Advantage
Asexual organisms increase the number of individuals in a population quickly. For example, some plants have runners that are able to grow and cover large areas. These new plants root and have continual support of the patent plant as they grow. Survivorship is higher in plants produced from runners than those produced from seed.

Parthenogenesis is another form of asexual reproduction. Parthenogenesis is the development of an organism from an unfertilized egg. Parthenogenesis always results in female offspring. (e.g. Dandelions form flowers and sometimes functionless pollen grains)

Parthenogenesis also occurs in some invertebrates, fish, amphibians, and reptiles.

3. **Consequences of Life-History Patterns**
   Opportunistic organisms appear to lead risky lives, but these populations can recuperate their numbers quickly following a population crash because a population can be built from only a few organisms.

   Populations composed of long-lived, slow to mature individuals have an increases probability of long tern survival. However, they are slow to recuperate their numbers when population size is reduced.

II. COMMUITY INTERACTION
A community is composed of all of the populations of organisms inhabiting a common environment and interacting with one another. These interactions can be classified as competition, parasitism, predation, symbiosis, commensalism.

A. COMPETITION
Interaction between individual organisms off the same species (intraspecific competition) or different species (interspecific competition) that use the same resources which are present in limited supply. As a result of the competition, the overall fitness (reproductive success) of one or both competitors may be reduced.

1. Types

   a. **Interference Competition**
      In animals this involves over fighting face to face interactions. In plants it may take the form of secreting toxins that harm or restrict the growth of potential competitors.

   b. **Exploitative Competition**
      Removing a resource and leaves less of competitors. As a result, organisms with more similar needs have more intense competitive interactions.

   The principle of competitive exclusion was developed in 1934 by Russian biologist G.F. Gause. This states that if two species are in competition for the same limited resource, on of the species will be more efficient in utilizing or in obtaining access to the resource. That species will eliminate the other species in situations I which they occur together.

2. **The Ecological Niche**
   Thee total environment and way of life of all the members of a species in a community, or a specific role of a species within a community is termed its niche. The niche includes physical factors, such as temperatures and moisture; biological factors, such as food availability, competitors, or predators; and behavioral habits, such as seasonal activities and movements. These factors determine species and their interactions with the environment.

   a. **Fundamental Niche**
      This refers to the physiological limits of tolerance of the organism, the niche is occupied by the organism in the absence of interactions with other organisms.

   b. **Realized Niche**
      This is the portion of the fundamental niche actually used by an organism and is determined by physical factors and interactions with other organisms.

3. **Resource Partitioning**
   If two similar species are living in the same area, then their niches are expected to be different in some way. These species may appear to be competing for the same resources, but upon close examination one would find that their respective uses of the resources would differ in some way, thus lessening competition and avoiding competitive exclusion.

In some cases resource partitioning is thought to be due to ongoing competition for resources. In other cases, the partitioning is thought to have occurred because of competitive interactions in the past, leading to different adaptations that enabled the two species to coexist.

4. Character Displacement
Character displacement is a phenomenon in which species that live together in the same environment tend to diverge in those characteristics that overlap.

5. Winner Takes All
Competition may not only wipe out individual organisms, but competition between species may lead to the elimination of a species from an area.

B. PREDATION
Predation is the eating of live or freshly killed organisms. To do this predators use a number of techniques and foraging strategies. These strategies are under intense selective pressures. If an organism can procure prey, it reproduces more. If prey can avoid predators, then the prey are more likely to have offspring.

Arms race: Predators and prey are involved in an ever-escalating arms race.

Escape from Predation: Prey often escape predators without engaging in combat. Some are master of camouflage. Others use hiding places like burrows. Still others use temporal strategies/

1. Predation and Population Dynamics
For many populations predation is the main cause of death. However, if predation reduces the number of prey at a certain age group, then it can alter the structure of a population and promote adjustments in life history patterns.

Predation on large herbivores kills animals in poor physical condition. In some cases, predators limit their prey species.

Most predators have more than one prey species. When one prey species decreases, predation on the other species increases. The availability of prey is a major determinant of carrying capacity of the predator population. In many situations, when the prey population increases, so do the predators. When the predator population increases, the prey number decreases, bringing down the number of predators. Why do we see this?

