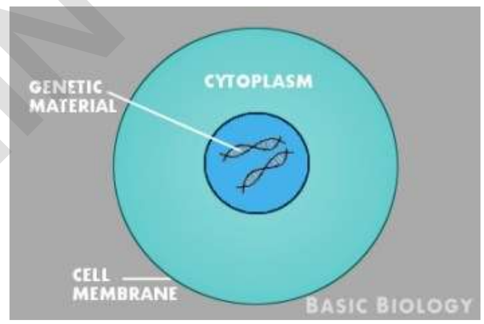
MODULE 1: INTRODUCTION TO BIOLOGY

The Cell: ***"A cell is defined as the smallest, basic unit of life responsible for all life's processes."***

- Cells are all living beings' structural, functional, and biological units.
- A cell can replicate itself independently. Hence, they are known as the building blocks of life.

Each cell contains a fluid called the **cytoplasm**, **enclosed by a membrane**. Also present in **the cytoplasm** are several biomolecules like proteins, nucleic acids, DNA, and lipids. Moreover, cellular structures called **cell organelles** are suspended in the cytoplasm.



Cell Structure: A cell consists of three parts: the **cell membrane, the nucleus,** and, between the two, the **cytoplasm.** Within the cytoplasm lie intricate arrangements of fine fibers and hundreds or even thousands of minuscule but distinct structures **called organelles.**

1. **Cell Membrane (Plasma Membrane)**

- Structure: Made up of a phospholipid bilayer with embedded proteins.
- Function: Controls the movement of substances in and out of the cell, maintains cell shape, and provides protection.

2. **Cytoplasm**

- The cytoplasm is a thick, clear, jelly-like substance present inside the cell membrane.
- Most of the chemical reactions within a cell take place in this cytoplasm.
- The cell organelles such as the endoplasmic reticulum, vacuoles, mitochondria, and ribosomes, are suspended in this cytoplasm.

The cellular components are called cell organelles. and they are involved in various cellular functions.

List of Cell Organelles and their Functions

1. **Nucleus**

- The nucleus contains the hereditary material of the cell, the DNA.
- It sends signals to the cells to grow, mature, divide and die.
- The nucleus is surrounded by the nuclear envelope that separates the DNA from the rest of the cell.
- The nucleus protects the DNA and is an integral component of a plant's cell structure.

2.

Types of Cells

Cells are similar to factories with different laborers and departments that work towards a common objective. Various types of cells perform different functions. Based on cellular structure, there are two types of cells 1. Prokaryotes 2. Eukaryotes

1. **Prokaryotes:**

- ***Prokaryotic cells have no nucleus***. Instead, some prokaryotes such as bacteria have a region within the cell where the genetic material is freely suspended. This region is called the nucleoid.
- They all are single-celled microorganisms. **Example** bacteria.
- The cell size ranges from **0.1 to 0.5 µm** in diameter.
- The hereditary material can either be **DNA or RNA**.
- Prokaryotes generally reproduce by **mitosis,** one cell divides to supply two genetically identical cells.

2. **Eukaryotic Cells:**

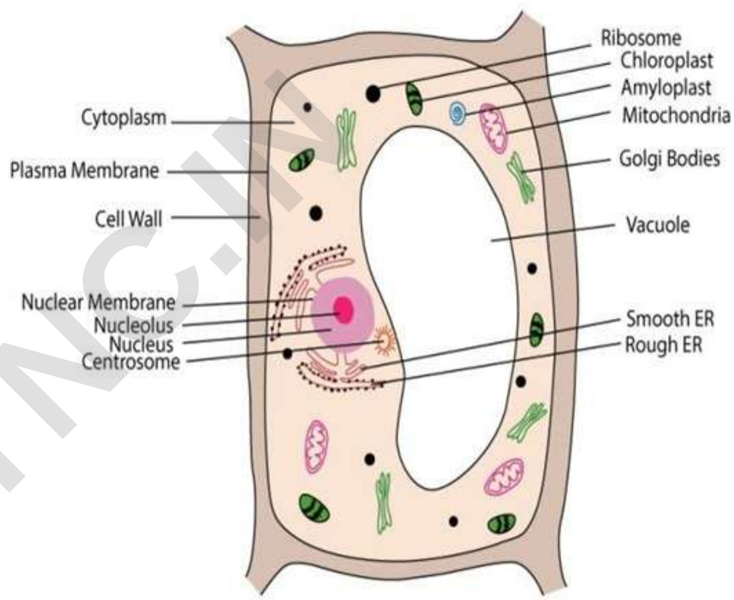
- Eukaryotic cells are characterized by a **true nucleus.**
- The size of the cells ranges between **10–100 µm in diameter**.
- This broad category involves **plants, fungi, and animals**.
- The **plasma membrane** is responsible for monitoring **the transport of nutrients** and electrolytes in and **out of the cells**. It is also responsible for **cell-to-cell communication**.
- Eukaryotes can reproduce both in **mitosis and through meiosis**.
    - In mitosis, one cell divides to supply two genetically identical cells.
    - In meiosis, DNA replication is followed by cellular division to produce four haploid daughter cells.
- There are some contrasting features between plant and animal cells. For eg., the plant cell contains chloroplast, central vacuoles, and other plastids, whereas the animal cells do not.

