جامعة بغداد

كلية العلوم

قسم التقنيات الاحيائية

علم الخلية

المرحلة الاولى

الفصل الاول

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Lecture one: Introduction to Biology

What is Biology?

Biology is the natural science that studies life and living organisms, including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development and evolution.
Biology recognizes the cell as the basic unit of life, genes as the basic unit of heredity, and evolution as the engine that induce the creation and extinction of species.

Characteristics of living organisms:

An individual living thing, such as an animal or a plant, is called an organism. The term 'living organism' is usually used to describe something which displays all the characteristics of living things. There are seven activities which make organisms different from non-living things, they are:

1- Nutrition: Living things take in materials from their surroundings that they use for growth or to provide energy. Nutrition is the process by which organisms obtain energy and raw materials from nutrients such as proteins, carbohydrates and fats.

2- Respiration: Respiration is the release of energy from break down food substances in all living cells to carry out the following processes.

3- Movement: All living things move, even plants move in various different ways. The movement may be so slow that it is very difficult to see.

4-Excretion: Excretion is defined as the removal of toxic materials, the waste products of metabolism and substances in excess from the body of an organism.

5- Growth: The permanent increase in cell number and size is called growth. It is seen in all living things. It involves using food to produce new cells.

6– Reproduction: All living organisms have the ability to produce offspring.

7- Sensitivity: All living things are able to sense and respond to stimuli around them such as light, temperature, water, gravity and chemical substances.

Elements of Life

An **element** is one of the basic building blocks of matter; an element cannot be broken down by chemical means. Considering the variety of living and nonliving things in the world, it's remarkable that there are only 92 naturally occurring elements. It is even more surprising that over 90% of the human body is composed of just four elements: **carbon, nitrogen, oxygen**, and **hydrogen.**

Even so, other elements, such as **iron**, are important to our health. Iron-deficiency anemia results when the diet doesn't contain enough iron for the making of hemoglobin. Hemoglobin serves an important function in the body, because it transports oxygen, another element, to our cells.

Each element has a name and a symbol. For example, **carbon** has been assigned the atomic symbol **C**, and **iron** has been assigned the symbol **Fe**. Some of the symbols we use for elements are derived from Latin. For example, the symbol for **sodium** is **Na** because *natrium*, in Latin, means "sodium." Likewise, the symbol for iron is Fe because *ferrum* means "iron." Chemists arrange the elements in a *periodic* table, so named because all the elements in a column show *periodicity,* meaning that all the elements in each column behave similarly during chemical reactions.

Molecules and Compounds

Atoms often bond with one another to form a chemical unit called a **molecule.** A molecule can contain atoms of the same type, as when an oxygen atom joins with another oxygen atom to form oxygen gas.
Or the atoms can be different, as when an oxygen atom joins with two hydrogen atoms to form water. When the atoms are different, a **compound** is formed.

Oxygen gas **Water (H_2O)**

Water

Water is the most abundant molecule in living organisms, usually making up about 60–70% of the total body weight. Furthermore, the physical and chemical properties of water make life as we know it possible.
In water, the electrons spend more time circling the oxygen (O) atom than the hydrogens, because oxygen has a greater ability to attract electrons than do the hydrogen (H) atoms. The negatively charged electrons are closer to the oxygen atom, so the oxygen atom becomes slightly negative. In turn, the hydrogens are slightly positive. Therefore, water is a **polar** molecule; the

oxygen end of the molecule has a slight negative charge, and the hydrogen end has a slight positive charge.

Properties of Water

1. Water is a liquid at room temperature. The hydrogen bonding between water molecules keeps water a liquid and not a gas at room temperature.

2. Water is the universal solvent for polar (charged) molecules and thereby facilitates chemical reactions both outside of and within our bodies.

Ions and molecules that interact with water are called **hydrophilic.** Nonionized and nonpolar molecules that do not interact with water are called **hydrophobic.**

3. Water molecules are cohesive or union, so they stay together because of hydrogen bonding, and yet, water flows freely. This property allows dissolved and suspended molecules to be evenly distributed throughout a system (e.g.; blood).

4. The temperature of liquid water rises and falls slowly, preventing sudden or severe changes, therefore, water protects us and other organisms from rapid temperature changes and helps us maintain our normal internal temperature. Since the many hydrogen bonds that link water molecules cause water to absorb a great deal of heat before it boils.

The control of body temperature is an example of homeostasis, which is the maintenance of the internal environment within normal limits.

Frozen water is less dense than liquid water so that ice floats on water. As water cools, the molecules come closer together and hydrogen bonding becomes more rigid.

Lecture Two: The chemistry of life

Molecules of Life

Four categories of organic molecules:

- Carbohydrates.
- Lipids.
- Proteins.
- Nucleic acids.

In biology, “organic” doesn’t refer to how food is grown; it refers to a molecule that contains carbon (C) and hydrogen (H) and is usually associated with living organisms. Each type of organic molecule in cells is composed of subunits. When a cell forms a macromolecule, a molecule that contains many subunits, it uses a dehydration reaction, a type of synthesis reaction. During a dehydration reaction, a -OH (hydroxyl group) and a -H (hydrogen atom), the equivalent of a water molecule, are removed as the molecule forms.

- **Carbohydrates**

Carbohydrates are almost universally used as an energy source for living organisms, including humans. In some organisms, such as plants and bacteria, carbohydrates have a structural function. Carbohydrate molecules all have carbon, hydrogen, and oxygen atoms grouped H-C-OH, which is why they are often abbreviated as CHO. The ratio of hydrogen atoms (H) to oxygen atoms (O) is approximately 2:1. This ratio is the same as the ratio in water (hydros in Greek means “water,” so the name “hydrates of carbon” seems appropriate).

1- Simple Carbohydrates: Monosaccharides

Monosaccharides (mono, one; saccharide, sugar) consist of only a single sugar molecule and are commonly called simple sugars. A monosaccharide can have a carbon backbone of three to seven carbons. For example, **pentoses** with five carbons (Ribose), and **hexoses** with six carbons. The most common monosaccharide, and the one that our bodies use as an immediate source of energy, is the hexose **glucose.** There are several different ways a glucose molecule may be presented in figure (1) below:

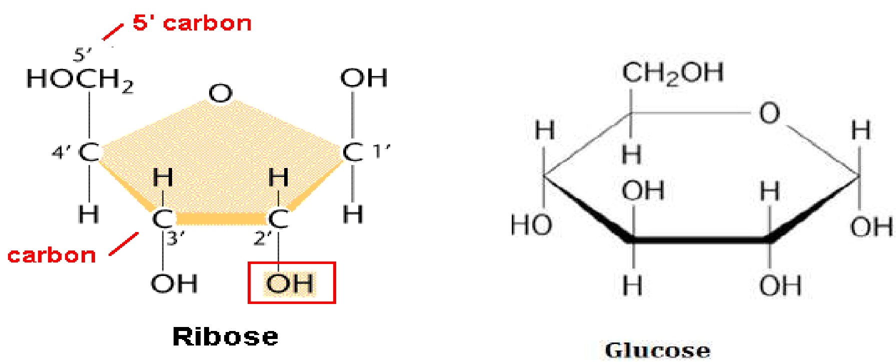


Figure 1: Ribose and Glucose molecules

2-Disaccharides

A disaccharide (di, "two"; saccharide, "sugar") is made by joining only two monosaccharides together by a dehydration reaction. **Maltose** is a disaccharide formed by a dehydration reaction between two glucose molecules (Figure 2). When our hydrolytic digestive juices break down maltose, the result is two glucose molecules. When glucose and fructose join, the disaccharide sucrose forms, **Sucrose**, ordinarily derived from sugarcane and sugar beets, is commonly known as table sugar. You may also have heard of lactose, a disaccharide found in milk. **Lactose** is glucose combined with galactose. Some people are lactose intolerant because they cannot break down lactose. This leads to unpleasant gastrointestinal symptoms when they consume dairy products.

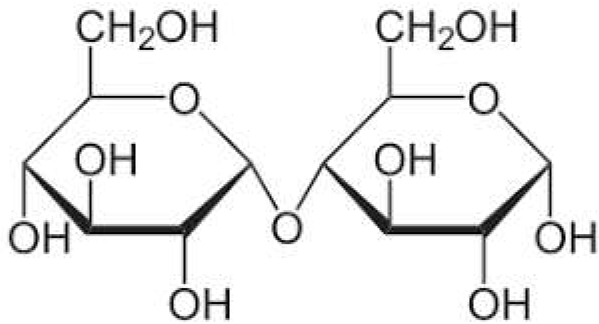


Figure 2: Disaccharide molecules (Maltose)

3-Complex Carbohydrates: Polysaccharides

Long polymers such as **starch, glycogen**, and **cellulose** are polysaccharides (poly, many) that contain long chains of glucose subunits. Due to their length, they are sometimes referred to as complex carbohydrates. The polysaccharides starch and glycogen are long polymers of glucose that are found in plants and animals, respectively. These chains may vary in length, but may contain several thousand glucose molecules.

Both starch and glycogen are used to store glucose to meet the energy needs of the cell. Starch and glycogen have slightly different structures, starch has fewer side branches, or chains, than does glycogen . Because starches are the storage form of carbohydrates in plants, we typically find them in roots (such as potatoes) and in seeds, (such as wheat). After we eat these starchy foods, the digestive system breaks down the starch into glucose, which then enters the blood stream. The release of the hormone insulin from the pancreas promotes the storage of glucose as glycogen in the liver (and to a lesser extent, in muscle tissue). In between eating, the hormone glycogen instructs the liver to release glucose; this maintains the normal blood glucose concentration at about 0.1%.

The polysaccharide **cellulose,** commonly called fiber, is found in plant cell walls. In cellulose, the glucose units are joined by a slightly different type of linkage than that in starch or glycogen . Though this might seem to be a technicality, it is important, because we are unable to digest foods containing this type of linkage; therefore, cellulose largely passes through our digestive tract as fiber, or roughage.

- **Lipids**

Lipids are diverse in structure and function, but they have a common characteristic: They do not dissolve in water. Their low solubility in water is due to an absence of hydrophilic polar groups. They contain little oxygen and consist mostly of carbon and hydrogen atoms. Lipids contain more energy per gram than other biological molecules; therefore, fats in animals and oils in plants function well as energy storage molecules. Others (phospholipids) form a membrane so that the cell is separated from its environment and has inner compartments as well. Steroids are a large class of lipids that includes, among other molecules, the sex hormones.

Phospholipids have a phosphate group. They are constructed like fats, except that in place of the third fatty acid, there is a phosphate group or a grouping that contains both phosphate and nitrogen. These molecules are not electrically neutral, as are fats, because the phosphate and nitrogen-containing groups are ionized. They form the polar (hydrophilic) head of the molecule, and the rest of the molecule becomes the nonpolar (hydrophobic) tails. Phospholipids are the primary components of the plasma membranes in cells. In a water environment, they spontaneously form a bilayer (a sort of molecular "sandwich") in which the hydrophilic heads (the sandwich "bread") face outward toward watery solutions, and the tails (the sandwich "filling") form the hydrophobic interior .

- **Proteins**

Proteins are macromolecules with **amino acid** subunits. The central carbon atom in an amino acid bonds to a hydrogen atom and to three other groups of atoms. The name amino acid is appropriate because one of these groups is an -NH_2 (amino group) and another is a -COOH (carboxyl group, an acid). The third group is the R group for an amino acid (figure 3).

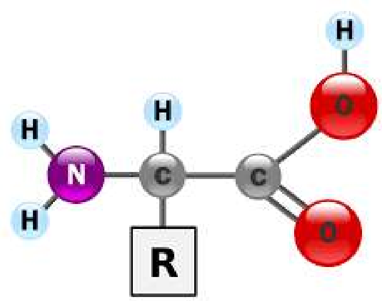


Figure 3: The structure of the amino acid

The covalent bond between two amino acids is called a **peptide bond**. When three or more amino acids are linked by peptide bonds, the chain that results is called a **polypeptide**.

Proteins are of primary importance in the structure and function of cells. Some of their many functions in humans include:

1-Support: Some proteins are structural proteins. Keratin, for example, makes up hair and nails. Collagen lends support to ligaments, tendons, and skin.

2-Enzymes: Enzymes bring reactants together and thereby speed chemical reactions in cells. They are specific for one particular type of reaction and only function at body temperature.

3-Transport: Channel and carrier proteins in the plasma membrane allow substances to enter and exit cells. Some other proteins transport molecules in the blood of animals; hemoglobin in red blood cells is a complex protein that transports oxygen.

4-Defense: Antibodies are proteins. They combine with foreign substances, called antigens. In this way, they prevent antigens from destroying cells and upsetting homeostasis.

5-Hormones: Hormones are regulatory proteins. They serve as intercellular messengers that influence the metabolism of cells.

6-Motion: The contractile proteins actin and myosin allow parts of cells to move and cause muscles to contract. Muscle contraction facilitates the movement of animals from place to place.

Lecture Three: The chemistry of life

- **Nucleic Acids**

Nucleic acids, which are polymers of **nucleotides,** store information, include instructions for life, and conduct chemical reactions. The general structure of a nucleotide is shown in Figure (1).

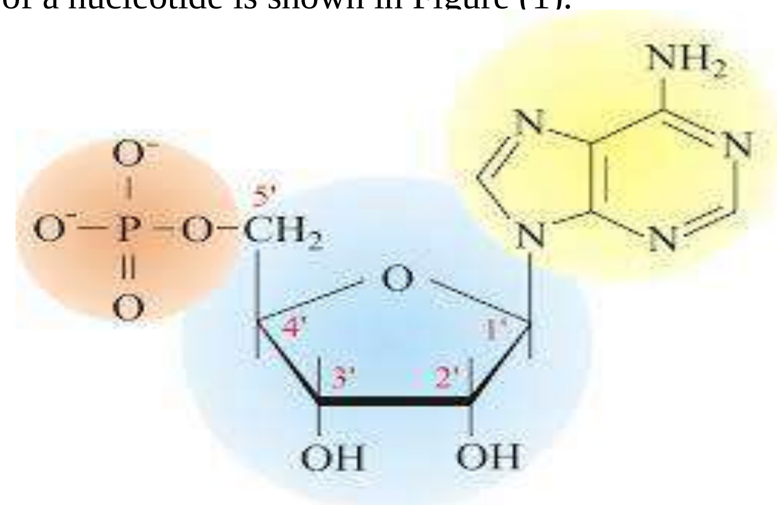


Figure 1: The general structure of a nucleotide

Two types of nucleic acids are important in the storage and processing of the genetic information. **DNA (deoxyribonucleic acid)** is the type of nucleic acid that not only stores information about how to copy, or replicate, itself but also specifies the order in which amino acids are to be joined to make a protein.

Nucleotide Structure

Each **nucleotide** is a molecular complex of three types of subunit molecules phosphate (phosphoric acid), a pentose (5-carbon) sugar, and a nitrogen-containing base. The nucleotides in DNA contain the sugar deoxyribose, and the nucleotides in RNA contain the sugar ribose; this difference accounts for their respective names, also, there are four different types of bases in DNA:

adenine (A), thymine (T), guanine (G), and **cytosine (C)** (Table 1).

The base can have two rings (adenine or guanine) or one ring (thymine or cytosine). In RNA, the base **uracil (U)** replaces the base thymine. These structures are called bases because their presence raises the pH of a solution.

The nucleotides link to make a polynucleotide called a strand, which has a backbone made up of phosphate-sugar-phosphate-sugar. The bases project to one side of the backbone.

DNA (deoxyribonucleic acid)

DNA is double-stranded, with the two strands twisted about each other in the form of a double helix (Figure 2). In DNA the two strands are held together by hydrogen bonds between the bases. When coiled, DNA resembles a spiral staircase. When unwound, it resembles a stepladder. The uprights (sides) of the ladder are made entirely of phosphate and sugar molecules, and the rungs of the ladder exhibit complementary base pairing.