There are three hypotheses.
    a. When the population of prey decreases, predators have no food, and thus the population of predators decreases, the prey population increases.
    b. Prey population may undergo a regular cycle, (e.g. a regular 10 year cycle.)
    c. Predator populations may undergo a regular cycle.

2. Predation and Species Diversity
Predators can affect the number and types of species. Predators can eliminate species in an area, but can also maintain species diversity. Predation often keeps a species that would normally dominate an area in check. Without predators, one species could competitively eliminate other species.

C. SYMBIOSIS
Symbiosis is the close and long term association between organisms of two different species.

There are three types of symbiotic relationships:

1. Parasitism
This occurs when one species benefits and the other species is hurt. This can be considered a special form of predation in which the predator is smaller than the prey. Parasitic diseases are more apt to kill the very young, the very old or the disabled. However, if a parasite kills a host, it too dies.

2. **Mutualism**
   This occurs when both species benefit from the relationship. Examples include the evolution of the eukaryotic cell, mycorrhizae, nitrogen fixing bacteria, and lichens.

3. **Commensalism**
   Commensalism is when one species benefits, and the other neither benefits nor is harmed, (e.g. the remora-shark relationship.)

D. COMMUNITY COMPOSITION AND THE QUESTION OF STABILITY
What determines the number of species in a community? What factors underlie the changes in community composition that are revealed by close observation to occur with the passage of time?

1. Island Biography Model
There is a balance between the rate at which species already present become locally extinct. The number of species is an equilibrium between those two rates. The composition of the species is in non-equilibrium. When a species becomes extinct, it may be replaced by a different immigrating species.

There are two variables in the Island Biography Model of species diversity: island size and the distance from a source of flora or fauna.

2. The Intermediate Disturbance Hypothesis
Among the most diverse communities are not the tropical rainforests and coral reefs. It is now thought that their diversity is a function of the frequency and magnitude of the disturbances.

Disturbances can take many different forms. After the disturbance, the open area is invaded by immature forms of species. These species are species that live in close proximity to the open area and are reproducing at the time of the disturbance. If disturbances occur frequently, the species that can invade, mature, and reproduce quickly will be successful.

According to the intermediate disturbance hypothesis, as the intervals between disturbances increases, so does species diversity, However, if the interval between the disturbances continues to increase, the species diversity decreases. What causes this decline is the competition between species for resources. Also, predation and diseases would affect the community over time.

3. Ecological succession
This process occurs when the intervals between disturbances is long. The photosynthetic organisms are usually the first to recolonize. These organisms are usually replaced by other photosynthetic organisms. As the photosynthetic organisms changer, the subsequent animal life changes.

In a field which is abandoned, the field is bombarded by seeds from other vegetation. These will germinate and grow. Some plants will dominate the community. Eventually, these will replaced by a tree-community. These trees may be replaced by other trees.

4. The facilitation hypothesis
This hypothesis states that the sequence of photosynthetic organisms is so regular and predictable that success in can be viewed s analogous to the development of a simple organism. At each stage, the organisms prepare the way for the next organism. Ultimately, the community would reach a mature stable state which is a climax community.

5. The inhibition hypothesis
A more recent hypothesis which states that early species inhibit rather than help other organisms to colonize. Eventually, the earlier colonists are replaced by other invaders. These recent invader may in turn inhibit others from colonizing.

6. Tolerance hypothesis

The tolerance hypothesis states that the earliest colonist neither help nor hinder colonization by later species. The dominant species at any time is the species that can best tolerate the existing physical conditions and available resources.
Experiments support all of the hypotheses.

III. Ecosystems
Ecosystems: combination of biotic and abiotic components through which energy flows and materials cycle.

A. Solar energy
Life on our planet is powered by the sun. The sun is also responsible for climate, wind and weather.

On average the energy that arrives from the sun to the upper atmosphere is 1.3×10^{24} calories per year or 1.94 calories per cm^2/min. This is known as the solar constant which is only a tiny fraction of the energy produced by the sun. Because of the planet's upper atmosphere, only a fraction of that energy ever reaches the surface of earth.