Plant Cell

- Plant cells are a type of eukaryotic cell found in the organism within the plant kingdom.
- The organelles present in plant cells differ from other eukaryotic cells.
- The major difference in the plant cell is that the plant cell contains a rigid cell wall around its cell wall. The cell wall provides the cell with the protection and gives the plant its shape and structure.
- The plant cell contains the chlorophyll. The chlorophyll gives the plants their green pigment and allows them to perform photosynthesis.

- Photosynthesis is the process that plants use to make their food by using carbon dioxide, water, and sunlight.
- The plant cells contain large central vacuoles. Vacuoles are larger structures in plant cells as in some other eukaryotes.

Structure of Plant Cell:



- **Cell Wall:** Plant cells are surrounded by a rigid cell wall composed of cellulose, which provides structural support and protection.
- **Cell Membrane:** Just inside the cell wall is the cell membrane, a semi-permeable membrane that controls the movement of substances in and out of the cell.
- **Cytoplasm:** The cytoplasm is a jelly-like substance that fills the cell and contains **various organelles.**
- **Nucleus:** The nucleus is the control center of the cell, containing the cell's **DNA** and directing the cell's activities.
- **Mitochondria:** Mitochondria are the powerhouses of the cell, responsible for generating energy through cellular respiration.

  Chloroplasts: Chloroplasts are organelles that contain chlorophyll, allowing plants to perform photosynthesis and convert light energy into chemical energy.
- **Vacuole:** Plant cells typically have a large central vacuole filled with fluid, which helps maintain **turgor pressure** and stores nutrients and waste products.
- **Endoplasmic Reticulum (ER):** The ER is a network of membranes that assists in **the production, processing, and transport of proteins and lipids.**
- **Golgi Apparatus:** The Golgi apparatus **processes and packages proteins and lipids produced by the ER** for transport to other parts of the cell or for secretion.
- **Ribosomes: Ribosomes are the site of protein synthesis** in the cell, where they translate mRNA into proteins.

Functions of Plant Cell:

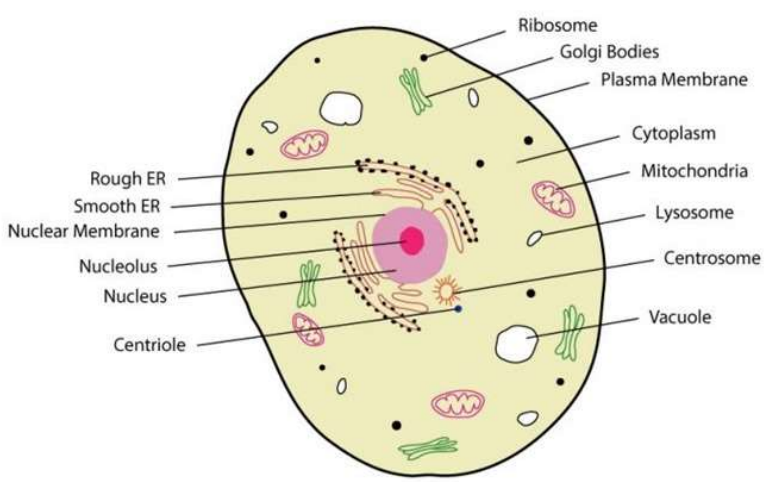
- Plant cells are the basic building block of plant life, and they carry out all the functions necessary for survival.
- Photosynthesis is the process of making food from light energy, carbon dioxide, and water. It occurs in the chloroplasts of the cell.