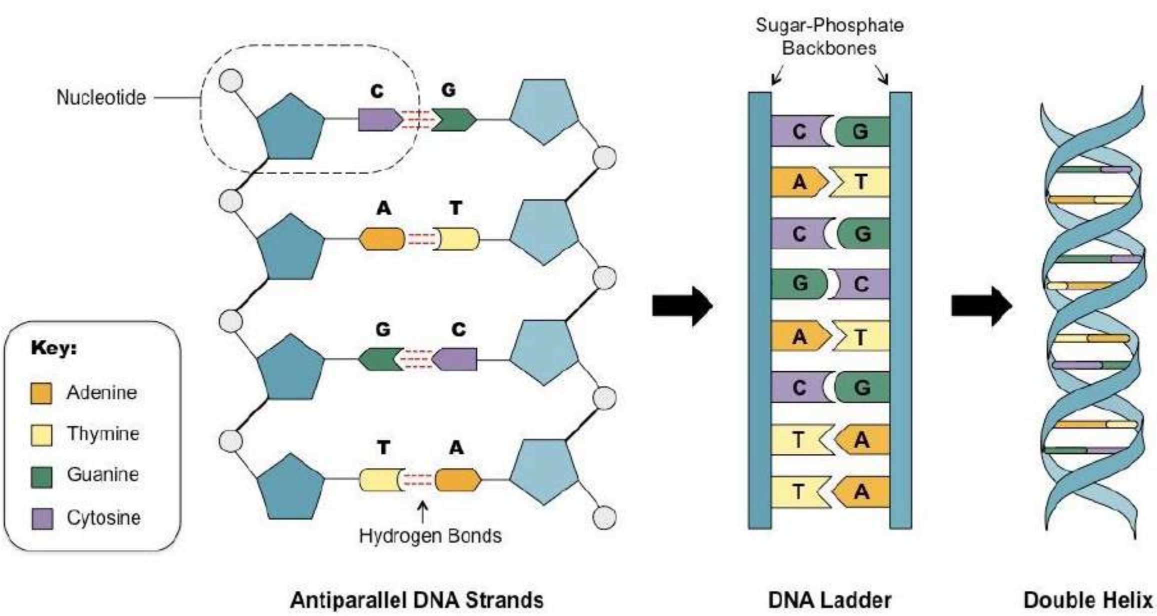


Figure 2: DNA structure

Thymine (T) always pairs with adenine (A), and guanine (G) always pairs with cytosine (C). Complementary bases have shapes that fit together. Complementary base pairing allows DNA to replicate in a way that ensures that the sequence of bases will remain the same. This is important because it is the sequence of bases that determines the sequence of amino acids in a protein. RNA is single-stranded. When RNA forms, complementary base pairing with one DNA strand passes the correct sequence of bases to RNA. RNA is the nucleic acid directly involved in protein synthesis.

RNA (ribonucleic acid) is a diverse type of nucleic acid that has multiple uses, RNA main types contains:

1-**Messenger RNA (mRNA)** is a temporary copy of a gene in the DNA that specifies what the amino acid sequence will be during the process of protein synthesis.

2-**Transfer RNA (tRNA)** is also necessary in synthesizing proteins and helps translate the sequence of nucleic acids in a gene into the correct sequence of amino acid during protein synthesis.

3-**Ribosomal RNA (rRNA)** is the RNA component of the ribosome, it works as an enzyme to form the peptide bonds between amino acids in a polypeptide.

Not all nucleotides are made into DNA or RNA polymers. Some nucleotides are directly involved in metabolic functions in cells. For example, some are components of **coenzymes,** nonprotein organic molecules that help regulate enzymatic reactions.

ATP (adenosine triphosphate) is a nucleotide that stores large amounts of energy needed for synthetic reactions and for various other energy-requiring processes in cells.

Differences in the Structures of DNA and RNA

Though both DNA and RNA are polymers of nucleotides, there are some small differences in the types of subunits each contains and in their final structure. These differences give DNA and RNA their unique functions in the body.

Table 1: Comparison between DNA and RNA Structure

	DNA	**RNA**
Sugar	Deoxyribose Ribose	Ribose
Bases	Adenine, guanine, thymine, cytosine	Adenine, guanine, uracil, cytosine
Strands	Double-stranded with base pairing	Single-stranded
Helix	Yes	No

Lecture Four: Structure and function of cell

The cell

All organisms, including humans, are composed of cells. From the single-celled bacteria to plants and complex animals such as human, the cell is the fundamental unit of life. Despite their importance, most cells are small and can be seen only under a microscope. The small size of cells means that they are measured using the smaller units of the metric system, such as the *micrometer* (μm). Most human cells are about 100 μm in diameter, about the width of a human hair. The internal contents of a cell are even smaller and, in most cases, may only be viewed using microscopes. Because of this small size, the **cell theory,** one of the fundamental principles of modern biology, was not formulated until after the invention of the microscope in the seventeenth century.

The Cell Theory

A cell is the basic unit of life. According to the cell theory, nothing smaller than a cell is considered to be alive. A single-celled organism exhibits the basic characteristics of life. There is no smaller unit of life that is able to reproduce and grow, respond to stimuli, remain homeostatic, take in and use materials from the environment, and become adapted to the environment.

All living organisms are made up of cells. While many organisms, such as the bacteria, are single-celled, other organisms, including humans and plants, are multicellular. In multicellular organisms, cells are often organized as tissues, such as nervous tissue and connective tissue. Even bone consists of cells (called osteocytes) surrounded by the material that they have deposited.

The prokaryotes and eukaryotes

Biologists classify cells into two broad categories the prokaryotes and eukaryotes. The primary difference between a prokaryotic cell and a eukaryotic cell is the presence or absence of a nucleus, a membrane-bound structure that houses the DNA. **Prokaryotic cells** lack a nucleus, whereas **eukaryotic cells** (Fig. 1) possess a nucleus.

The prokaryotic group includes two groups of bacteria, the eubacteria and the archaebacteria. Within the eukaryotic group are the animals, plants, and fungi, as well as some single-celled organisms called protists. Despite their differences, both types of cells have a **plasma membrane,** a membrane that regulates what enters and exits a cell.

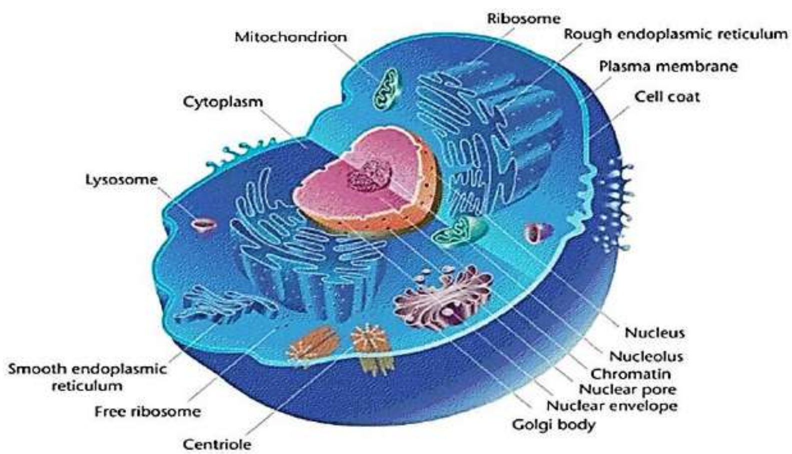


Figure (1): Eukaryotic cell

Cell structure:

Plasma membrane

The plasma membrane is a phospholipid bilayer "sandwich" made of two layers of phospholipids. Their polar phosphate molecules form the top and bottom surfaces of the bilayer, and the nonpolar lipid lies in between. The phospholipid bilayer is selectively permeable, which means it allows certain molecules-but not others-to enter the cell. Proteins scattered throughout the plasma membrane play important roles in allowing substances to enter the cell. All cells are surrounded by an outer plasma membrane (Fig. 2). The plasma membrane marks the boundary between the outside and the inside of the cell. The function of the plasma membrane is necessary to the life of the cell.

When phospholipids are placed in water, they naturally form a spherical bilayer. The polar heads, being charged, are hydrophilic (attracted to water). They position themselves to face toward the watery environment outside and inside the cell. The nonpolar tails are hydrophobic (not attracted to water). They turn inward toward one another, where there is no water. At body temperature, the phospholipid bilayer is a liquid. It has the consistency of olive oil. The proteins are able to change their position by moving laterally. The **fluid-mosaic model** is a working description of membrane structure. It states that the protein molecules form a shifting pattern within the fluid phospholipid bilayer.

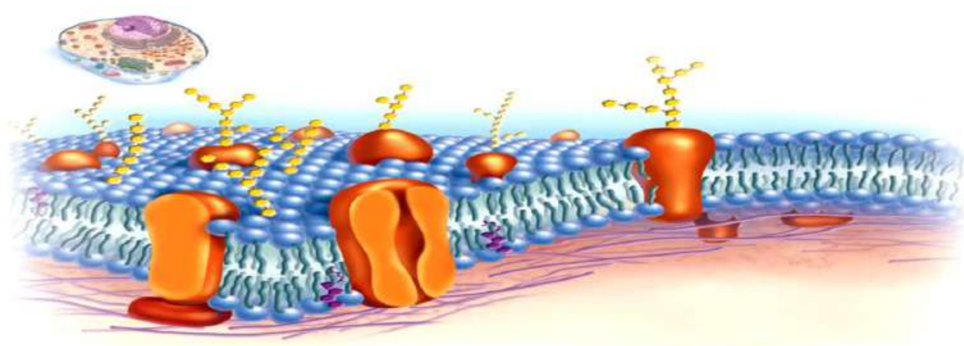


Figure 2: Organization of the plasma membrane

Cell wall

A **cell wall** is a structural layer surrounding some types of cells, just outside the cell membrane. It can be tough, flexible, and sometimes rigid. It provides the cell with both structural support and protection, and also acts as a filtering mechanism. Cell walls are present in most prokaryotes (except mollicute bacteria), in algae, fungi and eukaryotes including plants but are absent in animals. A major function is to act as pressure vessels, preventing over-expansion of the cell when water enters. The composition of cell walls varies between species and may depend on cell type and developmental stage. The primary cell wall of land plants is composed of the polysaccharides cellulose, hemicelluloses and pectin. Often, other polymers such as lignin, suberin or cutin are anchored to or embedded in plant cell walls. Algae possess cell walls made of glycoproteins and polysaccharides such as carrageenan and agar that are absent from land plants. In bacteria, the cell wall is composed of peptidoglycan. Fungi possess cell walls made of the N-acetylglucosamine polymer chitin. Unusually, diatoms have a cell wall composed of biogenic silica.

Cytoplasm

All types of cells contain cytoplasm, which is a semi-fluid medium that contains water and various types of molecules suspended or dissolved in the medium. The presence of proteins accounts for the semi-fluid nature of the cytoplasm. The cytoplasm of a eukaryotic cell contains organelles, internal compartments that have specialized functions. Eukaryotic cells have many types of organelles. Organelles allow for the compartmentalization of the cell. This keeps the various cellular activities separated from one another.

The Nucleus

The **nucleus,** a prominent structure in cells, stores genetic information (Fig. 3). Every cell in the body contains the same genes. Genes are segments of DNA that contain information for the production of specific proteins. Each type of cell has certain genes turned on and others turned off. DNA, with RNA acting as an intermediary, specifies the proteins in a cell. Proteins have many functions in cells, and they help determine a cell's specificity.

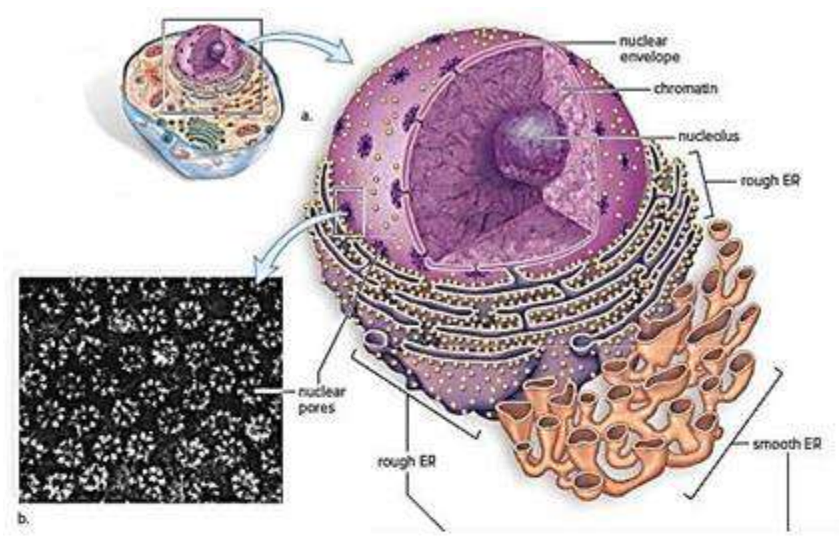


Figure 3: The nucleus and endoplasmic reticulum
a. **Nuleolus, b. nuclear envelope**

Chromatin is the combination of DNA molecules and proteins that make up the **chromosomes.** Chromatin can coil tightly to form visible chromosomes during meiosis (cell division that forms reproductive cells in humans) and mitosis (cell division that duplicates cells). Chromatin is immersed in a semifluid medium called the **nucleoplasm.** A difference in pH suggests that nucleoplasm has a different composition from cytoplasm. There were one or more dark regions of the chromatin, these are nucleoli (sing., **nucleolus**), where ribosomal RNA (rRNA) is produced. This is also where RNA joins with proteins to form the subunits of ribosomes. The nucleus is separated from the cytoplasm by a double membrane known as the **nuclear envelope.** This is continuous with the **endoplasmic reticulum**. The nuclear envelope has **nuclear pores** of sufficient size to permit the passage of ribosomal subunits out of the nucleus and proteins into the nucleus.

Lecture Five: Structure and function of cell

Ribosomes

Ribosomes are organelles composed of proteins and rRNA. Protein synthesis occurs at the ribosomes. Ribosomes are often attached to the endoplasmic reticulum; but they also may occur are digested by lysosomal enzymes into simpler subunits that then enter the cytoplasm. In a process called autodigestion, parts of a cell may be broken down by the lysosomes.

Mitochondria

Mitochondria (sing., mitochondrion) are often called the powerhouses of the cell. Just as a powerhouse burns fuel to produce electricity, the mitochondria convert the chemical energy of glucose products into the chemical energy of ATP molecules. In the process, mitochondria use up oxygen and give off carbon dioxide. Therefore, the process of producing ATP is called **cellular respiration.**

The inner membrane is folded to form little shelves called **cristae**. This project into the matrix, an inner space filled with a gel-like fluid (Fig. 1). The matrix of a mitochondrion contains enzymes for breaking down glucose products. ATP production then occurs at the cristae. Protein complexes that aid in the conversion of energy are located in an assembly-line fashion on these membranous shelves.

The structure of a mitochondrion supports the hypothesis that mitochondria were originally prokaryotes that became engulfed by a cell. Mitochondria are bound by a double membrane. Mitochondria have their own genes—and they reproduce themselves ATP-ADP Cycle. The ATP resembles that of a rechargeable battery. The breakdown of glucose during cellular respiration is used to produce ATP from ADP and inorganic phosphate P.

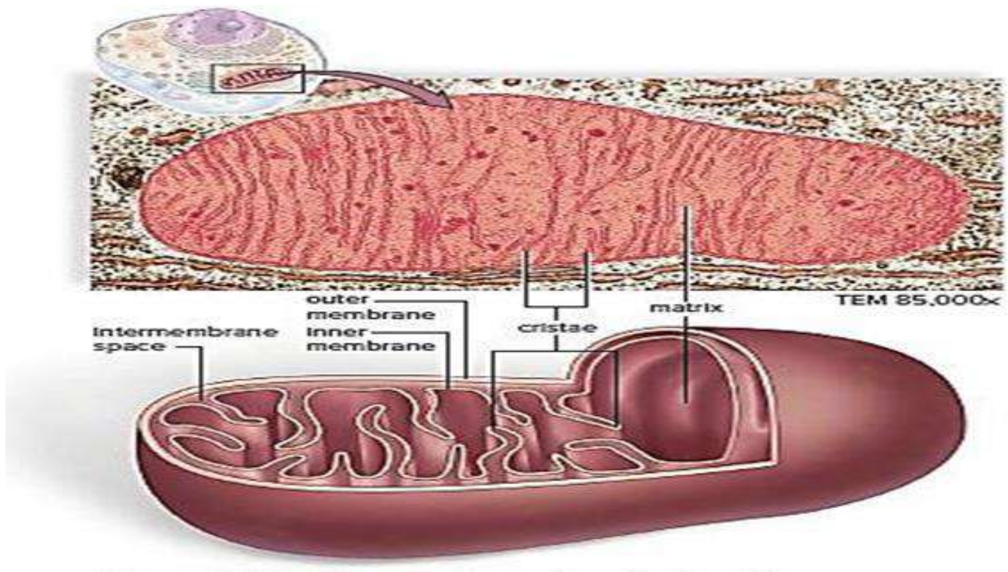


Figure 1: The structure of mitochondria

The Endoplasmic Reticulum

The **endoplasmic reticulum (ER)** has two portions. Rough ER is studded with ribosomes on the side of the membrane that ribosomes enter the interior of the ER for additional processing and modification. Some of these proteins are incorporated into the plasma membrane (for example, channel proteins), whereas others are packed into vesicles and sent to the Golgi apparatus. The smooth ER is continuous with the rough ER, but it does not have attached ribosomes (fig. 2). Smooth ER synthesizes the phospholipids and other lipids that occur in membranes. It also has various other functions, depending on the particular cell.

The Golgi apparatus

The **Golgi apparatus** is named for Camillo Golgi, who discovered its presence in cells in 1898. The Golgi apparatus consists of a stack of slightly curved saccules, whose appearance can be compared to a stack of pancakes. Here proteins and lipids received from the ER are modified. The vesicles that leave the Golgi apparatus move to other parts of the cell. Some vesicles proceed to the plasma membrane, where they discharge their contents. In all, the Golgi apparatus is involved in processing, packaging, and secretion.