1. Influence of the atmosphere
The atmosphere consists of four layers that are distinguishable by the temperature differences between each level.

a. Troposphere
The troposphere is the lowest layer, closest to the earth. The troposphere extends upwards 10 km. About 75% of all the molecules in the atmosphere are contained in this layer. At the upper boundary the temperature is about 50ºC.

b. Stratosphere
The stratosphere extends to an altitude of 50 km. The temperature in the stratosphere increases with altitude. At the upper boundary the temperature is similar to the earth's surface. A layer of Ozone is the reason for the increase in the temperature. The ozone is densest at the upper boundary. Ozone is formed when oxygen is broken apart by radiant energy and recombined. Ozone absorbs most of the ultraviolet rays- converting this energy to heat. About 99% of the atmosphere lies below the upper boundary of the stratosphere.

c. Mesosphere
The mesosphere is the next layer. In the mesosphere, the ozone level decreases and the temperature decreases.

d. Thermosphere
The thermosphere is the top layer. The molecules in the thermosphere are unshielded from the sun's rays. The molecules in this layer move at great speed, and have high kinetic energy.

30% of solar energy from the sun is reflected back into space from the clouds and dust. 20% of solar energy is absorbed by the atmosphere, 50% of the incoming radiation hits the earth's surface and a small amount is reflected, most is absorbed.

`   Energy absorbed by the ocean causes water evaporation which powers the water cycle. The energy absorbed by the ground is reradiated as infrared energy.

2. Climate, Wind, and Weather
The amount of energy received by the earth is not uniform. This is the major factor in the distribution of life on earth. At the equator, the suns rays are almost perpendicular. This sector receives more energy per unit area than the regions to the north and south, with the polar regions receiving the least amount of energy.

Since the earth is tilted, revolves and rotates; the amount of energy reaching different parts of the surface changes hour by hour, season by season.

Temperature variations over the surface of the earth and earth's rotation establish patterns of air circulation and rainfall. The patterns depend on the fact that cold air is denser than warm air. Hot air rises, cold air falls. Air rises and is exposed to low pressure, the air expands as it cools. Cool air holds less moisture, so rising cooling air loses moisture as precipitation.

The air is warmest along the equator, thus the air rises, creating an area of low pressure. Air must replace the air that rose; this air comes in from the north and south. The rising air cools, loses moisture and falls again at the 30º north and south latitudes where most deserts are found. The air picks up more moisture, heats up, and rises again at about the 60º latitude; this is a polar front. There is a third, but weaker, rising at the polar front and descending at the poles. The earth's spinning and the rising and falling air from the equator to the poles create the major wind patterns.

B. The flow of energy

The flow of energy through the ecosystem is the most important factor in the trophic relations of an ecosystem. On average .1% of the solar energy reaches the earth's surface. Only 1-3% of light that hits plants is used in photosynthesis.

1. Trophic levels

A food chain is the passage of energy from one organism to another, a chain of who eats whom, starting with autotrophs. It is a sequence of organisms related trophically to one another, such as prey and predator. The first (autotroph) is eaten by the second; the second is eaten by the third and so on. This is a series of feeding levels. The sequence of feeding or trophic levels is known as a food chain. In most ecosystems, food chains are linked together in complex food webs, which have branches and interconnections between many species.

Producers are found on the first trophic level of a food web and are primary producers. Terrestrial primary producers are plants. Aquatic producers are algae.

These organisms use light to produce carbohydrates through photosynthesis. Carbohydrates are the source for chemical energy. The biomass of the producers usually outweighs the consumers in an ecosystem. 99% of all organic matter is made up of algae and plants.

Gross Productivity is the measure of the rate at which energy is assimilated by the organisms in a particular trophic level. An analogy is the gross income of a business.

Net Productivity is the gross productivity less the cost of all the metabolic activities of the organisms in question. It measures the rte in which the organisms store energy which then becomes available to the organisms of the next trophic level. This is usually expressed in the amount of energy stored in chemical compounds or as the increase in the biomass in a particular period of time.

Biomass is the total dry weight of all organisms measured at any one time.

Sunlight intensity, temperature, and precipitation influence productivity in terrestrial ecosystems. Availability of essential minerals influences the productivity of aquatic ecosystems.

2. Consumers

Energy enters the animal world through herbivores (herbivores are primary consumers), which are animals that eat plants and/or algae. Most energy from the food is used to maintain life processes. Very little of the chemical energy is converted to new biomass. The actual increase of biomass is equal to the weight of individual animals and the weight of their offspring.

