# BIOLOGY - 2201 .
# UNIT 1 : MATTER and ENERGY for LIFE.

**NAME : ______________________________**

**Biology** is the study of life (living things). Living things are much more than a mere set of chemical reactions or a physical machine. They are composed of individual units called cells, considered to be the basic unit of structure and function and the smallest independent unit capable of displaying the characteristics of life. A one-celled organism is said to be ***unicellular*** . Organisms with more than one cell are said to be ***multicellular***.

**Cell Theory :** (First stated in 1858)

1. All living organisms are composed of one or more cells.
2. Cells are the basic unit of structure and function in all organisms.
3. All cells are derived from pre-existing cells.
4. In a multicellular organism, the activity of the entire organism depends on the total activity of its independent cells.

## HISTORICAL DEVELOPMENT OF CELL THEORY :

Spontaneous generation states that living things come from non living sources ; (eg.) maggots appear on meat if left out too long ; after it rains — frogs , insects and plants seem to come out of mud in ponds. All ideas of spontaneous generation were supported by observation. In 1870, Thomas Henry Huxley used the term **abiogenesis** to describe the concept of spontaneous generation. In actual fact, we know that life only arises from life or that living things come from other living things ; this is known as **biogenesis**.

334 B.C.E. Aristotle put forward the idea of spontaneous generation — organisms can arise spontaneously from non-living matter. He classified all organisms as plants or animals.

l668 Francesco Redi — (challenged the idea of spontaneous generation).
In his controlled experiment, he hypothesized that if maggots come from flies eggs ,then maggots will appear only in open jars where flies can deposit eggs on meat. When testing, he placed some meat samples in covered jars and some in uncovered jars. He found that maggots appeared only in uncovered containers. He tested many times and obtained the same results even with different meats.

1675 Leewenhoek discovers and invents the simple microscope. Using his microscope, he sees microorganisms. This refuels the spontaneous generation debate.

1748 John Needham performed an experiment similar to Redi's. He boiled a meat broth (to kill microbes); sealed one container ( not airtight — sterile) and left another open. The result was microbes were present. This supported spontaneous generation.

1776 Spallanzani repeated Needham's experiment. He boiled the containers for one hour; then, sealed the flasks tightly. No microbes were present. The microbes appeared hours after the seals were broken. He believed that microorganisms were carried in air and multiply when they had a food supply.

1861 Pasteur repeated Spallanzani's work. He used S - shaped necked flasks (heat flask and bend into an S-shaped curve) which allowed air and microbes in. However when he boiled the solution in the base of the flask this created steam which condensed and formed water droplets which trapped microbes in the neck of the flask. The broth remained clear. He broke the necks of the flasks. The broth turned cloudy. Flasks were tipped and the microbes mixed with the broth. The broth turned cloudy. Some of his flasks (on display) are still sterile today.

**THE CELL : The basic unit of life.**

1665 - Robert Hooke studied slices of cork and saw cells — (looked like cells in a honeycomb).
1835 - Dujardin : Many microorganisms were composed of a single cell.
1838 - Schleiden : Cells were present in plant tissue.
1839 - Schwann : Cells were present in animal tissue.
~ This suggested that all organisms were composed of one or more cells.
1858 - Virchow observed dividing cells and concluded that cells can arise only from other cells .

These scientists suggested that cells can only arise from other cells formed the basis of the cell theory. The cell is the basic unit of organization for all organisms. All organisms are formed from cells or cell products. All cells come from other cells.

**Microscopes :**

Cells are tiny structures. The smallest object that the human eye can view is around 100 µm ; (the limit of human sight). A **microscope** consists of a lens or combination of lenses that produce enlarged images of small objects. Microscopes are an important tool used to extend the abilities of human vision. The earliest microscope consisted of a single strongly curved lens mounted on a metal plate. In the late 1600's , a Dutch naturalist, Antony von Leeuwenhoek, made a simple microscope (a single lens) with a magnification of 400 x. He was the first person to observe microscopic organisms. Later, the ***compound (light) microscope*** was developed. The compound microscope has two lenses *(the ocular and objective)* rather than one. The two lenses and improvements in lens making allowed for less distortion effects that were found in earlier microscopes. Both simple and compound microscopes use visible light to illuminate the objects being viewed. The **resolution** or **resolving power** (of a microscope) refers to the ability to distinguish between separate objects that are close together.