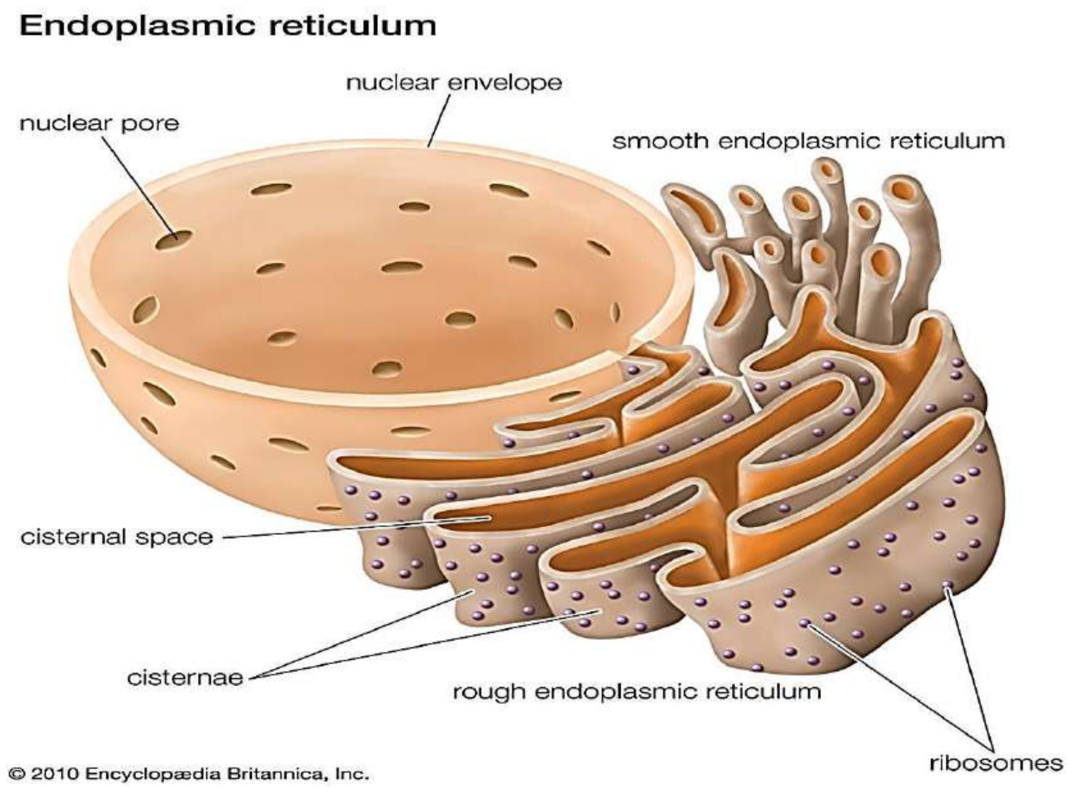


Figure 2 : Endoplasmic reticulum

Lysosomes

Lysosomes, membranous sacs produced by the Golgi apparatus, contain hydrolytic enzymes that can break down many kinds of biomolecules. A lysosome has a specific composition, of both its membrane proteins, and its luminal proteins. The lumen's pH (~4.5–5.0) is optimal for the enzymes involved in hydrolysis. Lysosomes are found in all cells of the body but are particularly numerous in white blood cells that engulf disease-causing microbes.

Cilia and Flagella

Cilia (sing., **cilium)** and **flagella (**sing., **flagellum)** are involved in movement. The ciliated cells that line our respiratory tract sweep back up the throat the debris trapped within mucus. Similarly, ciliated cells move an egg along the uterine tube, where it may be fertilized by a flagellated sperm cell (Fig. 3). Motor molecules, powered by ATP, allow the microtubules in cilia and flagella to interact and bend and, thereby, move.

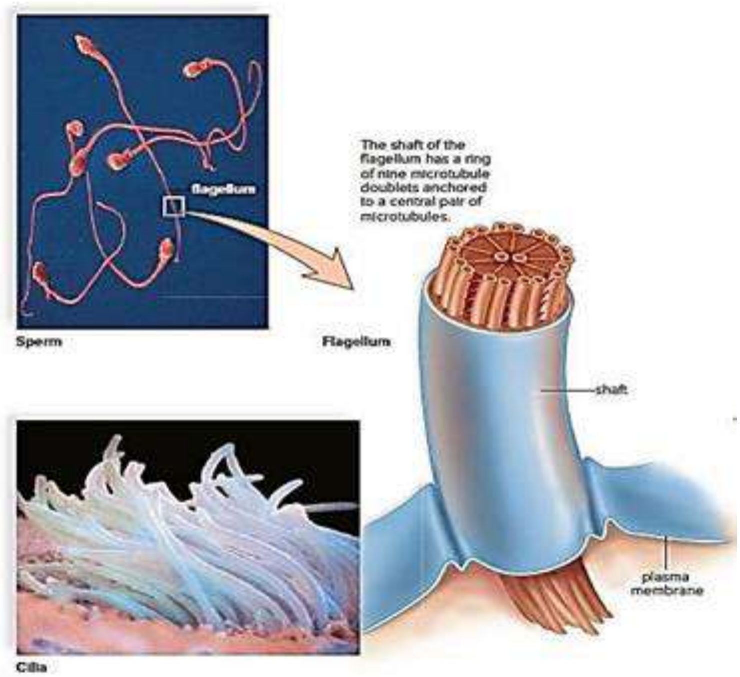


Figure 3 : Structure of cilia and flagella

Centriole

In cell biology a **centriole** is a cylindrical organelle composed mainly of a protein called **tubulin**. Centrioles are found in most eukaryotic cells. A bound pair of centrioles, surrounded by a shapeless mass of dense material, called the **pericentriolar material** (PCM), makes up a structure called a **centrosome**. Centrioles are typically made up of nine sets of short microtubule triplets, arranged in a cylinder (figure 4). The main function of centrioles is to produce cilia during interphase and the aster and the spindle during cell division. Centrioles are involved in the organization of the mitotic spindle and in the completion of cytokinesis. The centrioles can self-replicate during cell division. Centrioles are a very important part of centrosomes, which are involved in organizing microtubules in the cytoplasm. The position of the centriole determines the position of the nucleus and plays a crucial role in the spatial arrangement of the cell.

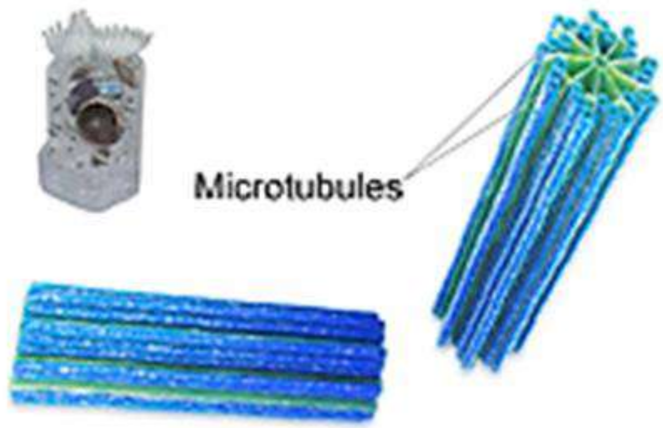


Figure 4: The centriole structure

The Cytoskeleton

Movement and Cell Junctions

It took a high-powered electron microscope to discover that the cytoplasm of the cell is containing by several types of protein fibers, called the **cytoskeleton**. The cytoskeleton helps maintain a cell's shape and either anchors the organelles or assists in their movement, as appropriate. In the cytoskeleton, **microtubules** are much larger than **actin** filaments. Each is a cylinder that contains rows of a protein called **tubulin**. Microtubules help maintain the shape of the cell and act as tracks along which organelles move. During cell division, microtubules form spindle fibers, which assist in the movement of chromosomes.

Actin filaments, made of a protein called actin, are long; extremely thin fibers that usually occur in bundles or other groupings. Actin filaments are involved in movement. Microvilli, which project from certain cells, contain actin filaments.

Intermediate filaments, as their name implies, are intermediate in size between microtubules and actin filaments.

Vacuole

A vacuole is a membrane-bound organelle which is present in all plant and fungal cells and some protist, animal, and bacterial cells. Vacuoles are essentially enclosed compartments which are filled with water containing inorganic and organic molecules including enzymes in solution, though in certain cases they may contain solids which have been engulfed. Vacuoles are formed by the fusion of multiple membrane vesicles and are effectively just larger forms of these. The organelle has no basic shape or size.

Vacuole Functions

The function of vacuoles varies according to the type of cell in which they are present. In general, the functions of the vacuole include:

1) Isolating materials that might be harmful or a threat to the cell.
2) Containing waste products.
3) Containing water in plant cells.
4) Maintaining internal hydrostatic pressure within the cell.
5) Maintaining an acidic internal pH.
6) In protists, vacuoles have the function of storing food which has been absorbed by the organism and assisting in the digestive and waste management process for the cell. In animal cells, vacuoles assist in processes of exocytosis and endocytosis, (there are some animal cells that do not have any vacuoles).

Lecture Six: Structure and function of cell

Plasma Membrane Functions

The plasma membrane keeps a **cell intact**. It allows only certain molecules and ions to enter and exit the cytoplasm freely. Therefore, the plasma membrane is said to be **selectively permeable** (Figure 1). Small, lipid-soluble molecules, such as oxygen and carbon dioxide, can pass through the membrane easily. The small size of water molecules allows them to freely cross the membrane by using protein channels called **aquaporins**.

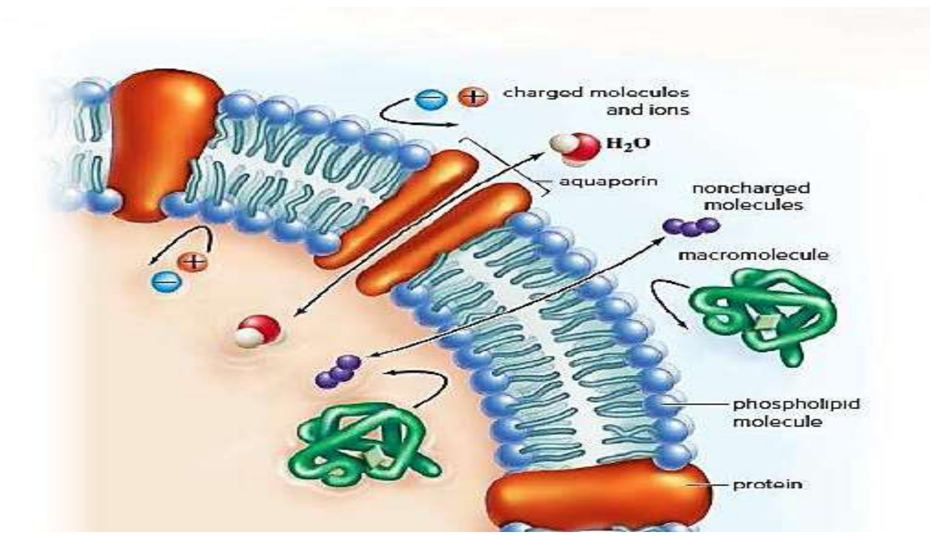


Figure 1: Selective permeability of the plasma membrane

Plasma membrane contributes in different activities:

1-Diffusion

Diffusion is the random movement of molecules from an area of higher concentration to an area of lower concentration, until they are equally distributed. Diffusion is a passive way with no cellular energy is needed (Figure 2). Oxygen diffuses across the plasma membrane, and the net movement is toward the inside of the cell. This is because a cell uses oxygen when it produces ATP molecules for energy purposes.

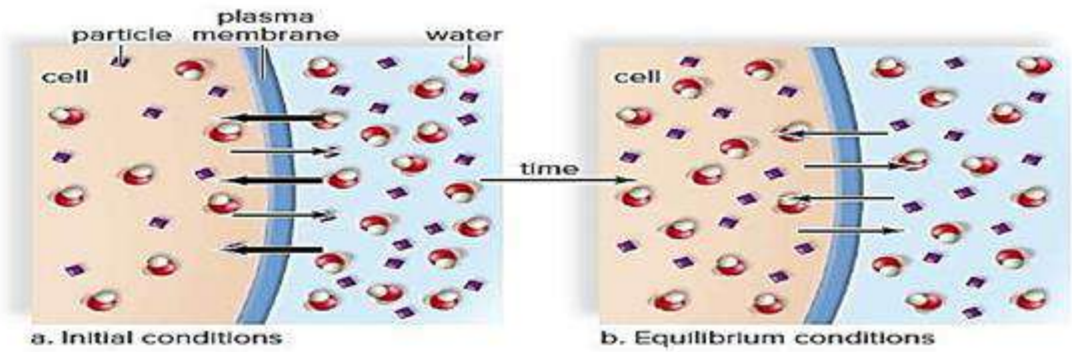


Figure 2: Diffusion across the plasma membrane

2-Osmosis

Osmosis is the net movement of water across a semipermeable membrane, from an area of higher concentration to an area of lower concentration. The membrane separates the two areas, and solute is unable to pass through the membrane. Water will tend to flow from the area that has less solute (and therefore more water) to the area with more solute (and therefore less water). **Tonicity** refers to the osmotic characteristics of a solution across a particular membrane, such as a red blood cell membrane. Normally, body fluids are isotonic to cells. There is the same concentration of non-diffusible solutes and water on both sides of the plasma membrane.

Therefore, cells maintain their normal size and shape. Intravenous solutions given in medical situations are usually isotonic. Solutions that cause cells to swell or even to burst due to an intake of water are said to be **hypotonic**. A hypotonic solution has a lower concentration of solute and higher concentration of water than the cells. If red blood cells are placed in a hypotonic solution, water enters the cells. They swell to bursting. Lysis is used to refer to the process of bursting cells. Bursting of red blood cells is termed hemolysis. Solutions that cause cells to shrink or shrivel due to loss of water are said to be **hypertonic**. A hypertonic solution has a higher concentration of solute and lower concentration of water than do the cells. If red blood cells are placed in a hypertonic solution, water leaves the cells; they shrink. These changes have occurred due to osmotic pressure which control water movement in our bodies. For example, in the small and large intestines, osmotic pressure allows us to absorb the water in food and drink. In the kidneys, osmotic pressure controls water absorption as well.

Osmosis and Diffusion Similarities

Osmosis and diffusion are related processes that display similarities:

- Both osmosis and diffusion equalize the concentration of two solutions.
- Both diffusion and osmosis are passive transport processes, which means they do not require any input of extra energy to occur. In both diffusion and osmosis, particles move from an area of higher concentration to one of lower concentration.

Osmosis and Diffusion Differences

- Diffusion can occur in any mixture, including one that includes a semipermeable membrane, while osmosis always occurs across a semipermeable membrane.
- Osmosis in biology, it always refers to the movement of water. In chemistry, it's possible for other solvents to be involved. In biology, this is a difference between the two processes.
- One big difference between osmosis and diffusion is that both solvent and solute particles are free to move in diffusion, but when we talk

about osmosis, only the solvent molecules (water molecules) cross the membrane.

3-Facilitated Transport

Many solutes do not simply diffuse across a plasma membrane. They are transported by means of protein carriers within the membrane. During **facilitated transport,** a molecule is transported across the plasma membrane from the side of higher concentration to the side of lower concentration (Figure 3). This is a passive means of transport because the cell does not need to expend energy to move a substance down its concentration gradient. Each protein carrier, sometimes called a transporter, binds only to a particular molecule, such as glucose.

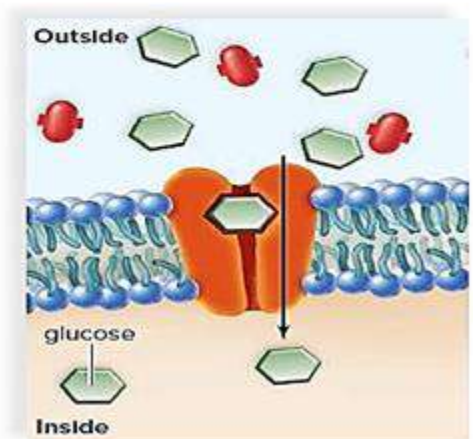


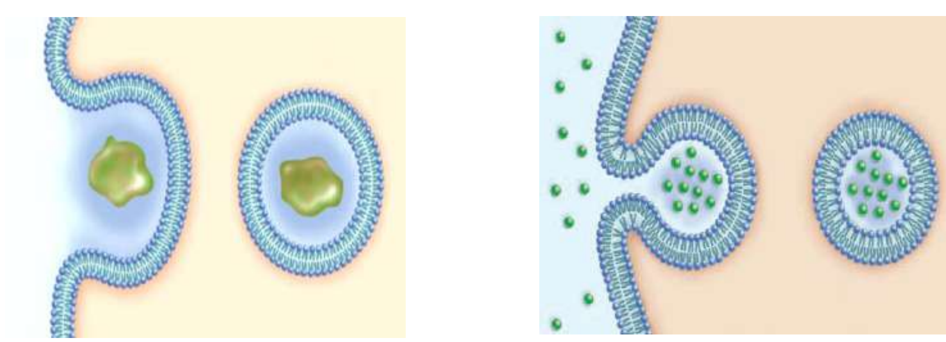
Figure 3: Plasma membrane facilitated transport

4- Active Transport

During **active transport,** a molecule is moving from a lower to higher concentration. One example is the digestive tract; sugar is completely absorbed from the gut by cells that line the intestines. Active transport requires a protein carrier and the use of cellular energy obtained from the breakdown of ATP. When ATP is broken down, energy is released. In this case, the energy is used to carry out active transport. Proteins involved in active transport often are called **pumps**. Just as a water pump uses energy to move water against the force of gravity, energy is used to move substances against their concentration gradients.