Animal Cell

- An animal cell is a typical eukaryotic cell with a membrane-bound nucleus with the presence of DNA inside the nucleus.
- Unlike the eukaryotic cells of plants and, animal cells do not have a cell wall.
- They comprise of **other organelles** and **cellular structures** which carry out specific functions necessary for the cell to function properly.
- The main difference between the animal and plant cell is that the animal cell **is not able to make their own food.** There are trillions of cells in the animal body and each one is different depending on the function and type.
- Most animal cells have at least three main parts: **nucleus, cell membrane, and cytoplasm.**

Structure of animal Cell:

- **Cell Membrane:** A thin, flexible barrier that surrounds the cell, regulating what enters and exits the cell.
- **Nucleus:** The control center of the cell, containing the cell's DNA and directing the cell's activities.
- **Cytoplasm:** A jelly-like substance that fills the cell and supports the organelles.
- **Mitochondria:** Organelles that generate energy for the cell through cellular respiration.



- **Endoplasmic Reticulum (ER):** A network of membranes that aids in the production of proteins and lipids.

- **Golgi Apparatus:** A stack of membrane-bound vesicles that processes, packages, and distributes proteins and lipids.
- **Ribosomes:** Structures that synthesize proteins.
- **Lysosomes:** Organelles that contain digestive enzymes to break down waste materials and cellular debris.

Functions of Animal Cell:

- The cells are highly specialized to carry out the specific tasks. All the cells function together in coordination with each other and help the organism to sustain itself.
- Multiple cells will form the tissues into a group of cells which will help in carrying out the various functions.
- The group of similar tissues will form the various organs of the **body like heart, lungs, etc.** and these organs work together to form the organ system like the nervous system, digestive system, circulatory system etc.
- Depending upon the organism the organ system will vary accordingly. **Example, Skin, Tissue, etc.**

Difference Between Plant Cell and Animal Cell

Feature	Plant Cells	Animal Cells
Cell Wall	The cell wall is present in plant cells and is made up of cellulose. The cell wall is the outermost layer of plant cells.	It Is Absent In The Animal Cell.
Shape	They have a definite and rigid shape which means they usually exist in rectangular or cubical shapes.	They exist in round and irregular shapes.
Chloroplast	Chloroplasts are present in plant cells that make their food.	Chloroplast absent in animal cell
Mitochondria	It is present in a small number of plant cells. Plant cells generally have approximately 200-	It is present in a large number compared to plant cells, Animal cells generally have

	600 mitochondria per cell.	approximately 2000 per cell.
Nucleus	It is present and controls the functioning of cells.	It is present and stores the cell's DNA,
Plasma Membrane	PM is present and it is surrounded by cell walls in the plant cell.	PM is present in animal cells. it protects the cell.
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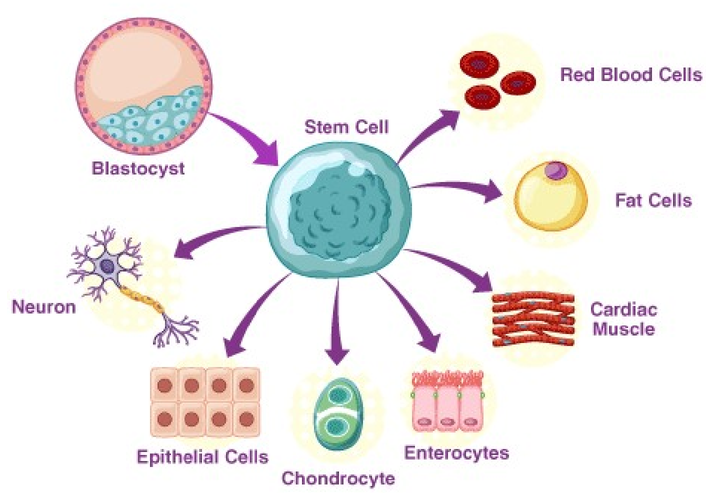
Plasma Membrane	PM is present and it is surrounded by cell walls in the plant cell.	PM is present in animal cells. it provides protection for the cell.