Reference : Core Lab # 1 : "Using the Microscope" ; (pp. 15 - 19).

**<u>Microscope Imaging Today (pp. 20 - 21) :</u>** Light microscopes have limited resolving power (around 200 nm) due to the nature of visible light itself. To overcome the limitation of the light microscope, a new source of illumination (the electron) was used and electron microscopes were invented (1932). An **electron microscope** is a microscope that uses a beam of electrons instead of light to illuminate objects. Electrons are able to penetrate the small spaces between cell components much better than light.

**<u>TYPES:</u>**

1) **TEM (*transmission electron microscope)*** : directs a beam of tiny particles (electrons) through an object. It uses magnets rather than lenses and the result is shown or projected on a screen because the eye cannot respond to electrons. The problem with this microscope is that the object being viewed must undergo extensive preparation. It must be very thin and as it is prepared, it is sliced frozen and treated with chemicals which may distort the image. The magnification is 1,000,000 x.

2) **SEM *(scanning electron microscope)*** takes pictures rather than slices. It is almost three dimensional. In many cases , whole organisms are used.

***<u>Comparison of the light microscope with an electron microscope :</u>***

| Type of Microscope | Source of Illumination | Magnification | Resolution | Specimen Preparation |
|---|---|---|---|---|
| **Light** | visible light | up to 2000 x | about 0.2_ m | usually killed, fixed and stained |
| **Electron** | electrons | # TEM : typically 10 000 x to 500 000 x<br><br># SEM : typically 1 000 x to 10 000 x | # TEM : about 0.2 nm<br><br># SEM : about 1 to 10 nm | # usually killed, dried and fixed<br><br># fixed, cleaned, and coated with metal |

All living cells must :

3 obtain food and energy
3 convert energy from an external source into a form that the cell can use
3 construct and maintain the molecules that make up cell structures
3 carry out chemical reactions
3 eliminate wastes
3 reproduce
3 keep records of how to build structures

**<u>Types of Cells :</u>**

**<u>Prokaryotic cells</u> (prokaryotes)** do not contain a nucleus; (eg.) all bacterial cells. *Pro* means "before" and *Karyon* means "nucleus". Prokaryotes have no membrane-bound organelles and lack a true membrane-bound nucleus. Their DNA is concentrated in an area called the **nucleoid.**
(ex.) Figure 1.10 ; p. 23 — the bacterium, *Escherichia coli.*

**<u>Eukaryotic cells</u> (eukaryotes)** are cells that contain a nucleus. *Eu* means "true"and *Karyon* means "nucleus". The nucleus is an enclosed region that separates the DNA from the rest of the cell contents. Eukaryotes contain a number of specialized structures called **organelles**.

***<u>Structures (organelles) found in eukaryotic cells:</u>***

| Organelle name | Description of structure | Description of function | Plant or animal? |
|---|---|---|---|
| nucleus | round;<br>occupies center of cell | control center of the cell | both |
| mitochondrion | "peanut-shaped" | site of cellular respiration | both |
| ribosome | little balls | site of protein synthesis | both |
| centrosome | not visibly distinct | aids in mitosis | animal |
| vacuole | round vesicle (large in plants, small in animals) | storage of food, wastes, water etc. | both |
| chloroplast | "cucumber-shaped" | site of photosynthesis | plant |
| lysosome | round sac | site of digestion | both (limited in plants) |
| Golgi apparatus | stacked discs | site of vesicle formation, packages products for shipment to other cells | both |
| ER | long, thin membranes; thick structure surrounding | transport of materials | both |
| cell wall | cell membranes | structural support | plant |
| microtubules | thin, long structures | skeletal support | |
| cell membrane | thin lipid bilayer | controls entry/ exit of materials | both |

Mini Lab p. 24 — Observing stained cells.
***CELL STRUCTURE and FUNCTION :*** (See Figure 1.12 ; p. 25)

**Chromatin :** Fibers of DNA and attached proteins which coil-up during the early stages of cell division to form the visible chromosomes.