5-Endocytosis and Exocytosis

During endocytosis, a portion of the plasma membrane invaginates, or forms a pouch, to envelop a substance and fluid. Then the membrane pinches off to form an endocytic vesicle inside the cell (Figure 4). Some white blood cells are able to take up pathogens (disease-causing agents) by endocytosis. Here the process is given a special name: **phagocytosis.** Usually, cells take up molecules and fluid, and then the process is called **pinocytosis**. During exocytosis, a vesicle fuses with the plasma membrane as secretion occurs. This is the way that signaling molecules, called neurotransmitters, leave one nerve cell to excite the next nerve cell or a muscle cell.



A. Endocytosis (Phagocytosis) **B. Pinocytosis**

Figure 4: Movement of large molecules across the membrane

Cell communication

Individual cells, like multicellular organisms, need to sense and respond to their environment. A free-living cell—evens a humble bacterium—must be able to track down nutrients, tell the difference between light and dark, and avoid poisons and predators. And if such a cell is to have any kind of 'social life,' it must be able to communicate with other cells.

In a multicellular organism, things are much more complicated. Cells must interpret the multitude of **signals** they receive from other cells to help coordinate their behaviors. The signals that pass between living cells are simpler than the sorts of messages that humans ordinarily exchange. In a typical communication between cells, the **signaling cell** produces a particular type of *signal molecule* that is detected by the **target cell**. As in human conversation, most animal cells both send and receive signals, and they can therefore act as **both signaling cells and target cells**. Target cells possess ***receptor proteins*** that recognize and respond specifically to the signal molecule. **Signal transduction** begins when the receptor protein on a target cell receives an incoming extracellular signal and converts it to the intracellular signals that alter cell behavior. Cells in multicellular organisms use hundreds of kinds of extracellular molecules to send signals to one another. The signal molecules can be **proteins**, **peptides**, **amino acids**, **nucleotides**, **steroids**, **fatty acid derivatives**, or even **dissolved gases.**

Lecture Seven: Structure and function of cell

The cell and the lows of thermodynamics

The laws of thermodynamics are important unifying principles of biology. These principles govern the chemical processes (metabolism) in all biological organisms. The First Law of Thermodynamics, also known as the law of conservation of energy, states that energy can neither be created nor destroyed. It may change from one form to another, but the energy in a closed system remains constant.

The Second Law of Thermodynamics states that when energy is transferred, there will be less energy available at the end of the transfer process than at the beginning. Due to entropy, which is the measure of disorder in a closed system, all of the available energy will not be useful to the organism. Entropy increases as energy is transferred.

In addition to the laws of thermodynamics, the cell theory, gene theory, evolution, and homeostasis form the basic principles that are the foundation for the study of life.

First Law of Thermodynamics in Biological Systems

All biological organisms require energy to survive. In a closed system, such as the universe, this energy is not consumed but transformed from one form to another. Cells, for example, perform a number of important processes. These processes require energy. In photosynthesis, the energy is supplied by the sun. Light energy is absorbed by cells in plant leaves and converted to chemical energy. The chemical energy is stored in the form of glucose, which is used to form complex carbohydrates necessary to build plant mass.

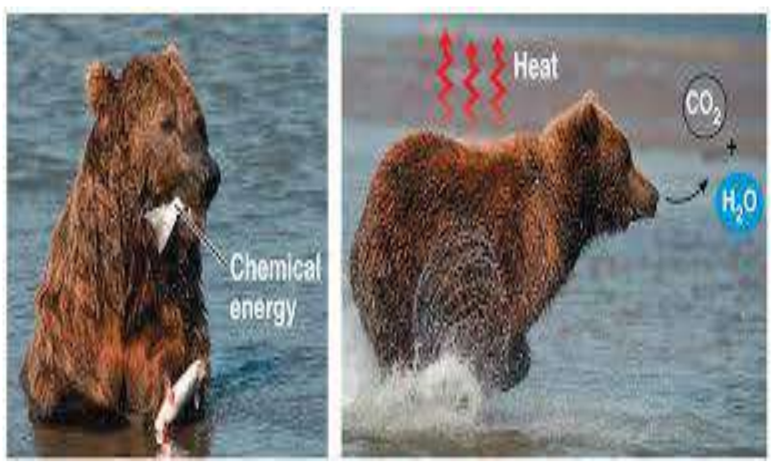
The energy stored in glucose can also be released through cellular respiration. This process allows plant and animal organisms to access the energy stored in carbohydrates, lipids, and other macromolecules through the production of ATP. This energy is needed to perform cell functions such as DNA replication, mitosis, meiosis, cell movement, endocytosis, exocytosis, and apoptosis.

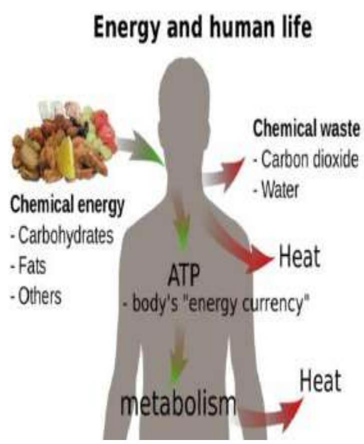
Second Law of Thermodynamics in Biological Systems

As with other biological processes, the transfer of energy is not 100 percent efficient. In photosynthesis, for example, not all of the light energy is absorbed by the plant. Some energy is reflected, and some is lost as heat. The loss of energy to the surrounding environment results in an increase of disorder or entropy. Unlike plants and other photosynthetic organisms, animals cannot generate energy directly from the sunlight. They must consume plants or other animal organisms for energy.

The higher up an organism is on the food chain, the less available energy it receives from its food sources. Much of this energy is lost during metabolic processes performed by the producers and primary consumers that are eaten. Therefore, much less energy is available for organisms at higher trophic levels. (Trophic levels are groups that help ecologists understand the specific role of all living things in the ecosystem.) The lower the available energy, the less number of organisms can be supported. This is why there are more producers than consumers in an ecosystem.

Living systems require constant energy input to maintain their highly ordered state. Cells, for example, are highly ordered and have low entropy. In the process of maintaining this order, some energy is lost to the surroundings or transformed. So while cells are ordered, the processes performed to maintain that order result in an increase in entropy in the cell's/organism's surroundings. The transfer of energy causes entropy in the universe to increase.





Reduction–oxidation reaction

Reduction–oxidation reaction (Redox) is a type of chemical reaction in which the oxidation states of atoms are changed. Redox reactions are characterized by the transfer of electrons between chemical species, most often with one species (the reducing agent) undergoing oxidation (losing electrons) while another species (the oxidizing agent) undergoes reduction (gains electrons).

Oxidation is the loss of electrons or an increase in the oxidation state of an atom by a molecule, an ion, or another atom.

Reduction is the gain of electrons or a decrease in the oxidation state of an atom by a molecule, an ion, or another atom.

Redox Reactions in Cellular Respiration

During cellular respiration, the fuel glucose is being consumed to generate energy in a long series of enzyme-catalyzed reactions; in simple words, electrons can be transferred from glucose to molecular oxygen, oxidizing the carbon molecules to carbon dioxide and reducing O2 to water.

This aspect of redox reactions in living organisms is called cellular respiration by which cells break down molecules of food (glucose) in a series of chemical reactions to produce energy, carbon dioxide, and water; the process depends heavily on the reduction of NAD+ to NADH and the reverse oxidation reaction of NADH to NAD+ as intermediate steps.

Oxidation–reduction reactions exist in all cells and are critical for cell homeostasis and signalling, including energy metabolism, gene expression, cell cycle regulation, immune response, cell growth, and cell apoptosis. In addition, this redox couple also function in rhythms, apoptosis, aging, development, and carcinogenesis.

Other biological processes that involve the redox reaction is the production of free radicals, which can be produced by detaching electrons from certain type of molecules and react to another type of molecule instantaneously; free radicals play an important role for the programmed cell death (apoptosis), and any uncontrolled production of free radicals may lead to cause cancer.

Co enzyme

Aerobic cellular respiration made up of 3 parts: glycolysis, the Krebs cycle, and oxidative phosphorylation. In glycolysis, glucose is metabolized into 2 molecules of pyruvate, with an output of ATP and nicotinamide adenine dinucleotide (NADH). The pyruvate is oxidized into acetyl CoA and NADH and carbon dioxide (CO_2). The acetyl CoA is then used in the Krebs cycle, also known as the citric acid cycle, which is a chain of chemical reactions that produce CO_2, NADH, flavin adenine dinucleotide ($FADH_2$), and ATP. In the final step, the NADH, $FADH_2$ amassed from the previous steps is used in oxidative phosphorylation, to make water and ATP.

Lecture Eight: Structure and function of cell

Cellular Respiration

Plants, algae, and some bacteria harvest the energy of sunlight through photosynthesis, converting radiant energy into chemical energy. These organisms are called **autotrophs**. All other organisms live on the energy autotrophs produce and are called **heterotrophs**. At least 95% of the kinds of organisms on earth (all animals and fungi, and most protists and bacteria) are heterotrophs.

Most foods contain a variety of carbohydrates, proteins, and fats, all rich in energy-laden chemical bonds. Carbohydrates and fats, for example, possess many carbon-hydrogen (C—H), as well as carbon-oxygen (C—O) bonds. The job of extracting energy from this complex organic mixture is tackled in stages. First, enzymes break the large molecules down into smaller ones, a process called **digestion.** Then, other enzymes dismantle these fragments a little at a time, harvesting energy from C—H and other chemical bonds at each stage. This process is called **catabolism.**

Cellular respiration

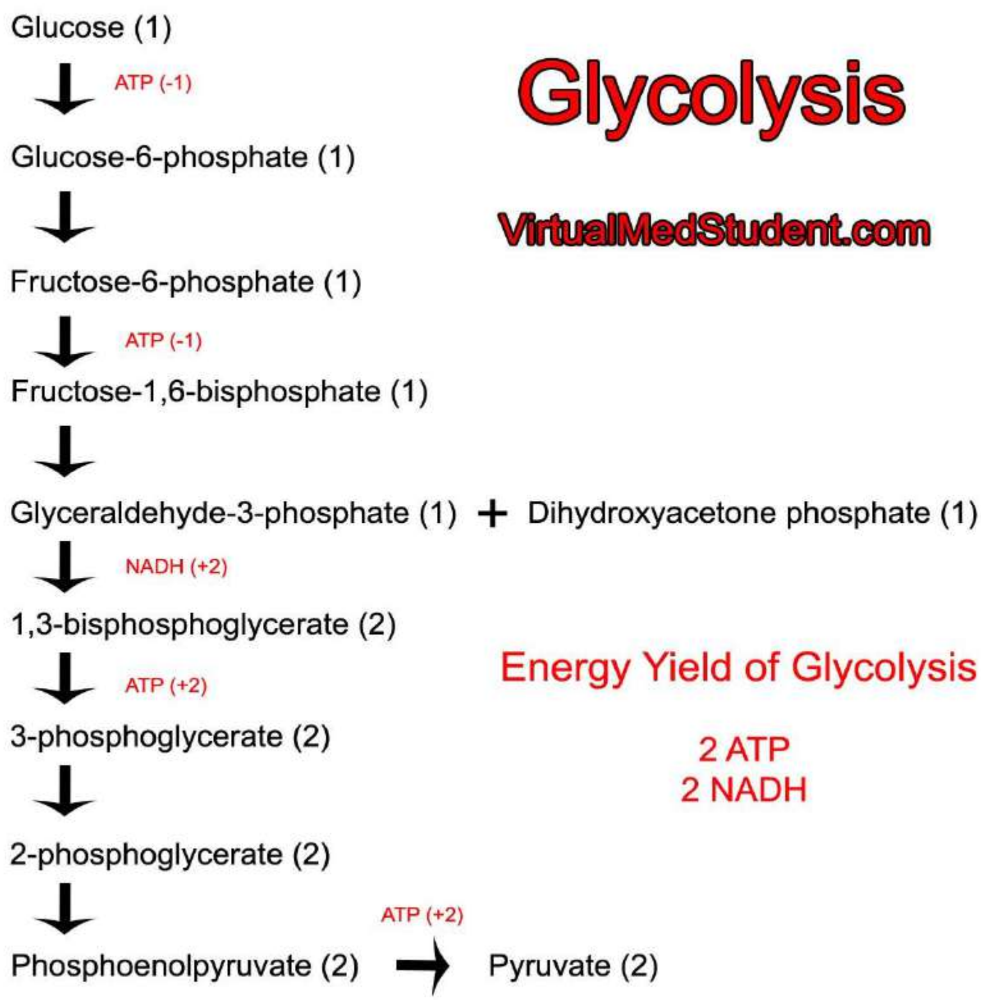
When oxygen gas (O2) accepts the hydrogen atom, water forms, and the process is called **aerobic respiration.** When an inorganic molecule other than oxygen accepts the hydrogen, the process is called **anaerobic respiration.** When an organic molecule accepts the hydrogen atom, the process is called **fermentation.**

Stage One: Glycolysis

This process occurs in the cytoplasm and involves a sequence of 10 reactions that convert glucose into 2 three carbon molecules of pyruvate. For each molecule of glucose that passes through this transformation, the cell nets two ATP molecules by substrate-level phosphorylation.

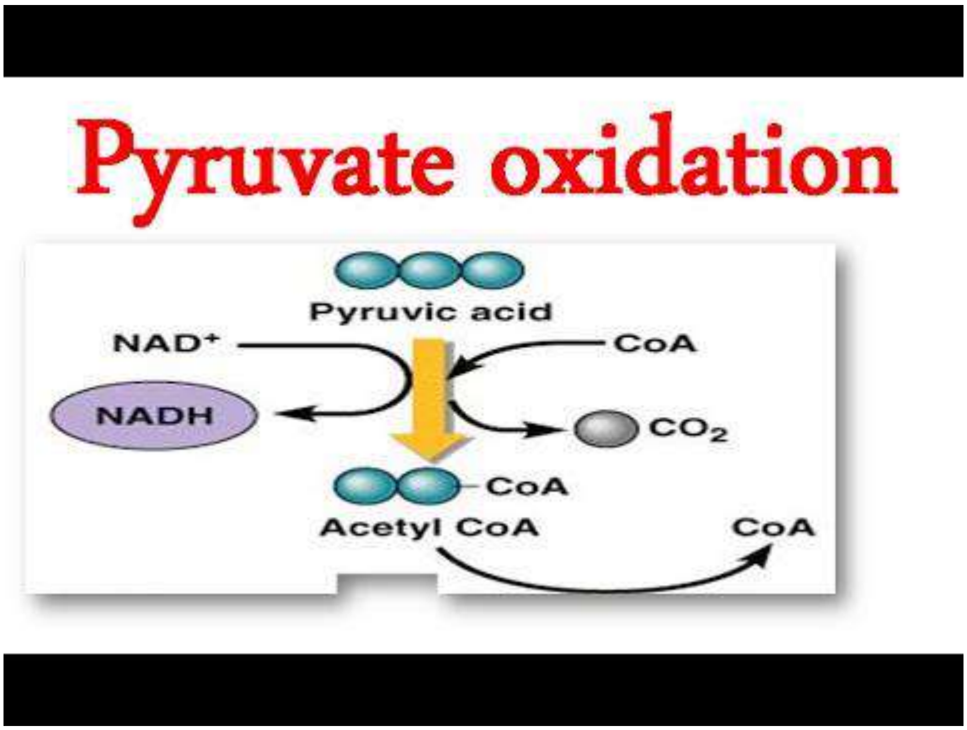
The first half of glycolysis consists of five sequential reactions that convert one molecule of glucose into two molecules of the three-carbon compound, glyceraldehyde 3-phosphate (G3P). These reactions demand the expenditure of ATP, so they are an energy-requiring process. This process generates two ATP molecules.

Because each glucose molecule is split into two G3P molecules, the overall reaction sequence yields two molecules of ATP, as well as two molecules of NADH and two of pyruvate.