Vacuoles	Vacuoles are few large or single and centrally positioned and provide structural support. One huge vacuole.	Vacuoles are commonly small in size and sometimes they are absent.
Mode of Nutrition	It is the present mainly autotrophic mode of nutrition which means they synthesize their own nutrients such as amino acids, vitamins coenzymes that are required by the plant.	The mode of nutrition is heterotrophic. which means they cannot synthesize their own nutrients.
Golgi apparatus	A Single highly difficult and prominent Golgi apparatus is present.	The mode of nutrition is heterotrophic. which means they cannot synthesize their own nutrients.

Stem Cells

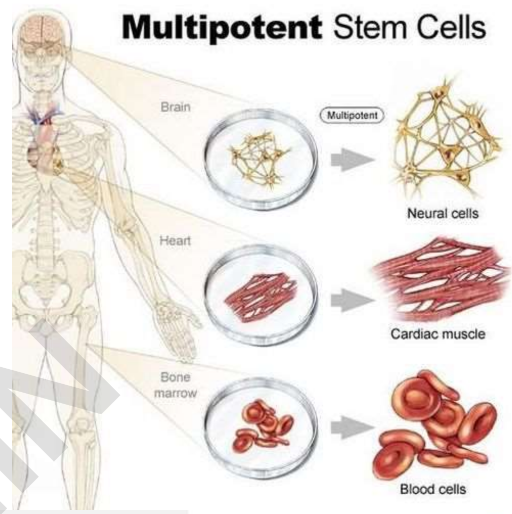
- In multicellular organisms, stem cells are partially distinguished cells that can change into various types of cells. Stem cells have remarkable potential to develop into many different cell types in the body during early life and growth.



They serve as a sort of repair system for the body, dividing essentially without limit to replenish other cells. When a stem cell divides, each new cell has the potential either to remain a stem cell or become another type of cell with a more specialized function, such as a muscle cell, a red blood cell, or a brain cell. The stem cells can be used to repair or regenerate damaged or diseased cells. These cells can develop into any kind of cell.

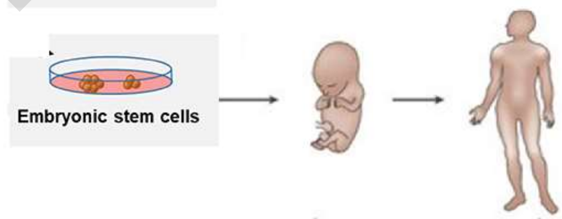
Stem cells are categorized into two main types based on their source and potential:

1. **Adult stem cells**



- Also known as **somatic or tissue-specific** stem cells, are found in **various tissues** and **organs throughout the body**. They are multipotent, meaning they can differentiate into a limited range of cell types.
- **These stem cells are acquired from fully-grown adult organs** and tissues found in differentiated tissues (bone marrow and brain). They can fix and supplant the harmed tissues in the area where they are located.

2. Embryonic stem cells (ESCs)



- are derived from embryos. They are pluripotent, meaning they **can give rise to all cell types in the body.**
- The **pluripotent cells** play a vital role in developing the **fetus.** Thus, these stem cells are f ound only during the embryonic stage and are termed embryonic stem cells. These cells can differentiate into any type of cell.

Adult Stem Cells	Embryonic Stem Cells
Adult stem cells are undifferentiated stem cells in differentiated organs/tissues.	Embryonic stem cells are found during the early blastocyst stage.
They are multipotent. It means they can develop only into closely related cell types.	They are pluripotent. Hence, they can develop into any cell.

Applications of Stem Cells

- **Tissue Regeneration:** This is the most important application of stem cells. The stem cells can be used to grow a specific type of tissue or organ. This can be helpful in kidney and liver transplants.
- **Treatment of Cardiovascular Disease:** A team of researchers have developed blood vessels in mice using human stem cells. Within two weeks of implantation, the blood vessels formed their network and were as efficient as the natural vessels.

- **Treatment of Brain Diseases:** Stem cells can also treat diseases such as Parkinson's disease and Alzheimer's. These can help to replenish the damaged brain cells.
- **Blood Disease Treatment:** Adult hematopoietic stem cells are used to treat cancers, sickle cell anaemia, and other immunodeficiency diseases. These stem cells can be used to produce red blood cells and white blood cells in the body.