**Nucleoplasm :** The semi-fluid substance within the nucleus.

**Nuclear Envelope :** The double membrane which encloses the nucleus. The membranes composing the envelope contain protein channels called nuclear pores.

**Endoplasmic Reticulum (ER) :** A membranous tubule system throughout a cell.

**Rough Endoplasmic Reticulum (RER) :** A network (reticulum) of tubular membranes in which are embedded large numbers of ribosomes (the black dots). Secretory proteins as well as membrane proteins are produced by the ribosomes on the surface of the RER.

**Smooth Endoplasmic Reticulum (SER) :** Lacks chromosomes; detoxifies cell poisons; the site of steroid synthesis and phospholipid production..

**Ribosomes :** Very small non-membrane bound structures which occur free-floating in the cytoplasm or attached to the membranes of rough endoplasmic reticulum. Ribosomes are the sites of protein synthesis.

**Golgi body :** Groups of flattened membrane bound sacs which package, store, modify, and transport products produced by the endoplasmic reticulum (both rough and smooth).

**Transport Vesicles :** Small membrane bound sacs which move materials from the endoplasmic reticulum to the Golgi apparatus and/or materials from the Golgi apparatus to other sites in the cell or to the outside of the cell.

**Lysosomes :** Membrane-bound sacs containing digestive (hydrolytic) enzymes. They are produced by the Golgi apparatus.

**Peroxisomes :** Membrane-bound sacs containing enzymes that can break down lipids and toxic waste products.

**Vacuoles :** Membranous sacs that store nutrients, wastes and water.

**Mitochondria (mitochondrion = singular) :** Organelles which are bounded by two membranes and within which many of the biochemcial reactions of aerobic respiration occur. Mitochondria contain DNA (called m-DNA) and ribosomes.

**Microtubules and Microfilaments :** A linear arrangement of proteins that function in the transport of materials within the cell; also involved in the movement of cell DNA during cell division.

**Centrioles :** Short microtubules that during cell division elongate to seek out and capture cell chromososmes.

**Centrosomes :** Organelle located near the nucleus that organizes the cell's microtubules and helps to organize the even distribution of cell components when cells divide; it contains a pair of centrioles that are made up of microtubules.

**Cell Membrane :** The very thin (9-10 nm) membrane which separates a cell's contents from its outside environment. It is composed of two layers of phospholipids, proteins, glycolipids, glycoproteins, and cholesterol (only in animal cell membranes). The cell membrane is semi-permeable.

***Organelles — Summary :***

Organelles are to cells what organs are to the body. They carry out the individual tasks of gaining and working with energy, as well as directing the overall behavior of the cells.

| ORGANELLE | DESCRIPTION |
|---|---|
| Nucleus | This is the main planner of the cell. It contains the DNA and RNA and manufactures proteins. |
| Mitochondria | The mitochondria are the energy producers of the cell. |
| Ribosomes | The ribosomes produce proteins. |
| Endoplasmic Reticulum | The endoplasmic reticulum transports proteins from the nucleus. |
| Golgi Bodies | The Golgi body produces and packages proteins. |
| Chloroplasts | The chloroplasts are involved in photosynthesis. |
| Vacoules | This is an organelle with little or no internal structure. |

*While not exactly organelles, the following are important parts of cells:*

| CELL PART | DESCRIPTION |
|---|---|
| Cell Membrane | This surrounds the cell. |
| Cell Wall | The cell wall is a stiff wall that surrounds the cell membrane. |
| Cytoplasm | Cytoplasm is packaging of the cell. |

*There are a few important processes which the cell engages in:*

| PROCESS | DESCRIPTION |
|---|---|
| Diffusion | How food, air, and water gets in and out of the cell. |
| Photosynthesis and Cellular Respiration | How the cell gets energy. |

***PLANTS :***

**Plastids :** the carbohydrate producers of the cell — found in plant cells and some unicellular autotrophs. Types are : *chloroplasts, chromoplasts and leucoplasts.* Chloroplasts contain chlorophyll. Chromoplasts contain red, orange and yellow pigments which give flowers and fruit its color. Leucoplasts are colorless and are the sites where starch is synthesized from sugar.