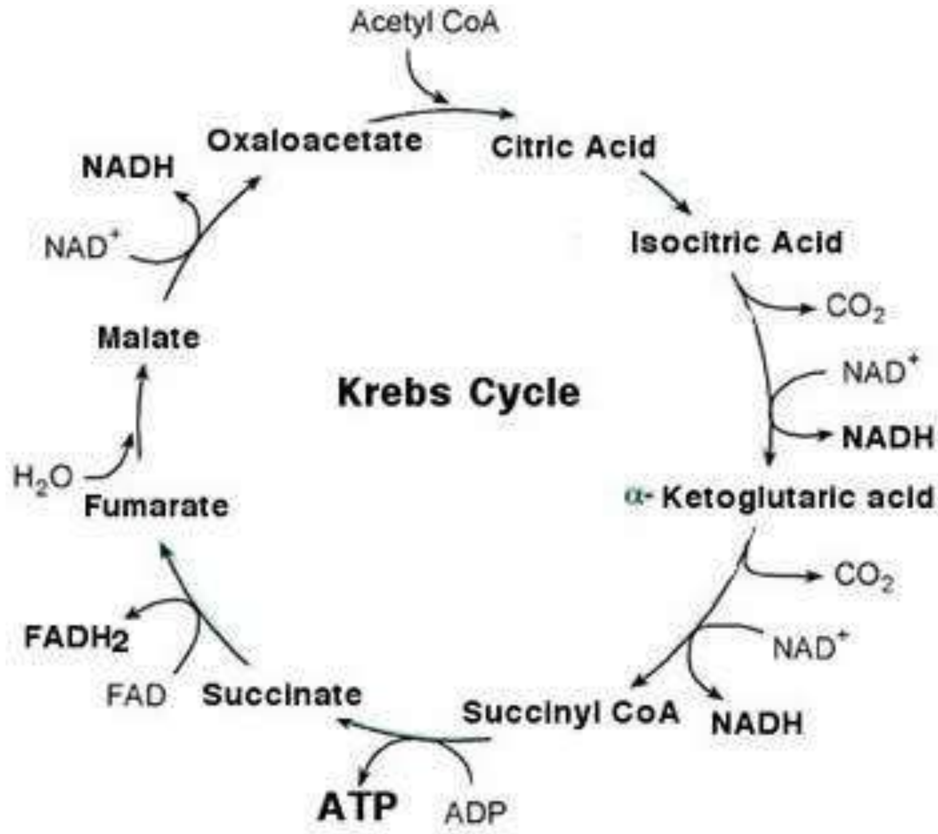
Stage Two: The Oxidation of Pyruvate

In the presence of oxygen, the extraction of additional energy from pyruvate takes place inside mitochondria. The cell harvests pyruvate's energy in two steps: first, by oxidizing pyruvate to form acetyl-CoA, and then by oxidizing acetyl-CoA in the Krebs cycle.



Stage Three: The Krebs cycle

In this third stage, acetyl-CoA is oxidized in a series of nine reactions called the Krebs cycle. These reactions occur in the matrix of mitochondria. In this cycle, the two-carbon acetyl group of acetyl-CoA combines with a four-carbon molecule called oxaloacetate. The resulting six-carbon molecule then goes through a sequence of electron-yielding oxidation reactions, during which two CO2 molecules split off, restoring oxaloacetate. The oxaloacetate is then recycled to bind to another acetyl group. In each turn of the cycle, a new acetyl group replaces the two CO2 molecules lost, and more electrons are extracted to drive proton pumps that generate ATP.



Stage Four: The Electron Transport Chain

The NADH and FADH2 molecules formed during the first three stages of aerobic respiration each contain a pair of electrons that were gained when NAD+ and FAD were reduced.

The NADH molecules carry their electrons to the inner mitochondrial membrane, where they transfer the electrons to a series of membrane associated proteins collectively called the electron transport chain.

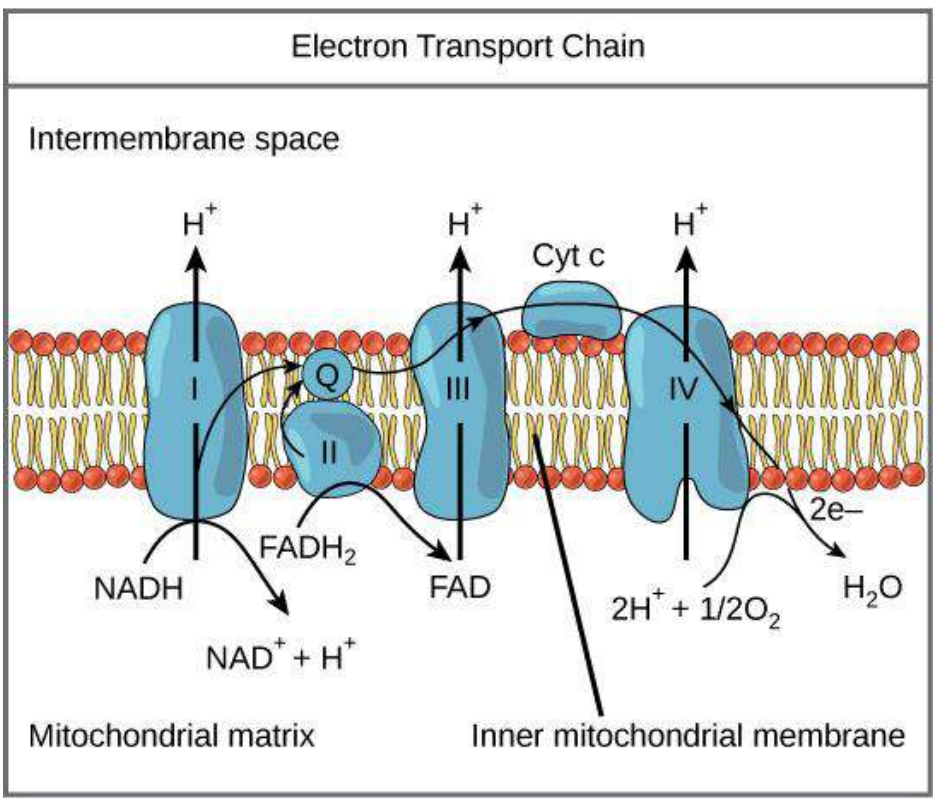
Moving Electrons through the Electron Transport Chain

The first of the proteins to receive the electrons is a complex enzyme called **NADH dehydrogenase.** A carrier called ubiquinone then passes the electrons to a protein-cytochrome complex called the **bc1 complex**. Cytochromes are respiratory proteins that contain heme groups. The electron is then carried by another carrier, **cytochrome c,** to the **cytochrome oxidase complex**. This complex uses four such electrons to reduce a molecule of oxygen, then each oxygen combines with two hydrogen ions to form water:

O2 + 4 H+ + 4 e- → 2 H2O

This series of electron carriers is collectively called the electron transport chain.

The electron transport chain uses electrons harvested in aerobic respiration to pump a large number of protons across the inner mitochondrial membrane. Their subsequent re-entry into the mitochondrial matrix drives the synthesis of ATP.



Anaerobic Respiration

In the absence of oxygen to accept the electrons, some organisms can still respire anaerobically, using inorganic molecules to accept the electrons. For example, many bacteria use sulfur, nitrate, or other inorganic compounds as the electron acceptor in place of oxygen.

Methanogens. These bacteria use CO2 as the electron acceptor; reducing CO2 to CH4 (methane) and they called methanogens.

Sulfur Bacteria. These bacteria derived energy from the reduction of inorganic sulfates (SO4) to H2S. They do the same thing methanogens do, but they use SO4 as the oxidizing agent in place of CO2.

Lecture Nine: Structure and function of cell

Photosynthesis

Introduction:

Photosynthesis is considered the most important process for all living organisms except anaerobic bacteria, which can fix CO_2 without using hydrogen of H_2O as a source of protons. In addition, the process is essential for life in terms of energy transfer. The photosynthetic organisms produce about 50 million ton of sugar annually by this process and this amount of sugar require transfer of 10^{21} calories of sun energy to chemical energy. Photosynthesis is sometimes called as carbon assimilation (assimilation: absorption into the system). This is represented by the following traditional equation.

$$6CO_2 + 6H_2O \xrightarrow[\text{Green pigments}]{\text{Light}} 6O_2 + \underset{\text{carbohydrates}}{C_6H_{12}O_6}$$

During the process of photosynthesis, the light energy is converted into chemical energy and is stored in the organic matter, which is usually the carbohydrate. One molecule of glucose for instance, contains about 686 K Calories energy. CO2 and water constitute the raw material for this process and oxygen and water are formed as the byproduct during photosynthesis.

Photosynthesis needs the following essential requirements:

1. Source of light energy
2. Source of energy capture
3. Means for energy storage

Photosynthesis pigments:

Studied conducted by plant physiologists indicated that the pigments absorbed light energy and transfer it to chemical energy are the chlorophylls which occurred in the plastids. The pigments are classified as follow:

1. **Chlorophyll**

The quantity of chlorophyll is 10 times more than carotenoids and it includes the following types:

a. Chlorophyll a: occurred in all photosynthetic plants and maximum absorption of light appeared at 430 and 660 nm wavelengths.
b. Chlorophyll b: occurred in all higher plants and green algae and maximum absorption of light appeared at 450 and 640 nm wavelengths.
c. Chlorophyll c: Occurred in brown algae
d. Chlorophyll d: Occurred in red algae
e. Chlorophyll e: Occurred in some plant species

The chemical structure of chlorophyll a and chlorophyll b are well established. The molecular formula for chlorophyll a: $C_{55}H_{72}O_5N_4$ Mg and chlorophyll b: $C_{55}H_{70}O_6N_4$ Mg. Both of them consist of Mg porphyrin head, which is hydrophilic, and a phytol tail, which is lipophilic. The two chlorophylls differ because in chlorophyll b there is a –CHO group instead of CH_3 group at the 3^{rd} C atom in pyrrole ring II.

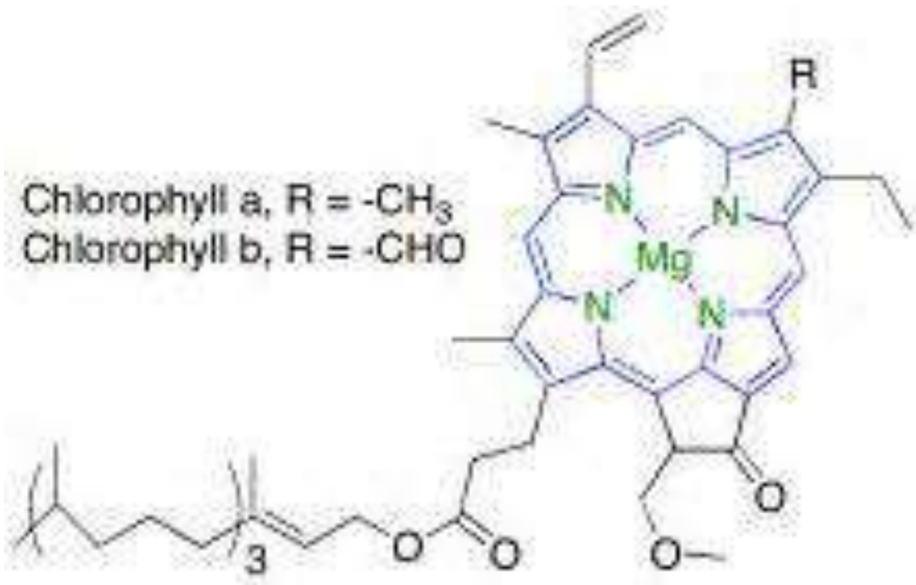


Figure1. Chlorophyll structure

2-Other pigments: It consists of two groups:

a. Carotenoids

Carotenoids are lipid compounds that are distributed widely in both animals and plants and range in color from yellow to purple. Carotenoids are present in variable concentrations in nearly all higher plants and in many microorganisms (e.g., red and brown algae, photosynthetic bacteria and fungi). It includes α-carotene, β-carotene and lycopene .

b- Xanthophylls

The xanthophylls are more abundant in nature than carotenes and located in chloroplast. Xanthophylls are carotenes containing oxygen.

Functions of Carotenoids:

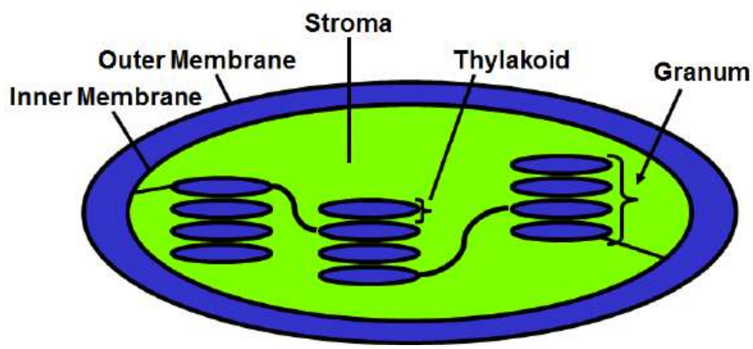
a- Protect chlorophylls against photooxidation in excessive light.

b- Absorption of light and transfer it to chlorophylls.

c- Causes phototropism in plants.

Location of photosynthetic pigments in chloroplast

The photosynthetic pigments are located in grana portions of the chloroplast. They are present in the thylakoid membrane or membrane of grana lamella. The membrane of thylakoid is made up of proteins and lipids or the membrane consists of both lipid layer and protein layer. The hydrophilic heads of the chlorophyll molecules remain embedded in the protein layer while lipophilic phytol tail in the lipid layer.



Grana portions of the chloroplast

Light

The chief source of light energy for photosynthesis is sun. The solar radiation or solar energy passes through the space and reaches the earth in the form of *electromagnetic radiation* with waves of varying lengths. The various portions of electromagnetic spectrum are gamma rays, ultraviolet rays, visible rays and infrared rays. The wavelength of these rays ranges from 280 nm to 1000 nm.

Photosynthetic pigments absorb light energy only in the visible part of the spectrum. The earth receives only about 40% of the total solar energy. Only about 1% of the total solar energy received by the earth is absorbed by the pigments and utilized in photosynthesis.

Mechanism of Photosynthesis

Photosynthesis process is a chain of successive redox-reactions, which requires sunlight at early stages (Robin Hill phase), while subsequent steps can occur in the dark (F.F. Blackman phase).

In the light phase of photosynthesis absorption of light occurs by chlorophyll molecules "a" with the participation of auxiliary pigments (chlorophyll "b", carotenoids, phycobilins) and transformation of solar energy into ATP and NADPH +H+. All these processes are carried out in photochemically active chloroplasts membranes, and represent a complex system of photophysical, photochemical and chemical reactions. In the dark phase of photosynthesis carbon fixation by the primary acceptor (ribulose-1,5-diphosphate) happens, involving enzymes located in the chloroplast stroma and with energy consumption in the form of ATP and NADPH+H+ which are the final products of the light phase.

Light Phase of Photosynthesis

The processes occurring during the light phase of photosynthesis can be related to:

(1) Absorption of carbon dioxide;

(2) Absorption of solar energy and its transformation into chemical energy.

(1) Absorption of carbon dioxide from the external environment happens through the open ostiole (photoactive physiological reaction). Carbon dioxide enters the sub substomatal cavity, from where it diffuses through the free intercellular spaces to directly contact the cellulose membranes of palisade assimilatory parenchyma, situated on the upper side of the leaf blade, or the cells of the spongy parenchyma from the inferior side.

In the envelopes of assimilatory cells are continuously irrigated with water absorbed from the soil, the CO2 from the air that circulates in the intercellular spaces, possessing a high hydrosolubility, dissolves and forms carbonic acid (H2CO3), which dissociates in H+, $HCO3^{-}$, CO 3^{-2}. In the ionic form carbon dioxide enters the cytoplasm and reaches chloroplasts. Consequently, it results that the first condition of photosynthesis is the degree of osteole opening and the presence of a sufficient amount of water in foliar tissues. At night, when stomata are closed (photoactive closure) as well as in drought conditions (hydroactive closure), when the cellular membranes of the leaf mesophyll cells are dry, photosynthesis is blocked and plant growth stagnates.

(2) Absorption of solar energy and its transformation into chemical energy

Happens via several successive stages:

• Solar energy absorption and excitation energy migration to the system of pigments.

• Oxidation of the reaction centre and stabilization of the separated charges.

• Electron transfer through the electron transport chain (ETC).

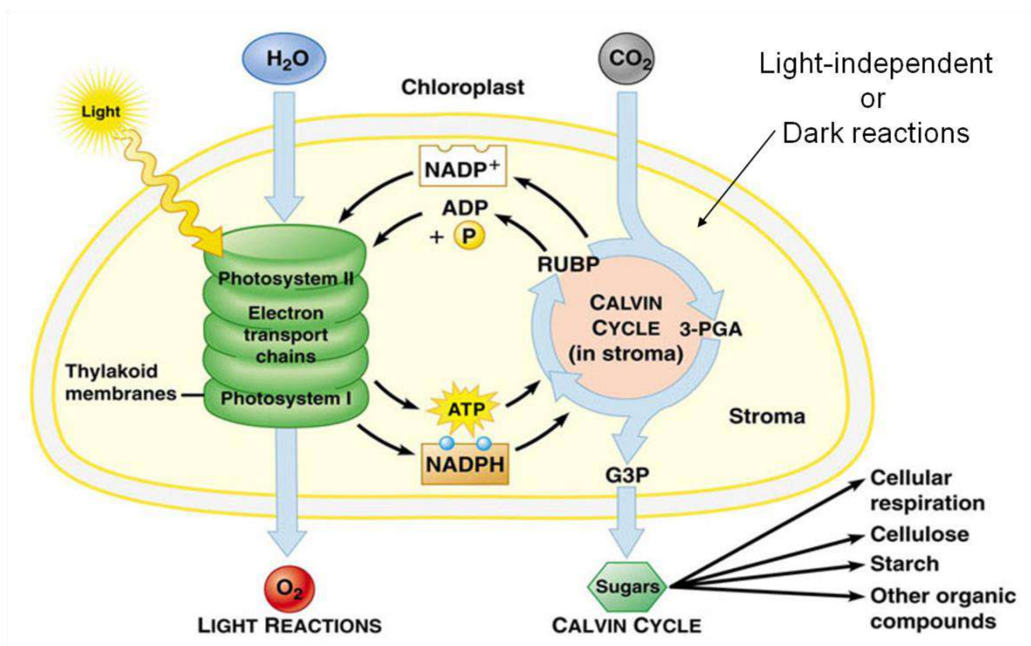
• Water photooxidation and molecular oxygen elimination.