Biomolecules

- Biomolecules are biological molecules produced by the cells of the living organism. They are critical for life as it help organisms to carry out basic biological processes.
- Biomolecules are the most essential organic molecules, which are involved in the maintenance and metabolic processes of living organisms.
- The large molecules necessary for life that are built from smaller organic molecules are called biological macromolecules.

Important Terms

- **Biological macromolecule:** A large, organic molecule such as carbohydrates, lipids, proteins, and nucleic acids.
- **Monomer:** A molecule that is a building block for larger molecules (polymers). For example, an amino acid acts as the building block for proteins.
- **Polymer:** A large molecule made of repeating subunits (monomers). For example, a carbohydrate is a polymer that is made of repeating monosaccharides.

Carbohydrates

Carbohydrates are the most abundant biomolecules on earth. Oxidation of carbohydrates is the central energy-yielding pathway in most non-photosynthetic cells.

Definition: Carbohydrates are polyhydroxy aldehydes or ketones, or substances that yield such compounds on hydrolysis. Carbohydrates have the empirical formula $(CH_2O)_n$. There are three major classes of carbohydrates:

1. Monosaccharides: Monosaccharides, or simple sugars, consist of a single polyhydroxy aldehyde or ketone unit. The most abundant monosaccharide in nature is the six-carbon sugar D- glucose, sometimes referred to as dextrose.

2. Oligosaccharides: Oligosaccharides consist of short chains of monosaccharide units, or residues, joined by characteristic linkages called glycosidic bonds. The most abundant are the disaccharides, with two monosaccharide units. Example: sucrose (cane sugar).

3. Polysaccharides: The polysaccharides are sugar polymers containing more than 20 or so monosaccharide units, and some have hundreds or thousands of units. Example: starch. Polysaccharides are of two types based on their function and composition.

Based on function, polysaccharides are of two types: storage and structural.

A. Storage polysaccharide - starch.

B. Structural polysaccharide - cellulose.

General properties of carbohydrates

- Carbohydrates act as energy reserves, also stores fuels, and metabolic intermediates.
- Ribose and deoxyribose sugars forms the structural frame of the genetic material, RNA and DNA.
- Polysaccharides like cellulose are the structural elements in the cell walls of bacteria and plants.
- Carbohydrates are linked to proteins and lipids that play important roles in cell interactions.
- Carbohydrates are organic compounds; they are aldehydes or ketones with many hydroxyl groups.

Physical Properties of Carbohydrates:

- **Stereoisomerism -** Compound shaving same structural formula but they differ in spatial configuration. Example: Glucose has two isomers with respect to penultimate carbon atom. They are D-glucose and L-glucose.
- **Optical Activity -** It is the rotation of plane polarized light forming (+) glucose and (-) glucose.
- **Diastereoisomerism -** It is the configurational change with respect to C2, C3, or C4 in glucose. Example: Mannose, galactose.
- **Anomerism -** It is the spatial configuration with respect to the first carbon atom in aldoses and second carbon atom in ketoses.

Biological Importance

- ➢ Carbohydrates are chief energy source, in many animals, they are instant source of energy.
- ➢ Glucose is the source of storage of energy. It is stored as glycogen in animals and starch in plants.
- ➢ Stored carbohydrates act as energy source instead of proteins.
- ➢ Carbohydrates are intermediates in biosynthesis of fats and proteins.
- ➢ Carbohydrates aid in regulation of nerve tissue and as the energy source for brain.

- Carbohydrates get associated with lipids and proteins to form surface antigens, receptor molecules, vitamins, and antibiotics.
- They form structural and protective components, like in cell wall of plants and microorganisms.
- In animals they are important constituent of connective tissues.
- They participate in biological transport, cell-cell communication, and activation of growth factors.
- Carbohydrates rich in fibre content help to prevent constipation.
- Also, they help in modulation of immune system.

Proteins

Proteins are polypeptides, which are made up of many amino acids linked together as a linear chain. The structure of an amino acid contains a amino group, a carboxyl group, and a R group which is usually carbon based and gives the amino acid it's specific properties.

Proteins form the very basis of life. They regulate a variety of activities in all known organisms, from replication of the genetic code to transporting oxygen, and are generally responsible for regulating the cellular machinery and determining the phenotype of an organism.