The next level, secondary consumers, is made up of carnivores, or animals that eat other animals, and omnivores, animals that eat both plants and animals. Only a small part of the original matter

and energy present in the body of the herbivores becomes incorporated into the body of the carnivore. Some food chains are made up of three or four consumer levels, five is usually the limit. With each trophic level, there is a decrease in the total amount of energy stored in the biomass; less energy is available to other consumers.

Detritivores are organisms that live off refuse of detritus, for example, dead leaves, branches, tree branches, animal feces, dead animals, discarded exoskeletons of insects. The category includes scavengers such as fungi, vultures. Decomposers are also included in this group. Scavengers are consumers that utilize dead prey. In forest communities, 99% of net primary production is consumed by detritivores.

C. EFFICIENCY OF ENERGY TRANSFER

Food chains are short because of the inefficiency in the transfer of energy from one trophic level to another. It is estimated that only 10%of energy stored in an organism is passed on to the nest trophic level.

Energy transfer and ecosystem structure:
The energy relationships between trophic levels determine the structure of an ecosystem in terms of both number of organisms and amount of biomass present.

D. BIOGEOCHEMICLE CYCLES

1. Sulfur Cycle
Sulfur occurs naturally in plants. It leaves the plant in two ways: through aerobic or anaerobic decomposition.

a.   Anaerobic
The plants decay in without oxygen. When this happens, hydrogen sulfide (H_2S) is formed. The H_2S enters the atmosphere and combines with oxygen to form sulfuric acid (H_2SO_4), which dissolves in the rain that falls to earth.

b. The plants decay in the presence of oxygen. Eventually, they form coal and oil. When burned, sulfur dioxide gas (SO_2) is formed. This gas enters the atmospheric water and combines with oxygen to form H_2SO_4. The sulfuric acid combines with rain which falls on the earth.

2. Phosphorous cycle
Phosphorous exists in inorganic compounds such as phosphate, PO_4^{3-}. The rain washes phosphorous from rocks into either the ground or into a river or stream.

a.   Ground Plants
These pick up the phosphorous. Animals eat the plants and produce wastes. The phosphorous from the wastes go back into the ground. When an animal dies, the phosphorous from its body also goes into the ground.

b.   River or stream
The river of stream empties into an ocean. The phosphorous compounds sink to the bottom of the ocean, where algae absorb them. Fish, snails, or other animals then eat the algae. Other animals, including humans, will eat the fish. The waste from the eaten fish will be absorbed into the ground.

3. Water Cycle
The water cycle contains a number of processes. The first process is evaporation, the process in which liquid water changes into water vapor. Most evaporation occurs from bodies of water, such as ponds, lakes, rivers, and oceans. Transpiration is the evaporation of water from plant leaves.

Condensation is the next process and is the reverse of evaporation,. In condensation, the water vapor changes to liquid water or ice. The clouds are formed by condensation.

Precipitation is the third process. In precipitation, enough water condenses that it falls to the ground in the form of rain, snow, hail.

Once the precipitation falls to he ground, the water may flow over the ground or in the ground into lakes, streams, rivers, oceans, or ponds. In these bodies of water, evaporation occurs and process begins again.

4. Nitrogen Cycle
The nitrogen cycle involves four processes. In the first process, atmospheric nitrogen is converted into ammonia. This process is carried out y either lightning or by nitrogen-fixing bacteria. These bacteria live symbiotically in the root nodules of plants.

In the second process, the ammonia is converted into nitrates. This process is also completed by bacteria. The nitrates are used by plants. The plans are then eaten by animals. Animal wastes, and the remains of dead plants and animals can be converted back to ammonia by ammonification bacteria; this is the third process.

Some of the nitrogen returns to the atmosphere. Denitrifying bacteria convert nitrates back into atmospheric nitrogen. This is the fourth pathway. The cycle is now complete.

5. Oxygen Cycle
Oxygen is used by organisms in the process of respiration, which takes in the oxygen and releases carbon dioxide. The carbon dioxide is absorbed by the photosynthetic organisms (plants, algae, and other protist and monerans) which convert the carbon dioxide into carbohydrates. These photosynthetic organisms release oxygen as a product.

Some of this oxygen enters oceans, lakes, streams, ponds, rivers, where fish and other animals use it. These organisms release carbon dioxide, which is absorbed by algae. The algae in turn use the carbon dioxide and release oxygen into the water or atmosphere. The cycle is now complete.