• Conjugation of electron transport with proton transfer and the synthesis of ATP.

These processes are carried out in granal and stromal thylakoids with the participation of different molecules that make up two specific structures in superior plants—photosystem I (PS I) and photosystem II (PS II), which differ in their protein components, pigments and optical properties. Each photosystem is formed of a reaction center conjugated with electron donors and acceptors together with the “antenna” pigments.

Chromoproteids of the antenna-complexes have no photochemical and enzymatic activity. Their role is reduced to the accumulation and transmission of energy quanta to a limited number of molecules, which carry out photochemical reactions.

Photosynthesis summary



Photorespiration

Photorespiration presents in all plants and takes place in the presence of light. The reactions of photorespiration are completed in 3 cellular structures namely *chloroplast, perexisome and mitochondria*. The process is important for biosynthesis of the amino acids (glycine and serine) which are essential for protein biosynthesis. The Photorespiration occurs as in follow conditions:

1. Occurs on hot, dry, bright days
2. Stomates close
3. Fixation of O_2 instead of CO_2
4. Produces 2-C molecules instead of 3-C sugar molecules
5. Produces no sugar molecules or no ATP

Because of photorespiration, plants have special adaptations to limit the effect of photorespiration in C_4 plants and CAM plants.

Lecture Ten: Genetics

Cell reproduction

Cell reproduction is the process by which cells divide to form new cells. Each time a cell divides, it makes a copy of all of its *chromosomes,* which are tightly coiled strands of DNA, the genetic material that holds the instructions for all life, and sends an identical copy to the new cell that is created.

Chromosome

Chromosomes: the microscopic threadlike part of the cell that carries the hereditary information in the form of genes consisting of DNA and associated proteins in the nucleus.

Bacteria (prokaryotes) typically have one circular chromosome, while eukaryotes usually have linear chromosomes and vary widely in their sizes and numbers of chromosomes.

The compactness of chromosomes plays an important role in helping to organize genetic material during cell division and enabling it to fit inside structures such as the nucleus of a cell, the average diameter of which is about 5 to 10 μm.

The chromosomes of a eukaryotic cell consist of two types of ribonucleic acids , primarily DNA attached to a protein core and RNA in the cytoplasm. Every eukaryotic species has a characteristic number of chromosomes (chromosome number). In species that reproduce asexually, the chromosome number is the same in all the cells of the organism.

Among sexually reproducing organisms, the chromosomes in the body consists of two types according to the type of the cells, in the somatic cells the chromosomes called somatic or autosomes chromosomes control the inheritance of all the characteristics except the sex-linked ones each somatic cells have diploid set of chromosomes so called diploid with 2*n*; a pair of each chromosome, the gametes (sex cells) contain each one have the half number of the somatic chromosomes therefore each gametes contain sex chromosomes which are controlled the sex-linked characteristics therfore called haploid cells with 1*n*.

Cell division

All cells arise from the division of preexisting cells of the multicellular organisms originated from the division of single cell, zygote, which is formed from the union (fertilization) of an egg and sperm. Cell division provides the bases for one form of growth for both sexual and asexual reproduction , and for transmission of hereditary qualities from one cell generation to another. The division of the cells include two types : **nuclear division (karyokinesis)** and **cytoplasmic division (cytokinesis)**

the nuclear material of the living body cells both somatic and reproductive cells requires division before the division of the cytoplasm ,therefore there are two types of nuclear division **mitosis** and **meiosis**

all living somatic cells require mitosis division, each daughter cells receiving a complete set of genetic material, thus all the somatic cells which number in hundreds and billions in large animals, have the same genetic content because all are result by reproduction of the original zygote by mitosis.

In animals that reproduce asexually, mitosis is the only mechanism for transverse the genetic information from parent to progeny, while the animals that reproduce sexually, the parent must produce sex cells (gametes) that contain only half number of chromosomes, so that the offspring formed by union of the gametes during fertilization will contain double content of parental genetic material, therefore the gametes require a special type of division called meiosis.

Cell cycle (cell division cycle)

The cells undergo cycles of growth and replication as they repeatedly divide. A cell cycle is mitosis-to-mitosis cycle that is the interval between one cell generation and the next i.e. between two nuclear divisions. We can define the cell cycle is series of events that take place in a cell leading to duplication of its DNA (DNA replication) and division of cytoplasm and organelles to produce two daughter cells.

Stages of the cell cycle

The two main parts of the cell cycle are mitosis and interphase. Mitosis is the phase of cell division, during which a “parent cell” divides to create two “daughter cells”

The longest part of the cell cycle is called “interphase” – the phase of growth and DNA replication between mitotic cell divisions.

In bacteria, which lack a cell nucleus, the cell cycle is divided into the B, C, and D periods. The B period extends from the end of cell division to the beginning of DNA replication. DNA replication occurs during the C period. The D period refers to the stage between the end of DNA replication and the splitting of the bacterial cell into two daughter cells.

In eukaryotic cells, or cells with a nucleus, the stages of the cell cycle are divided into two major phases: **interphase** and the **mitotic (M) phase**.

The eukaryotic cell cycle consists of four distinct phases:

- G_1 phase (Growth phase 1)
- S phase (synthesis phase)
- G_2 phase (Growth phase2) , collectively known as interphase
- M phase (mitosis and cytokinesis).

M phase is itself composed of two tightly coupled processes: mitosis, in which the cell's nucleus divides, and cytokinesis, in which the cell's cytoplasm divides forming two daughter cells. To divide a cell must complete several important tasks: it must grow, copy its genetic material (DNA), and physically split into two daughter cells. Cells perform these tasks in an organized, series of steps that make up the cell cycle. The cell cycle is a cycle, rather than a linear pathway, because at the end of each go-round, the two daughter cells can start the exact same process over again from the beginning.

During interphase, the cell grows and makes a copy of its DNA. While in the mitotic (M) phase, the cell separates its DNA into two sets and divides its cytoplasm, forming two new cells.

G1 , also called the first gap phase, the cell grows physically larger, copies organelles, and makes the molecular building blocks it will need in later steps.

In the great majority of cases, cells do indeed grow before division. However, in certain situations during development, cells may split themselves up into smaller and smaller pieces over successive rounds of cell division.

S phase. In S phase, the cell synthesizes a complete copy of the DNA in its nucleus. It also duplicates a microtubule-organizing structure called the centrosome. The centrosomes help separate DNA during M phase.

G2 also called the second gap phase, the cell grows more, makes proteins and organelles, and begins to reorganize its contents in preparation for mitosis, phase ends when mitosis begins.

The G, S, and G2 phases together are known as **interphase**. The prefix *inter-* means between, reflecting that interphase takes place between one mitotic (M) phase and the next (figure 2).

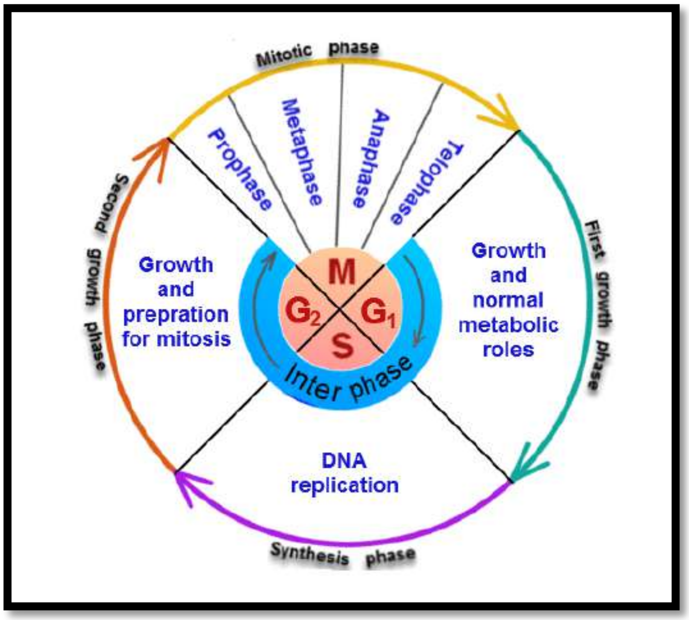


Figure 2 : Cell cycle

Mitosis

Is a part of the cell cycle when replicated chromosomes are separated into two genetically identical new nuclei? In **mitosis**, the nuclear DNA of the cell condenses into visible chromosomes and is pulled apart by the mitotic spindle, a specialized structure made out of microtubules. Mitosis takes place in four stages:

1- prophase (sometimes divided into early prophase and prometaphase)

2- metaphase 3-anaphase 4-telophase

Followed by a process known as cytokinesis, which begins in telophase, In **cytokinesis**, the cytoplasm of the cell is split in two, making two new cells. Cytokinesis usually begins just as mitosis is ending. Importantly, cytokinesis takes place differently in animal and plant cells (figure 3).

Mitosis occurs only in eukaryotic cells. Prokaryotic cells, which lack a nucleus, divide by a different process called binary fission. Mitosis is carried out by somatic cells. Every somatic cell that undergoes mitosis produces two genetically identical diploid daughter cells, meaning that the cell chromosome number remains the same during cell division. Mitosis can be divided into four phases - prophase, metaphase, anaphase and telophase,

- Prophase involves the condensing of chromatin into chromosomes, the movement of the centrioles to opposite poles of the cell and the synthesis of the mitotic spindle apparatus, the deterioration of the nuclear membrane and the disappearance of the nucleoulus, and the synthesis of the kinetochores on each chromosome. The two chromatids are joined at the centromere. Close to the nucleus of animal cells are structures called centrosomes, consisting of a pair of centrioles surrounded by a loose collection of proteins The centrosome is the coordinating center for the cell's microtubules.

- Metaphase, the centrioles are now on opposite poles and have attached their spindle fibers onto the kinetochores. They also align all the chromosome pairs along the center of the cell.
- Anaphase, disjunction takes place. Disjunction is the separation of the chromosome pairs by the pulling of the spindle fibers, which separate the chromosomes to opposite poles.
- telophase, is a reversal of prophase and prometaphase events the chromosomes have been separated and the nuclear membrane begins to reform around both sets, thereby forming two nuclei. The spindle

apparatus deteriorates and the chromosomes begin to decondense into chromatin in preparation for interphase.

Cytokinesis, Cytokinesis is not a phase of mitosis but rather a separate process, necessary for completing cell division, the end of cytokinesis marks the end of the M-phase. The process, by which the cell divides the cell membrane and cytoplasm into two cells, begins and continues after telophase ends. Once the cell undergoes mitosis, it produces two genetically identical diploid cells. Mitosis is complete. Each daughter nucleus has an identical set of chromosomes. Cell division may or may not occur at this time depending on the organism. There are many cells where mitosis and cytokinesis occur separately, forming single cells with multiple nuclei. The most notable occurrence of this is among the fungi, slime molds, and some algae, but the phenomenon is found in various other organisms.

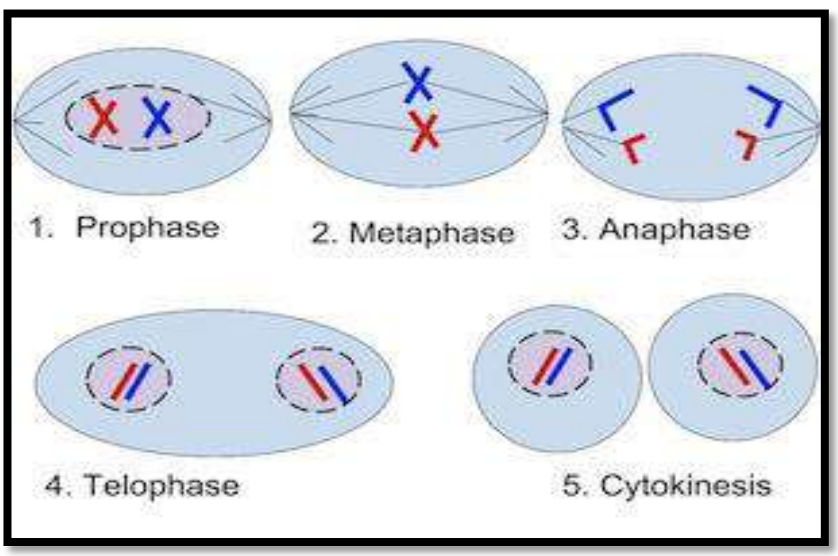


Figure 3 : Mitosis

Function of mitosis

1- Development and growth

The number of cells within an organism increases their numbers by mitosis. This is the basis of the development of a multicellular body from a single cell (zygote) and the growth of a multicellular body.

2- Cell replacement

In some parts of body, e.g. skin cells and endothelium of digestive tract, cells are constantly sloughed off and replaced by new ones, red blood cells have short lifespan (only about 4 months) and new RBCs are formed by mitosis.

3- Regeneration

Some organisms can regenerate body parts. The production of new cells in such instances is achieved by mitosis. For example, starfish regenerate lost arms through mitosis and tail of some lizards also regenerate by mitosis

4- Asexual reproduction

Some organisms produce genetically similar offspring through asexual reproduction. For example, the hydra reproduces asexually by budding. The cells at the surface undergo mitosis and form a mass called a bud. Mitosis continues in the cells of the bud and this grows into a new individual. The same division happens during asexual reproduction or vegetative propagation in plants.

Lecture Eleven: Genetics

Meiosis

Meiosis is reduction division that takes place in the germ cells to generate male and female gametes, sperm and egg cells, respectively. Meiosis requires two cell division, **meiosis I** and **meiosis II,** to reduce the number of chromosomes from diploid **(2n)** to haploid number **(1n)**. The end products of meiosis are 4 haploid (1n) cells.

Meiosis in males is called **(Spermatogenesis)** and produce → sperm

Meiosis in females is called **(Oogenesis)** and produce → egg or ovum (pleural =ova)

- Diploid cells (2n) have double structured chromosomes (46 chromosomes).

- Haploid cells (1n) have single stranded chromosomes (23 chromosomes).

- Fertilization is the fusion of a sperm (1n) and egg cell (1n) to produce a zygote.

-Zygote has a diploid chromosome (2n) number, one set from each parent.

In human, somatic cells (body cells) have 23 pairs of homologous chromosomes.

Homologous chromosomes

- Pair of chromosomes (one from each parent) that are similar in length, gene position, and centromere location .Human has 23 pairs of homologous chromosomes:-

22 pairs of autosomes + 1 pair of sex chromosomes

(XX in female, or XY in male)

Meiosis has two distinct stages:

1- Meiosis I 2- Meiosis II

Meiosis I consist of 4 phases

1- Prophase I 2-Metaphase I 3-Anaphase I 4-Telophase I

Male germ cells (primary spermatocytes) and female germ cells (primary oocyte) at the beginning of meiosis I similar to mitosis interphase, the gametes replicate their DNA so that each chromosome consists of two sister chromatids held together at a centromere. Centrioles pairs also replicate.