Classification of Proteins

Protein molecules are large, complex molecules formed by one or more twisted and folded strands of amino acids. Each amino acid is connected to the next amino acid by covalent bonds. Based on the structure proteins are classified as:

1. **Primary (first level) –** Protein structure is a sequence of amino acids in a chain.
2. **Secondary (secondary level) –** Protein structure is formed by folding and twisting of the amino acid chain.
3. **Tertiary (third level) –** Protein structure is formed when the twists and folds of the secondary structure fold again to form a larger three-dimensional structure.
4. **Quaternary (fourth level) –** Protein structure is a protein consisting of more than one folded amino acid chain.

Proteins can bond with other organic compounds and form "mixed" molecules. For example, glycoproteins embedded in cell membranes are proteins with sugars attached. Lipoproteins are lipid-protein combinations.

Functions of Proteins

Proteins carry out various functions in our body as below:

1. Proteins are required for the growth and repair of body tissues.

2. All our body muscles are made up of proteins. Roughly 30 per cent of our body is muscles.
3. Proteins provide the essential structure to the body. They provide elasticity, rigidity, and shape to many internal and external organs.
4. All enzymes in our body are made up of proteins. So, all biochemical reactions in the body are carried by proteins.
5. Every cell has a membrane composed of different proteins essential for all vital functions.
6. Many messengers of the body, i.e., hormones, are proteins. Thus, they act as messengers too.
7. Proteins contribute to our blood in a greater way:

   a. 6−8 per cent of blood plasma is proteins.

   b. The Hemoglobin of RBCs is protein.

   c. Many proteins present in the blood plasma like albumin, globulin maintain the osmotic pressure and pH of the blood and thus keep the body fluids of the entire body.

   d. Proteins boost our immunity by making up the immunoglobulins (antibodies) and complement proteins in our blood.

   e. They help with blood clotting.
8. It transports different types of substances across the body through blood.
9. Proteins also provide the energy required by our body for various functions.

Lipids

Lipids are organic compounds that contain hydrogen, carbon, and oxygen atoms, which form the framework for the structure and function of living cells." These organic compounds are nonpolar molecules, which are soluble only in nonpolar solvents and insoluble in water because water is a polar molecule. These molecules yield high energy and are responsible for different functions within the human body.

Classification of Lipids:

Based on their chemical composition lipids are classified into three types:

Simple lipids: These are esters of fatty acid with farious alcohols. Example: Fats and oils (triglycerides, triacylglycerols): These are esters of fatty acids with a trihydroxy alcohol, glycerol.

Fat is solid at ordinary room temperature wheras an oil is liquid.

Waxes: These are esters of fatty acids with high molecular weight monohydroxy alcohols.

Complex lipids: These are esters of fatty acids with alcohol and possess additional group(s). e.g., sulfur, phosphorus, amino group, carbohydrate, or proteins beside fatty acid and alcohol. Complex lipids are classified into the following types according to the nature of the additional group

1. Phospholipids
2. Glycolipids.
3. Lipoproteins
4. Sulfolipids and amino lipids.

Derived lipids: These are the substances derived from simple and compound lipids by hydrolysis. These include fatty acids, alcohols, mono- and diglycerides, steroids, terpenes and carotenoids.

Properties of Lipids

Physical properties

- Lipids may be either liquids or non-crystalline solids at room temperature.
- Pure fats and oils are colourless, odourless, and tasteless.
- They are energy-rich organic molecules
- Insoluble in water
- Soluble in organic solvents like alcohol, chloroform, acetone, benzene, etc.
- No ionic charges

Chemical properties

- **Hydrolysis of Tri glycerol's**

  Tri glycerol, like any other esters react with water to form their carboxylic acid and alcohol– a process known as hydrolysis.
- **Saponification:**

  Triacylglycerols may be hydrolyzed by several procedures, the most common of which utilizes alkali or enzymes called lipases. Alkaline hydrolysis is termed saponification because one of the products of the hydrolysis is a soap, generally sodium or potassium salts of fatty acids.
- **Hydrogenation**

  The carbon-carbon double bonds in unsaturated fatty acids can be hydrogenated by reacting with hydrogen to produce saturated fatty acids.
- **Halogenation**

Unsaturated fatty acids, whether they are free or combined as esters in fats and oils, react with halogens by addition at the double bond(s). The reaction results in the decolorization of the halogen solution.