**Chloroplasts :** Organelles within which the biochemical reactions of photosynthesis occur. During photosynthesis, light energy is used to convert carbon dioxide and water into simple sugars. The outer covering of chloroplasts is composed of two membranes. The interior of chloroplasts is traversed by a series of double membranes called thylakoids which are surrounded by a fluid called the stroma. In addition to enzymes, the stroma contains DNA, and ribosomes. The pigments (e.g., the green chlorophylls and orange carotenoids), responsible for absorbing the light energy, are embedded within the thylakoid membranes. Stacks of these thylkoid membranes are called grana (singular = granum). The grana (singular = granum) are coin-like stacks of thylakoid membranes within the fluid filled matrix (= stroma) of chloroplasts.
The pigments (e.g., the green chlorophylls and orange carotenoids), responsible for absorbing the light energy, are embedded within the thylakoid membranes.

**Cell Wall :** The primary function of the rigid or semi-rigid cell wall is to provide support for the cells; thus providing strength for the entire plant body. The exact composition of cell walls varies with the plant species and with cell type. All plant cell walls contain the polysaccharide cellulose which is composed of thousands of glucose (a monosaccharide) molecules attached end to end. Cellulose is an extremely strong organic compound. In general, cell walls contain 25-60% cellulose. Young cells and cells in actively growing regions such as those in stem and root tips generally have relatively thin and flexible cell walls whereas those cells primarily involved in support generally have walls of moderate to extensive thickness which contain relatively large amounts of lignin as well as cellulose. Plant cells that adjoin one another are often held together by pectins. Some tissues, such as the flesh of apples, are so rich in pectin that is extracted for use as a thickening agent in making jams and jellies

**<u>Cell Membrane Structure :</u>**

As was stated earlier, the purpose of the cell membrane is to separate one cell from another cell. It also controls the movement of materials into and out of the cell. It is this function that is of great importance in terms of regulating the movement of materials.

<u>The cell membrane must be able to :</u>

- **#** transport raw materials into the cell.
- **#** transport manufactured products and wastes out of the cell.
- **#** prevent entry of unwanted matter into the cell.
- **#** prevent the escape of matter needed to perform the cellular functions.

EM (electron microscope) diagram of the cell membrane shows that it is a **bilayer**: (ie.) it consists of two layers of molecules — mainly **phospholipid molecules**, a type of lipid. See Figure 2.22 on p. 51.

A living cell must maintain a good internal environment or **homeostasis**. This homeostasis refers to maintaining nearly constant internal conditions so that the cell can perform its life functions. It is a process of keeping a balance of solutes and solvent within a cell. The environment of the cell interior is kept at a steady state despite changes in the conditions of the external environment.

Materials have to pass into or out of the cell membrane. The cell membrane is said to be **selectively-permeable** allowing some molecules to pass through it while preventing others from doing so. The cells of a multicellular organism are bathed in a thin layer of **extracellular fluid** , containing a mixture of water and dissolved materials. Dissolved materials such as nutrients and oxygen can enter into a cell while other materials such as wastes and carbon dioxide can leave a cell. In a solution, the dissolved materials would be known as **solutes** (particles being dissolved) and the water would be the **solvent** (what is doing the dissolving). These materials move by means of passive transport. No cellular energy is required for the movement of these materials into or out of the cell.

**<u>Material Transport :</u>**

**Diffusion** is the driving force for substances to move around in cells. Diffusion results from the **random motion of molecules**. If some regions are more concentrated than others, diffusion will occur from the more concentrated region to the less concentrated region until the concentrations of both regions have become equal; (ie.) have reached a state of **equilibrium**. This difference in concentrations between regions is known as a **concentration gradient**.

Water flows smoothly across the cell membrane without needing any carrier. This free movement of water, (or diffusion of a solvent), across a semi-permeable membrane is known as **osmosis.** There are three situations which can result from water movement.