6. Carbon Cycle
In photosynthesis, organisms take in carbon dioxide from the atmosphere and make glucose. Some of this sugar is stored in the plant which is eaten by an animal.

The carbon enters the atmosphere again as carbon dioxide from respiration or decomposition of dead organisms.

7. Concentration of Elements
The elements needed by living organisms are generally present in their tissues in higher concentrations than in the surrounding air, soil, or water. This concentration is caused by the selective uptake of substances by living cells. Animals generally have a greater mineral requirement than plants because much of the biomass in plants is cellulose.

Foreign substances can enter the biogeochemical cycles and be passed on from one trophic level to the next. As this happens the substances can reach high concentrations at the top of the food chain, for example, DDT.

IV. BIOSPHERE
A biosphere is the part of the earth where life exits.

A. LIFE IN THE WATERS
Life began in the water. The aquatic environments and its inhabitants are the largest portion of the biosphere. There are two types of aquatic environments.

1) Freshwater
   a. Running water includes rivers and streams
   b. Standing water consists of lakes and ponds
2) Marine environment are oceans and seashores

1. Rivers and Streams

Rivers and streams are characterized by continuously moving water. These may start as runoffs from melting ice or snow or from springs, which are flows of groundwater from bedrock. They type of life found in rivers and streams depends upon the swiftness of the water. The farther from the source and the greater the volume the slower the water moves. In the swifter water, called riffles, photosynthetic organisms, algae and moss, cling to rocks. Insects live on the underside of rocks and gravel. In these areas, there is an abundance of oxygen and nutrients.

As the stream moves along, the riffles are interrupted by quieter pools where organic material may collect and decompose. Plants have a difficult time getting a foothold on the changing stream bottoms. Some invertebrates are typically found on the pools and still other organisms, for example, tout move back and forth between pools and riffles. As streams broaden, the currents become slower and they take on the characteristics of ponds and lakes.

2. Lakes and Ponds

These bodies of water vary in size; however, they all contain three distinct zones: littoral, limnetic and profundal.

a. Littoral Zone

The litoral zone is found at the edge of the lake and is the most richly inhabited zone. Here are many angiosperms, such as cattails, ruches, water lilies, duckweed. On these plants are invertebrates and other small organisms, such as snails, insect larvae, frogs, salamanders, water turtles, water snakes. Larger organisms like ducks, geese, and herons feed on the plants, insects, mollusks, fish and amphibians fond in the littoral zone. Other inhabitants include muskrats, otters, and beavers.

b. Limnetic Zone

The Limnetic Zone is the zone of open water. Small floating algae are the most common photosynthetic organisms. The zone extends downward to the limit of light penetration. Here are found fish, such as bass, bluegill.

c. Profundal Zone

The Profundal Zone is the deepwater zone and extends down from the limnetic zone. No plant life is found in this zone. The principal occupants are detritivores that consume the organic debris that filters down. These nutrients are released by bottom dwellers (decomposers) and recirculated to upper levels of the lake by the over turning of water.

3. Oceans

Oceans cover three quarters of the earth's surface. Life extends to the deepest portions off oceans but photosynthesis is restricted to upper levels. The average depth is 3 km; most of the ocean is dark and cold and inhabited by bacteria, fungi and animals.

Sea water readily absorbs sunlight. In clear water, less than 40% of light reaches a depth of one meter and less than 1% of light reaches a depth of 50 meters. Red, orange, and yellow wavelengths are absorbed first. The shorter blue and green waves penetrate deeper. Photosynthetic organisms living below the upper one meter use shorter wavelengths.

There are two main divisions of life in the oceans:

a. Pelagic

Pelagic contains free floating organisms. The main pelagic organisms are plankton. Phytoplankton are photosynthetic algae and unicellular protests, and zooplankton are heterotrophic protists, small shrimp and other crustaceans, jellyfish, and the eggs and larval forms of many fish and invertebrates. Plankton provides food for other larger pelagic animals.

b. Benthic

Benthic contains bottom dwelling organisms. The benthic division contains both sessile animals; for example sponges, sea anemones, clams, coral, and motile animals; such as worms and starfish. Some fungi and bacteria also live on the bottom feeding on organic debris.

Although the ocean covers three quarters of the earth's surface, the total productivity through photosynthesis is about one third as great because of the low concentrations of nutrients.

The oceans also play a role in land climate because of oceanic currents. The currents move warm and cold water around the world.