- **Rancidity:**
  The term rancid is applied to any fat or oil that develops a disagreeable odor. Hydrolysis and oxidation reactions are responsible for causing rancidity.

Functions of Lipids

- Lipids, like adipose tissue, act as **insulators and help to maintain body temperature** by reducing heat loss.
- Lipids, especially triglycerides, act as **energy storage in organisms**, providing a reserve of **metabolic fuel**.
- Phospholipids form the lipid bilayers of cell membranes and regulate the passage of molecules in and out of cells.
- Protecting the plant leaves from **direct heat and drying**.
- Steroid hormones, derived from cholesterol, play vital roles in regulating various physiological processes, including **metabolism, growth, and reproduction**.
- It acts as the structural component of the body and acts as the **hydrophobic barrier**.
- In plants, lipids can be stored as oils in seeds, providing a source of **energy for germination** and early growth.
- Lipids form **waterproofing structures**, such as the **waxy cuticle on plant leaves** or the **oil on the feathers of water birds**.
- It provides color to many fruits and vegetables with the presence of **carotenoid pigment**.

Nucleic Acids

Nucleic acids are naturally occurring chemical compounds that serve as the primary information-carrying molecules in cells. Nucleic acids are biopolymers or many biomolecules essential for all forms of life with the elemental composition of **carbon, hydrogen, oxygen, nitrogen and phosphorus.** Nucleic acids are vital components of all living systems, Responsible for all storage and transmission of genetic information from parents to offspring. Hence, they control growth and reproduction in the cell living system.

Nucleic acids refer to the genetic material found in the cell that carries all the hereditary information from parents to progeny. There are two types of nucleic acids namely,

1. **Deoxyribonucleic acid (DNA)**: In cells, DNA is located in the nucleus and mitochondria, it is the nucleic acid that functions as the original blueprint for the synthesis of proteins.
2. **Ribonucleic acid (RNA):** it is a nucleic acid which is directly involved in protein synthesis.

DNA (Deoxyribonucleic acid)	**RNA (Ribonucleic acid)**
It is a long polymer. It has a deoxyribose and phosphate backbone having four distinct bases: thymine, adenine, cytosine, and guanine.	Is a polymer with a ribose and phosphate backbone with four varying bases: uracil, cytosine, adenine, and guanine.
It is found in the nucleus of a cell and in the mitochondria.	It is found in the cytoplasm, nucleus and in the ribosome.
It has 2-deoxyribose.	It has Ribose.
The function of DNA is the transmission of genetic information. It acts as a medium for long-term storage.	RNA is critical for the transmission of the genetic code that is necessary for protein creation from the nucleus to the ribosome.
DNA is a double-stranded molecule that has a long chain of nucleotides.	RNA is a single-stranded molecule which has a shorter chain of nucleotides.
DNA replicates on its own, it is self-replicating.	RNA does not replicate on its own. It is synthesized from DNA when required.
The base pairing is as follows: GC (Guanine pairs with Cytosine) A-T (Adenine pairs with Thymine).	The base pairing is as follows: GC (Guanine pairs with Cytosine) A-U (Adenine pairs with Uracil).

FUNCTION OF DNA

1. **REPLICATION**: Double helix unwinds and acts as an information. A codon specifies a particular template and forms a double helix with the aid of DNA polymerase.
2. **ENCODING INFORMATION:** A codon specifies a particular amino acid that produces a particular protein.

3. **MUTATION/RECOMBINATION:** DNA plays a role in evolution of a species. It can repair itself through recombination and mutation occurs due to illegal base pairing. Both mutation and recombination either beneficial or create genetic diseases
4. **GENE EXPRESSION:** Cells from different tissues & organ, look & behave differently. DNA can respond to produce a particular protein by expressing a particular protein through transcription and translation.

FUNCTIONS OF DIFFERENT RNA

mRNA - It carries genetic formation of DNA (Gene) for protein synthesis from nucleus to ribosome in the form of genetic code.

tRNA - Acts as adapter molecule, carries Amino Acid and drops it to particular location by recognising codon on mRNA by virtue of having anticodon.

rRNA-It makes complex with proteins and form ribosomal subunits which provide space for protein synthesis, single ribosomal RNA of smaller subunit helps correct orientation of mRNA during attachment with respect to P and A sites.