2- Meiosis II

- No interphase occurs (no need for more DNA replication)
- Meiosis II is similar to mitosis

Meiosis II consist of 4 phases

1- Prophase II 2- Metaphase II 3- Anaphase II 4- Telophase II

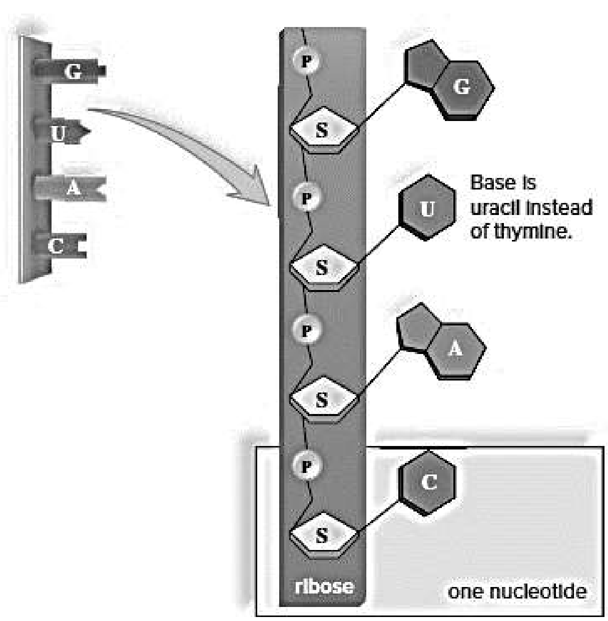
Comparison between meiosis I with meiosis II

	meiosis I	**meiosis II**
1-	Interphase I DNA replication	No interphase II
2-	Prophase I Pairing of homologous chromosomes	Prophase II No pairing of chromosomes
3-	Metaphase I Homologous duplicated chromosomes at equator	Metaphase II haploid number of duplicated chromosomes at equator
4-	Anaphase I Homologous chromosomes separate to the poles	Anaphase II Sister chromatids separate, becoming daughter chromosomes that move to the poles
5-	Telophase I Two haploid daughter cells	Telophase II Four haploid daughter cells

Gene Expression

RNA (ribonucleic acid)

RNA (ribonucleic acid) is made up of nucleotides (nt) containing the sugar ribose. This sugar accounts for the scientific name of this polynucleotide. The four nucleotides that make up the RNA molecule have the following bases: **adenine (A), uracil (U), cytosine (C), and guanine (G)**. One of the differences between RNA and DNA is the replacement of **thymine with uracil**. As with DNA, complementary base pairing may occur in RNA; cytosine pairs with guanine and adenine pairs with uracil. However, unlike the double-helix structure of DNA, most RNA is single-stranded. RNA is divided into coding and noncoding RNAs. The coding RNA is messenger RNA (mRNA), which is translated into protein. Noncoding RNAs are divided into ribosomal RNA (rRNA), transfer RNA (tRNA), and the small RNAs. The small RNAs are involved in the expression of the genes that code for mRNA and rRNA.



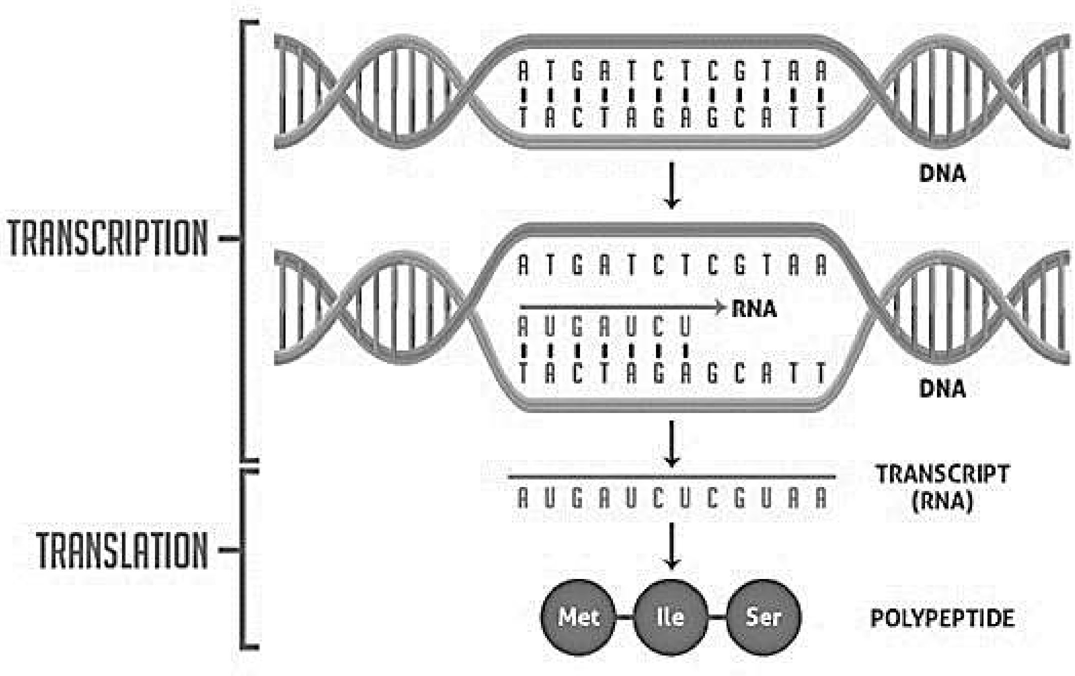
Messenger RNA (mRNA) is produced in the nucleus, where DNA serves as a template for its formation. This type of RNA carries genetic information from DNA to the ribosomes in the cytoplasm, where protein synthesis occurs. Messenger RNA is a linear molecule.

Ribosomal RNA (rRNA) is produced using a DNA template in the nucleolus of the nucleus. Ribosomal RNA joins with specific proteins to form the large and small subunits of ribosomes. The subunits then leave the nucleus and either attach themselves to the endoplasmic reticulum or remain free within the cytoplasm. During the process of protein synthesis, the large and small ribosomal subunits combine to form a complex (the ribosome) that acts as a workbench for the manufacture of proteins.

Transfer RNA (tRNA) is produced in the nucleus, and a portion of DNA also serves as a template for its production. Appropriate to its name, tRNA transfers amino acids to the ribosomes. At the ribosomes, the amino acids are bonded together in the correct order to form a protein. There are 20 different types of amino acids used to make proteins. Each type of tRNA carries only one type of amino acid; therefore, at least 20 different tRNA molecules must be functioning in the cell to properly make a protein.

Transcription

During transcription, a strand of DNA acts as a template upon which a strand of RNA is assembled from RNA nucleotides. A nucleotide can be added to a growing strand of RNA only if it is complementary to the corresponding nucleotide of the parent strand of DNA: G pairs with C, and A pairs with U. Thus. each new RNA is complementary in sequence to the DNA strand that served as its template.



Translation

Protein synthesis is accomplished through a process called translation. After DNA is transcribed into a messenger RNA (mRNA) molecule during transcription, the mRNA must be translated to produce a protein. In translation, mRNA along with transfer RNA (tRNA) and ribosomes work together to produce proteins.

Once mRNA has been modified and is ready for translation, it binds to a specific site on a ribosome. Ribosomes consist of two parts, a large subunit and a small subunit. They contain a binding site for mRNA and two binding sites for tRNA located in the large ribosomal subunit.

Mutations

Mutations are changes in the sequence of a cell's DNA. If a mutation changes the genetic instructions encoded in the DNA, an altered gene product may be the result. **More than one codon can specify the same amino acid**, so cells have a certain margin of safety. For example, a mutation that changes a UCU codon to UCC in an mRNA may not have further effects, because both codons specify serine.

Types of mutations:

1- Base-pair substitution: Type of mutation in which a single base-pair changes.

2- Deletion Mutation in which one or more base pairs are lost.

3- Insertion Mutation in which one or more base pairs become inserted into DNA.

Lecture Twelve: Evolution

Evolution

Evolution is change in the heritable characteristics of biological populations over successive generations. Or Change in the gene pool of a population from generation to generation by such processes as DNA mutation, natural selection, and genetic drift.

Source of variation

1-Genetic drift:

Genetic drift is a cause of allelic frequency change within populations of a species. Alleles are different variations of specific genes. They determine things like hair colour, skin tone, eye colour and blood type; in other words, all the genetic traits that vary between individuals. Genetic drift does not introduce new alleles to a population, but it can reduce variation within a population by removing an allele from the gene pool.

2- Modern synthesis:

The modern evolutionary synthesis is based on the concept that populations of organisms have significant genetic variation caused by mutation and by the recombination of genes during sexual reproduction. It defines evolution as the change in allelic frequencies within a population caused by genetic drift, gene flow between sub populations, and natural selection. Natural selection is emphasized as the most important mechanism of evolution; large changes are the result of the gradual accumulation of small changes over long periods of time.

Evidence for evolution comes from many different areas of biology:

- **Anatomy.** Species may share similar physical features because the feature was present in a common ancestor (**homologous structures**).
- **Molecular biology.** DNA and the genetic code reflect the shared ancestry of life. DNA comparisons can show how related species are.
- **Biogeography.** The global distribution of organisms and the unique features of island species reflect evolution and geological change.
- **Fossils.** Fossils document the existence of now-extinct past species that are related to present-day species.
- **Direct observation.** We can directly observe small-scale evolution in organisms with short lifecycles (e.g., pesticide-resistant insects).

Homology

In biology, **homology (homologous)**, similarity of the structure, physiology, or development of different species of organisms based upon their ancestry from a common evolutionary ancestor. Homology is contrasted with **analogy.**

Thus the forelimbs of such widely differing mammals as humans, bats, and deer are homologous; the form of construction and the number of bones in these varying limbs are practically identical, and represent adaptive modifications of the forelimb structure of their common early mammalian ancestors.

Analogy

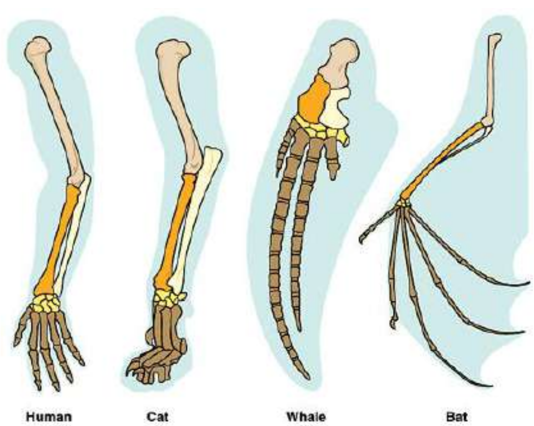
Analogous which is a functional similarity of structure based not upon common evolutionary origins but upon mere similarity of use?

Analogous structures, on the other hand, can be represented by the wings of birds and of insects; the structures are used for flight in both types of organisms, but they have no common ancestral origin at the beginning of their evolutionary development.

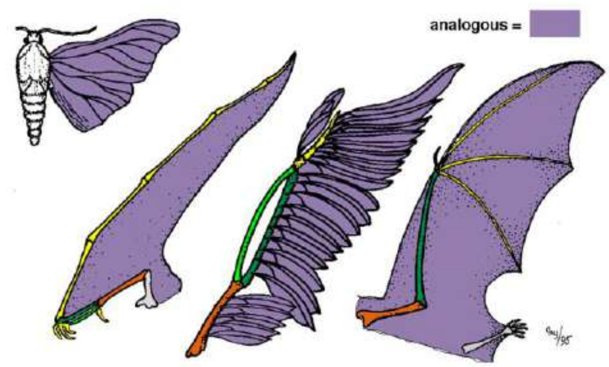
- **Morphological homology** - species (correctly) placed in the same taxonomic category show anatomical similarities.
- **Ontogenetic homology** - species placed in the same taxonomic category show developmental (embryonic) similarities.
- **Molecular homology** - species placed in the same taxonomic category show similarities in DNA and RNA and in their proteins.

Morphological Homology

A structure found in two (or more) different species, but derived from a common ancestral structure is said to be **Homologous** in those species. The structure may or may not be used for the same function in the species in which it occurs.



Homology



Analogy

In contrast, a structure that serves the same function in two species, but is not derived from a common ancestral structure is said to be Analogous. Examples of Analogous structures:

- wings of bat, bird (though the BONES are homologous!), insect:
- camera eye of the vertebrate and the cephalopod (squid & octopus):
- walking limbs of insects and vertebrates
- cranium of vertebrates and exoskeletal head shield of insects
- fusiform shape of fish and cetaceans (whales & dolphins)

Natural selection

Natural selection is the differential survival and reproduction of individuals due to differences in phenotype. It is a key mechanism of evolution, the change in the heritable traits characteristic of a population over generations. Charles Darwin popularized the term "natural selection", contrasting it with artificial selection, which in his view is intentional, whereas natural selection is not.

Population: All the members of a single species living in a defined geographic area. Though Darwin's idea (natural selection) was probably the most important and powerful one in the history of Biological Science, he didn't consider some of the other mechanisms by which evolution also can take place, most of which have to do with Random Processes.

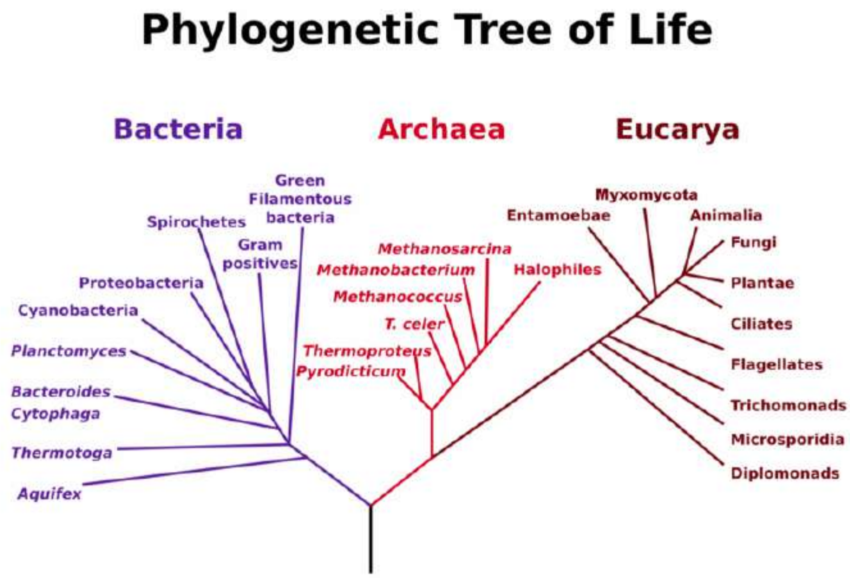
Lecture Thirteen: The evolutionary history of biological diversity

Phylogenetic tree

A **phylogenetic tree** or **evolutionary tree** is a branching diagram or "tree" showing the inferred evolutionary relationships among various biological species or other entities based upon similarities and differences in their physical and/or genetic characteristics. The taxa joined together in the tree are implied to have descended from a common ancestor.

In a **rooted** phylogenetic tree, each node with descendants represents the inferred most recent common ancestor of the descendants, and the edge lengths in some trees may be interpreted as time estimates. Each node is called a taxonomic unit. Internal nodes are generally called hypothetical taxonomic units, as they cannot be directly observed. Trees are useful in fields of biology such as bioinformatics, systematics, and comparative phylogenetics.

A **phylogenetic tree** of living things based on RNA data and proposed by Carl Woese, showing the separation of bacteria, archaea, and eukaryotes. Trees constructed with other genes are generally similar, although they may place some early-branching groups very differently, thanks to long branch attraction. The exact relationships of the three domains are still being debated, as is the position of the root of the tree. It has also been suggested that due to lateral gene transfer, a tree may not be the best representation of the genetic relationships of all organisms. For instance some genetic evidence suggests that eukaryotes evolved from the union of some bacteria and archaea (one becoming an organelle and the other the main cell).



Bacteria: Bacteria are a type of biological cell. They constitute a large domain of prokaryotic microorganisms. Typically a few micrometers in length, bacteria have a number of shapes, ranging from spheres to rods and spirals. Bacteria were among the first life forms to appear on Earth, and are present in most of its habitats. Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep biosphere of the earth's crust. Bacteria also live in symbiotic and parasitic relationships with plants and animals. Most bacteria have not been characterized, and only about 27 percent of the bacterial phyla have species that can be grown in the laboratory (specifically uncultivable phyla, known as candidate phyla, make up 103 out of approximately 142 known phyla). The study of bacteria is known as bacteriology, a branch of microbiology.

Archaea: Archaea (singular archaeon): constitute a domain of single-celled organisms. These microorganisms are prokaryotes, and have no cell nucleus. Archaea were initially classified as bacteria, receiving the name **archaebacteria** (in the Archaebacteria kingdom), but this classification is outmoded. Archaeal cells have unique properties separating them from the other two domains, Bacteria and Eukaryota. Archaea are further divided into multiple recognized phyla. Classification is difficult because most have not been isolated in the laboratory and have only been detected by analysis of their nucleic acids in samples from their environment.

Eukaryotes: Eukaryotes are organisms whose cells have a nucleus enclosed within membranes, unlike prokaryotes (Bacteria and Archaea), which have no membrane-bound organelles. Eukaryotes belong to the domain **Eukaryota** or **Eukarya**. Eukaryotic cells also contain other membrane-bound organelles such as mitochondria and the Golgi apparatus, and in addition, some cells of plants and algae contain chloroplasts. Unlike unicellular archaea and bacteria, eukaryotes may also be multicellular and include organisms consisting of many cell types forming different kinds of tissue. Animals and plants are the most familiar eukaryotes.

Protist: Protist is any eukaryotic that is not an animal, plant, or fungus. The protists do not form a natural group, or clade, since they exclude certain eukaryotes with whom they share a common ancestor;[a] but, like algae or invertebrates, the grouping is used for convenience. In some systems of biological classification, such as the popular five-kingdom scheme proposed by Robert Whittaker in 1969, the protists make up a kingdom called **Protista**, composed of "organisms which are unicellular or unicellular-colonial and which form no tissues" protista was first used by Ernst Haeckel in 1866. Protists were traditionally subdivided into several groups based on similarities to the "higher" kingdoms such as:

Protozoa:

These unicellular "animal-like" (heterotrophic, and sometimes parasitic) organisms are further sub-divided based on characteristics such as motility, such as the (flagellated) Flagellata, the (ciliated) Ciliophora, the (phagocytic) amoeba, and the (spore-forming) Sporozoa.