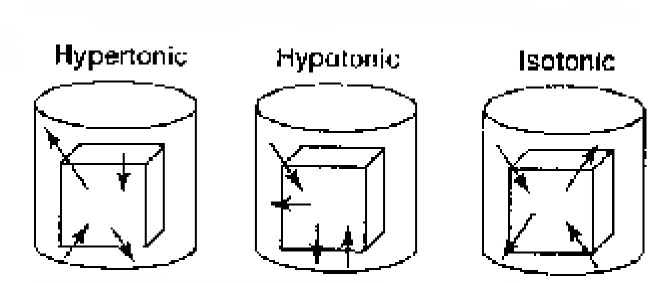
I) **<u>Isotonic environment</u>:** Water concentration outside (extracellular fluid) must equal the water concentration inside the cell. Since most cells contain about 0.9% dissolved salts + solutes, isotonic environments must contain 0.9% salt. In this situation, water flow out equals water flow in. For human cells, this is desirable state. Laboratory and clinical workers often use **Ringer's solution** to bathe exposed tissues and provide an isotonic environment.

II) **<u>Hypotonic environment:</u>** Water concentration outside the cell is higher (eg. pure water) than inside the cell. In other words, the solute concentration outside cell is lower than inside cell. The net result is that water moves in at greater rate than it moves out. A cell placed in a hypotonic solution will gain water. For an animal cell, it may swell until it bursts. For a plant cell, the cell wall inhibits bursting.

III) **<u>Hypertonic environment:</u>** Water concentration outside the cell is lower (eg. brine, syrup) than inside the cell. In other words, the solute concentration outside the cell is higher than inside the cell. The net result is that water moves out at greater rate than it moves in. This condition of losing water from a cell is called **plasmolysis**. For a plant cell, excessive amounts of salt will make the outside environment hypertonic and the cell will lose water causing the plant to wilt. You can restore cell activity by placing back in isotonic environment.

<u>Two possible results</u>: If a cell lacks a wall, it will shrivel up like a raisin. The cells stop metabolizing, but are not immediately killed.. If the cell has a **wall**, the membrane will shrink away from the wall as water leaves the cell, the rigid wall remains where it is. This leads to **plasmolysis**. This is undesirable state for walled cells because the cells stop metabolizing.

<u>See the diagram below for a potato cell.</u>




Some materials like ions and molecules such as glucose cannot pass through the phospholipid bilayer of the cell membrane. These particles pass through the cell membrane by the process of **facilitated diffusion**. Facilitated diffusion describes the passive movement of molecules from an area of high concentration to an area of low concentration. In order for these molecules to pass through the cell membrane, the cell membrane has such structures as protein channels and carrier proteins to carry out the material transport.

<u>NOTE :</u> In facilitated diffusion, the membrane has specific protein carrier which will bind to a molecule and bring it across the cell membrane. No energy is required and there is no preferential direction.

**<u>Passive vs. Active Transport :</u>**

Passive transport relies on the random motion of particles to establish equal concentrations. The cell does not expend energy. Active transport moves molecules against the concentration gradient. It will move a solute against a concentration gradient, so it can concentrate material even if diffusion would favor the opposite direction of flow. There is an energy requirement by a cell for this process to occur.

| | Active Transport | Passive Transport |
|---|---|---|
| Similarities | ! particles enter and exit the cell<br><br>! proteins in the membrane act as “doorways” | ! particles enter and exit the cell<br><br>! proteins in the membrane act as “doorways” for some particles |
| Differences | ! particles move against the concentration gradient<br><br>! cellular energy is used to move particles | ! particles move with the concentration gradient<br><br>! no cellular energy is needed to move particles |

**Bulk Material Transport — (Active Transport) :**

Large molecules (proteins, nucleic acids, polypeptides larger than a few amino acids, polysaccharides larger than a few sugars) are not carried by transport proteins. There are mechanisms for moving these larger molecules, but they don't enter into the cytoplasm of a cell.

The processes are :

(I) **Exocytosis** is where a vesicle from the inside of the cell moves to the cell surface where it fuses with the cell membrane vesicle fuses with cell membrane to release its contents into the extracellular fluid outside of the cell. For example, the release of digestive enzymes from pancreatic cells — such as mucus, milk, hormones, etc. It is the opposite process of endocytosis.