4. **Seashore**
The edges of the continents extend out into the sea 10-20 km. These are known as continental shelves. Nutrients are washed from the land into these areas; thus primary productivity is high.

Sessile animals are most abundant in relatively shallow areas, the areas close to shores. Predators also swim over the bottom of the shores.

In temperate regions, there are three types of seashores: rocky, sandy and muddy.

a. **Rocky**
In the rocky shores, organisms often have special adaptations for clinging to rocks. These organisms also face the problems of rising and falling tides.

   1) The supertidal zone is an area wetted by wave spray. Dark algae and lichen grow here.
   2) The intertidal zones are areas alternatively submerged and exposed by tides. Brown and red algae, animals, such as barnacles, oysters, mussels, limpets, periwinkles, etc. grow here.
   3) The subtidal zones are areas that are always submerged. This area often contains kelp forests and invertebrates.

The zone characteristics are due to gradients of light, temperature, wave action, competitive interaction, and predation.

b. **Sandy**
Sandy shores have fewer inhabitants because of constantly shifting sands. Some organisms live below the surface of the sand and feed on debris carried in and out by the tide.

c. **Muddy**
Muddy shores are not as diverse as rocky coast support a large number or organisms. Mud flats, salt marshes, and estuaries, where fresh water drains into the sea, receive a constant flow of nutrients from land and are rich in animal life. They often serve as spawning places and nurseries for many organisms.

B. **LIFE ON LAND**
The patterns of life on land are determined by physical factors- primarily temperature and precipitation. These factors are influenced by the angle of the earth's axis in relation to its orbit around the sun, the earth's rotation, which affects wind patterns, and major ocean currents. Temperature and precipitation are also affected by the topography of the continents.

The continents are composed primarily of igneous rock. Due to the motion of the plates, the continental surface is continually changing. Thus, the earth's surface is not uniform. Mineral content of the earth's surface is a major factor affecting growth of plants and animals.

Temperature is determined by altitude and latitude.
Latitude: The atmospheric temperature decreases by about 0.5 degrees Celsius for every degree increase in latitude.
Altitude: There is a 0.5 degree Celsius degrease in temperature for every rise of 100 meters.

There are differences between high latitude and high altitude habitats. In the high altitude, the air is clear, solar radiation is more intense. Most water vapor is found below 2,000 feet, causing nights to be cold at higher altitudes.

In the high latitudes, there are pronounced seasonal variations in both day length and temperature.

C. **BIOME**
Biomes are categories of characteristic plant life. They are a group of related ecosystems, where the climate is the same and the organisms are ecologically similar. Organisms of geographically separate patches of the same biome provide examples of convergence evolution.

Here is an incomplete list of biomes:
Temperate Forest
Taiga
Temperate Grassland
Chaparral / Mediterranean Scrub
Tropical Rainforest
Coniferous Forest
Tundra
Savannas
Desert

      ii.   Advantages of various shapes
          1) Being round, cocci allows for less distortion in a dried out organism.
          2) Rods have more surface are than the cocci. This allows the rod to take up more nutrients from the environment.
          3) Spirochetes are very motile; they move by using a corkscrew motion.

D. Movement of Prokaryotes
Prokaryotes move by way of chemotaxis. Chemotaxis is the movement of an organism towards or away from a chemical. Chemicals that cause the organism to move toward them (positive chemotaxis) are called attractants. Chemicals that induce the organism to move away (negative chemotaxis) are called repellents.

This response has been studied extensively. Chemotaxis suggests some type of sensing and response. Bacterial behavior can be described as a combination of runs and twiddles (tumbles). Run is a steady swim. Twiddle occurs when an organism stops and jiggles in place. This causes a change in direction.

As bacteria experience higher concentrations of the attractant, the twiddling movement becomes less frequent and they run for longer periods.
Temporal sensing can explain the above phenomenon. Bacteria sense the environment. There are receptors on the cell that can transfer molecules into the cell. The bacteria swim towards a higher concentration of the attractant.