Protophyta

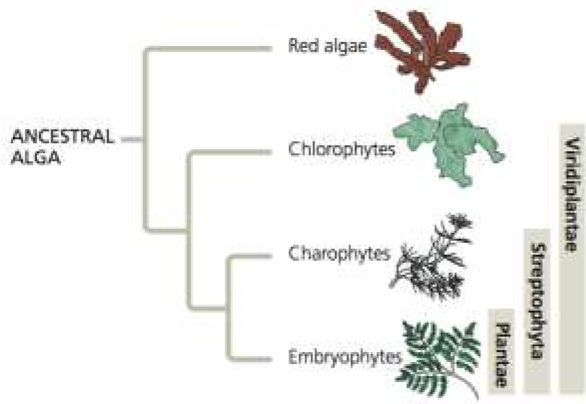
These "plant-like" (autotrophic) organisms are composed mostly of unicellular algae. The dinoflagelates, diatoms and *Euglena*-like flagellates are photosynthetic protists.

Molds

Slime molds and water molds are "fungus-like" (saprophytic) organisms. These are consumer-decomposer protists. Two separate types of slime molds exist, the cellular and acellular forms.

Plant Diversity : How Plants Colonized Land

Land plants evolved from green algae



Morphological and Molecular Evidence

1. Rings of cellulose-synthesizing proteins
2. Peroxisome enzymes
3. Structure of flagellated sperm
4. Formation of a phragmoplast

Derived Traits of Plants

Four key traits appear in nearly all land plants but are absent in the charophytes

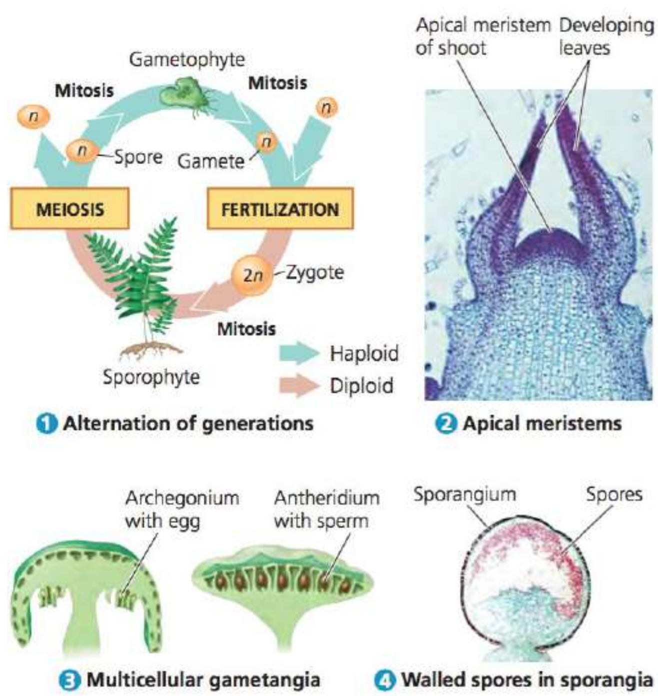
1. Walled spores produced in sporangia
2. Apical meristems
3. Embryophytes
4. Alternation of generations and multicellular, dependent embryos

Walled Spores Produced in Sporangia

- The sporophyte produces spores in organs called **sporangia**
- Diploid cells called **sporocytes** undergo meiosis to generate haploid spores
- Spore walls contain **sporopollenin**, which makes them resistant to harsh environments

Multicellular Gametangia

- Gametes are produced within organs called **gametangia**
- Female gametangia, called **archegonia**, produce eggs and are the site of fertilization
- Male gametangia, called **antheridia**, produce and release sperm



Apical Meristems

- Plants sustain continual growth in their **apical meristems**
- Cells from the apical meristems differentiate into various tissues

Additional derived traits include:

1-**Cuticle**, a waxy covering of the epidermis
2-Mycorrhizae, symbiotic associations between fungi and land plants that may have helped plants without true roots to obtain nutrients
3-Secondary compounds that deter herbivores and parasites

Plant Diversity: The Evolution of Seed plants:

Common traits of all seed plants:

1. Gametophyte reduction in size
2. Heterospory
3. Ovules and production of eggs
4. Pollen and production of sperm
5. Seeds

1. Reduced gametophytes can be microscopic:

Advantages of reduced gametophyte:

a. protection of female gametophytes from environmental changes
b. help prevent drought
c. protect from UV radiation
d. can obtain nutrients from sporophytes

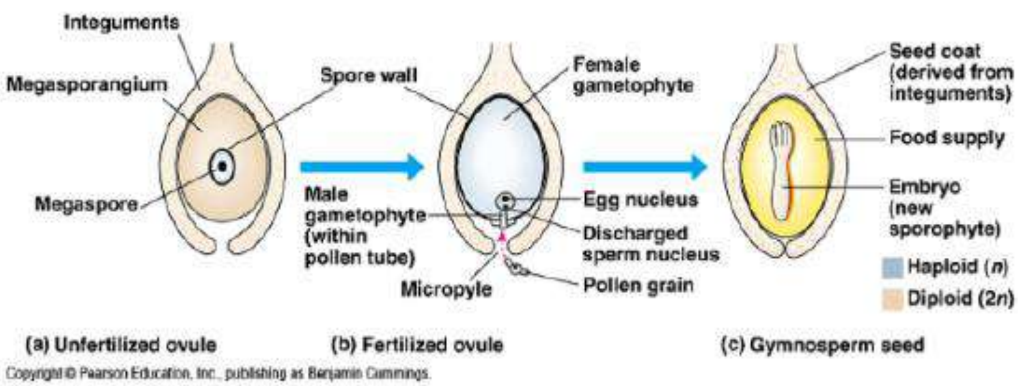
2. Heterospory

❖ each megasporangia produces 1 megaspore (spore from a heterosporous plant species that develops into a female gametophyte)

❖ each microsporangia produces many microspores (a spore from a hetersporous plant species that develops into a male gametophyte).

3. Ovules and production of eggs

Layers of **integument** enclose megaspore gymnosperms 1 integument angiosperms two integuments whole structure = **ovule**



4. Pollen and production of sperm

- microspores become **pollen grains** (male gametophytes)
- protected by sporopollenin (tough coat polymer)
- carried by wind, animals for pollination
- Purpose: reproduction over long distances
- advantages: long distance, no motility needed

5. Evolution of seeds Advantages:

-multicellular layer of tissue (seed coat) extra protection for embryo can resist harsh conditions

-Supply of food within can remain dormant for years

-disperse widely

Fungi: A **fungus** is any member of the group of eukaryotic organisms that includes microorganisms such as yeasts and molds, as well as the more familiar mushrooms. These organisms are classified as a kingdom, fungi, which is separate from the other eukaryotic life kingdoms of plants and animals.

A characteristic that places fungi in a different kingdom from plants, bacteria, and some protists is chitin in their cell walls. Similar to animals, fungi are heterotrophs; they acquire their food by absorbing dissolved molecules, typically by secreting digestive enzymes into their environment. Fungi do not photosynthesize.

Growth is their means of mobility, except for spores (a few of which are flagellated), which may travel through the air or water. Fungi are the principal decomposers in ecological systems. These and other differences place fungi in a single group of related organisms, named the *Eumycota* (*true fungi* or *Eumycetes*), which share a common ancestor (form a *monophyletic group*), an interpretation that is also strongly supported by molecular phylogenetics. This fungal group is distinct from the structurally similar myxomycetes (slime molds) and oomycetes (water molds).

Lecture Fourteen: The evolutionary history of biological diversity

An Overview of Animal Diversity

Animal evolution began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. Since then, animals have evolved into a highly diverse kingdom. Although over one million extant (currently living) species of animals have been identified, scientists are continually discovering more species as they explore ecosystems around the world. The number of extant species is estimated to be between 3 and 30 million.

But what is an animal? While we can easily identify dogs, birds, fish, spiders, and worms as animals, other organisms, such as corals and sponges, are not as easy to classify. Animals vary in complexity—from sea sponges to crickets to chimpanzees—and scientists are faced with the difficult task of classifying them within a unified system. They must identify traits that are common to all animals as well as traits that can be used to distinguish among related groups of animals. The animal classification system characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup. This classification scheme is constantly developing as new information about species arises. Understanding and classifying the great variety of living species help us better understand how to conserve the diversity of life on earth

Classification & the Animal Kingdom

How is Organisms Classified?

Classification: the grouping of anything according to its similar characteristics. The science of classifying organisms is known as **taxonomy.**

How is Organisms Classified?

There are eight classification groups of living things:

Domain
Kingdom
Phylum
Class
Order
Family
Genus
Species

What is an Animal?

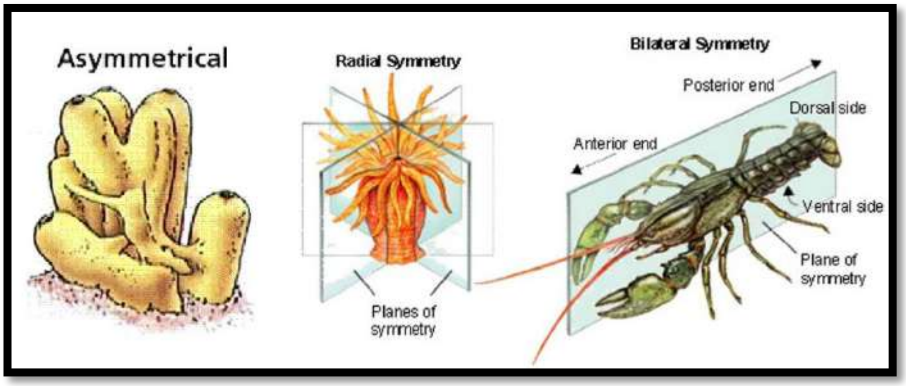
We will be focusing specifically on the Kingdom Animalia and its 9 phyla. Vertebrates: animals with backbones Invertebrates: animals without a backbone97% of all animal species are invertebrates!

What is Symmetry?

To classify animals, scientists also look at symmetry, or how the body parts are arranged.

1. **Radial symmetry:** body parts are arranged in a circle around a center point.
2. **Bilateral symmetry:** body can be divided into two mirror image halves.

3. **Asymmetry:** no pattern of symmetry



What are

the Characteristics of all Animals?

- ✓ Animals cannot make their own food (consumers).
- ✓ Animals digest their food.
- ✓ Many animals move from place to place.
- ✓ Animals have many cells.
- ✓ Animal cells have nuclei and organelles (eukaryotic cells).

What are the nine Different Phyla in Kingdom Animalia?

Phylum Porifera

Phylum Cnidaria

Phylum

Platyhelminthes

Phylum Nematoda

Phylum Mollusca

Phylum Annelida

Phylum Arthropoda

Phylum Echinodermata

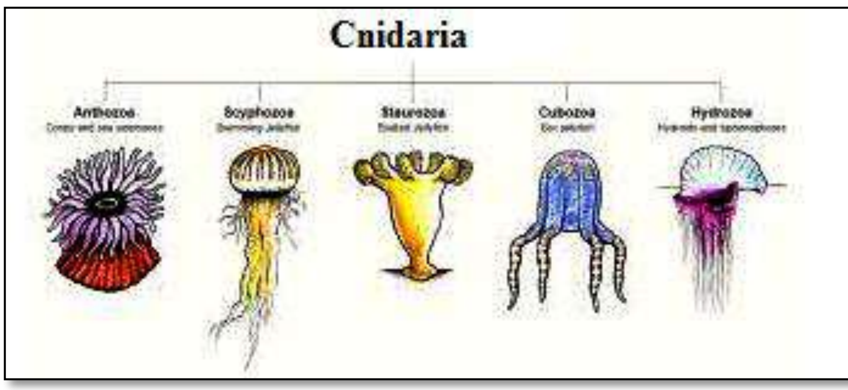
Phylum Chordata

- **Phylum Porifera**

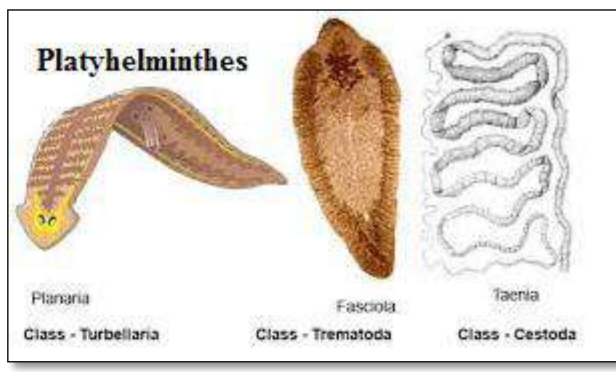
  Aquatic organisms lack tissues and organs asymmetrical, mostly sessile (do not move) Example: sponges. This is a "real" sponge are Aquatic organisms, lack tissues and organs Asymmetrical, mostly sessile (do not move).

- **Phylum Cnidaria**

  Aquatic organisms, radial symmetry, digestive cavity with one opening, tentacles with stinging cells; Examples: jellyfish, corals, hydra, sea anemones.



Phylum Platyhelminthes



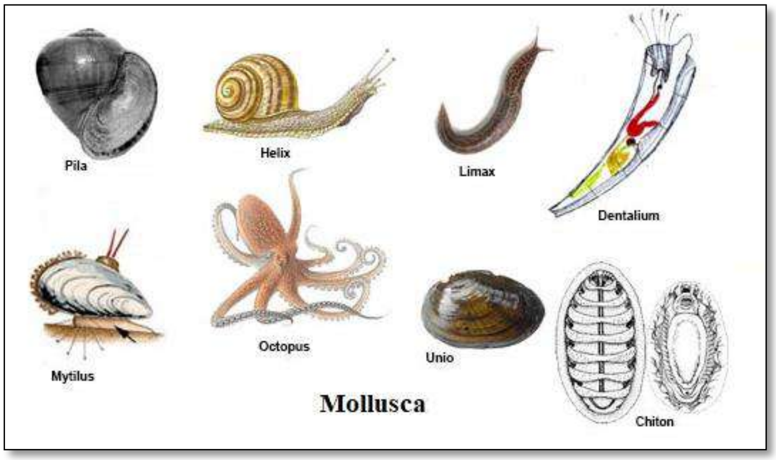
Bilaterally symmetrical worms, flat bodies, digestive system with one opening; Examples: parasitic and free-living species Examples: Flat worms.

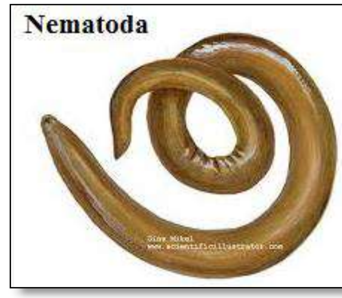
- **Phylum Nematoda**

  Round, smooth worms, Bilateral symmetry Digestive system with two openings free living and parasitic forms Examples: roundworms.

- **Phylum Mollusca**

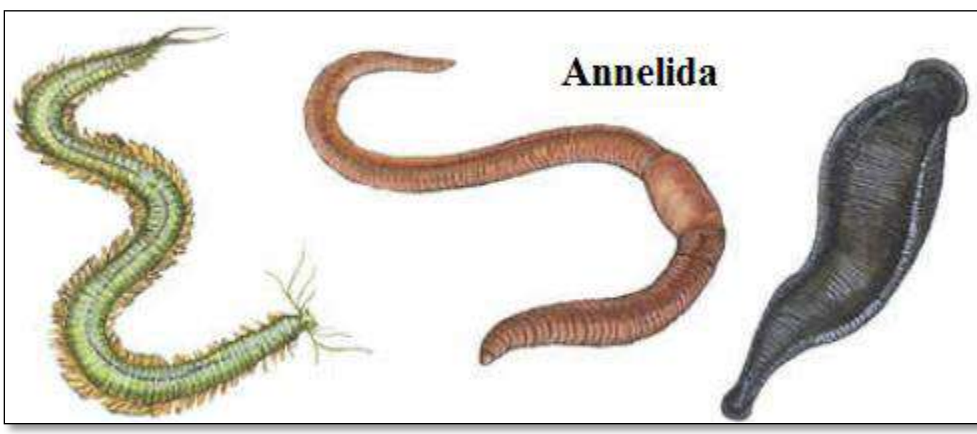
Soft-bodies, many with a hard shell or foot-like appendage, aquatic or terrestrial; Examples: clams, snails, squid, octopuses.





- **Phylum Annelida**

Round worms with segmented bodies, bilateral symmetry, Terrestrial and aquatic; Examples: earthworms, leeches, and marine polychaetes.



- **Phylum Arthropoda**

Largest animal group, bilateral symmetry, Have an exoskeleton, segmented bodies, and pairs of jointed appendages, Land and aquatic; Examples: insects, crustaceans, and spiders.

- **Phylum Echinodermata**

Marine organisms, Radial symmetry Spiny/leathery skin, Water-vascular system with tube feet; Examples: sea stars, sand dollars, sea urchins.

Arthropoda

- **Phylum Chordata**

Organisms with internal skeletons and specialized body systems, At some point all have a backbone (or notochord), gill slits, and a tail; Examples: fish, amphibians, reptiles, birds, and mammals.