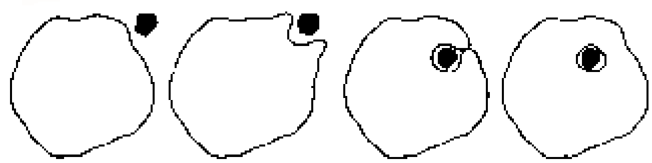
(II) **Endocytosis** is where the cell membrane folds inward trapping and enclosing small amounts of matter from the extracellular fluid. It creates a vesicle which surrounds the contents. Three common forms are:

- **Phagocytosis** is the engulfing of some extracellular fluid containing solid particles such debris from bacteria and other particulate matter. Vesicle contents in the cell woill fuse with a lysosome where the material is broken down. It is especially common in white blood cells such as macrophages and other leukocytes which are part of our immune system. A simple organism like the amoeba uses this process in obtaining its food.

- **Pinocytosis** is similar to phagocytosis, but takes in or engulfs fluid rather than particulate matter. You can think of it as being "cell drinking". For example, the cells lining a blood capillary will take fluid from the blood (but not from red cells), move the fluid across their cytoplasm, and then release the fluid into the extracellular space surrounding cells outside the capillary.

**- Receptor-Assisted Endocytosis** involves the intake of special molecules such as cholesterol that attach to special proteins in the cell membrane — act as receptors. These receptors have a unique shape that will only fit the shape of the molecule to be moved into the cell's interior.

**NOTE :** A diagram to illustrate vesicle formation for pinocytosis or phagosytosis.



**Cell Energy — Matter and Energy Transformations :**

The energy that is utilized by a cell has to come from an outside source. In terms of the makeup of feeding relationships for organisms, the basis of all energy will be the sun. In an ecological relationship, the sun is needed to provide the energy that producers need to make their own food by the process of **photosynthesis**. The producers ( green plants, algae and some kinds of bacteria) undergo photosynthesis and are known as **autotrophs**. Autotrophs become food for other organisms known as **heterotrophs** — obtain food from other sources. Therefore the autotrophs become the cornerstone for the passage of materials and energy in food chains or feeding relationships. The **heterotrophs** obtain energy by eating plants and then utilizing this energy by the process of **cellular respiration**.

The processes of photosynthesis and cellular respiration are opposite or complementary processes. **Photosynthesis** is the transformation of light energy from the sun into the chemical energy of glucose. The green color in plants is due to the presence of **chlorophyll**, a **pigment**, which is the energy trapper inside a plant for photosynthesis. **Cellular respiration** is the process of breaking down food (such as carbohydrates and other molecules) in order to release the (potential) energy present in food. Food is oxidized in the body to release energy. See figure 3.4, p. 73. The energy molecule released in cellular respiration is **ATP (adenosine triphosphate molecule)**. ATP is an energy carrier molecule used by an organism for its energy requirements.

The equations for each process is given below.
**Reactions of complementary processes :**

1. **PHOTOSYNTHESIS :**

*Reactants* *Products*

$6\ CO_2$ + $6\ H_2O$ + light ! $C_6H_{12}O_6$ + $6\ O_2$
carbon dioxide + water + light energy ! glucose + oxygen
For this reaction, we must have : sunlight and chlorophyll.

## 2. CELLULAR RESPIRATION :

*Reactants* *Products*

$C_6H_{12}O_6$ + 6 $O_2$ ! 6 $CO_2$ + 6 $H_2O$ + Energy
Glucose + oxygen ! carbon dioxide + water + ATP
Water vapour can enter water cycle and be used by autotrophs for photosynthesis.

***We can also summarize these reaction in terms of a table.***

| Process | Raw Materials | Products |
|---|---|---|
| photosynthesis | carbon dioxide<br>water<br>energy | sugar<br>oxygen |
| respiration | sugar<br>oxygen | carbon dioxide<br>water<br>energy |

There are two types of cellular respiration: **aerobic respiration and anaerobic respiration**.

**Aerobic respiration** is a process that requires oxygen. It will release 38 ATP molecules in bacterial cells and 36 ATP molecules in cells with mitochondria. See figure 3.14, p. 82.

**Anaerobic respiration** is a process that will occur in the absence of oxygen. An example would be glycolysis which can occur in muscle cells. It will only release 2 ATP molecules from the breakdown of one glucose molecule.