E. Prokaryote Survival
When environmental conditions are unfavorable, the bacterium becomes inactive. Some species of bacteria form endospores. An endospore is a thick wall that surrounds the genetic material while the rest of the cell disintegrates. The endospore is dormant and doesn't reproduce or show any signs of life, similar to a 'seed.' Endospores can withstand harsh environmental conditions (boiling, freezing, drying out). When the conditions are favorable, the endosperm germinates to form an active cell.
    H. Reproduction
          1. Asexual Reproduction
             a. Asexual fission / Binary fission
                 The single loop of DNA is copied, and both loops attach to the cell membrane.
                 The cell grows and divides by pinching between the two DNA loops
          2. Sexual Reproduction
             a. Conjugation

A bridge is formed between two cells using the pili. Conjugation requires a plasmid called the F plasmid (F for fertility). The F plasmid contains approximately 25 genes and controls the formation of the F pilus. The F pilus is a long, rod shaped structure which will conned the tow different bacteria
If a bacterium contains the F plasmid, it is known a F+ cell. If a bacterium does not contain the F plasmid, it is known as an F– cell. An F+ cell attaches to an F– cell with its F pilus. After connecting, the F+ cell will give a copy of the F plasmid to the F– cell, making the F- cell an F+ cell.

The F factor can become integrated into the bacterial DNA. When this happens the cell is called an H_{fr} (high frequency recombination) cell. An H_{fr} cell, when attached to an F– cell, will transport a copy of its DNA to the F– cell. DNA recombination may then occur in the F– cell after the Hfr DNA has entered it.

R plasmid: the R plasmid contains genes that make a bacteria resistant to certain antibiotics. These genes can be transmitted, on a plasmid through conjugation, to other bacteria. Once the DNA molecule has been integrated into the main DNA of the cell, the cell is resistant.

b. Transformation
A living Bacteria absorbs the genetic material of a dead cell or 'naked' genetic material in the environment

c. Transduction
Transfer of DNA from a host to another cell by means of a virus. Viruses are pieces of DNA or RNA, enclosed by a protein coat that can infect bacteria. Their DNA is small and contains information for making proteins involved in infection

During the lytic cycle of a virus life cycle, the virus makes use of the host cell's resources. All parts of the new viruses are made independently in the host cell and put together prior to lysis. The great number of viruses in a cell will cause the cell to lyse of break and release the newly formed viruses.

The viral nucleic acid (DNA) is usually incorporated into the host cell's DNA strand as the virus is producing all of the viral parts. The viral nucleic acid is in a long sequence of repeating units. Each unit will be placed in the protein the protein capsid or coat prior to cell lysis. A viral enzyme will cut each viral DNA unit, and this sequence will be packaged into the capsid by another viral enzyme.

Sometimes a host cell's DNA is cut by the viral enzyme, and this DNA can be incorporated into a capsid. The virus is released when the cell lyses. The virus recognizes and attaches to a new host cell. The virus will then inject the nucleic acid found in the capsid into the new host cell. This DNA (containing bacterial DNA) can integrate with the new DNA of the new host cell.

I.   Metabolic diversity in Prokaryotes
    1.   Heterotroph
        Organism that is dependant upon outside sources of organic molecules

        a.   Photoheterotrophs
            Organisms that can use light to produce ATP but they must obtain carbon from another source. This type of metabolism is only found in prokaryotes
        b.   Chemoheterotrophs
            The majority of bacteria are chemoheterotrophs. There are three different types.

1) Saprobes: decomposers that absorb nutrients from dead organic material.
2) Parasites: absorb nutrients from the body fluids of living hosts
3) Phagotrophs: ingest food ad digest it enzymatically within cells or multicellular bodies

2. Autotroph
Organism that is able to synthesize organic molecules from inorganic substances
   a. Photosynthetic Autotrophs (Phototrophs)
   Organisms that harness light energy to drive the synthesis of organic compounds from CO_2. These organisms use and internal membrane system with light harnessing pigments, (e.g. cyanobacteria, algae, and plants).
   b. Chemosynthetic Autotrophs (Chemotrophs)
   Organisms that use energy from specific inorganic substances to produce organic molecules from carbon dioxide and provide life processes
   c. Chemoautotrophs
   Organisms that need only carbon dioxide as their carbon source. They obtain energy by oxidizing inorganic substances like hydrogen sulfide, ammonia, ferrous or other ions. This group is unique to prokaryotes

The types of needed nutrients varies, depending on the species. For example, *E. coli*, can grow on a glucose medium. *Lactobacillus* can grow on a medium of 20 amino acids, several vitamins, and other organic compounds. Some bacteria can use petroleum while others can use plastics as nutrients.