Module-1

INTRODUCTION TO BIOLOGY

The cell: the basic unit of life, Structure and functions of a cell. The Plant Cell and animal cell, Prokaryotic and Eukaryotic cell, Stem cells and their application.

Biomolecules: Properties and functions of Carbohydrates, Nucleic acids, proteins, lipids. Importance of special biomolecules; Enzymes (Classification (with one example each), Properties and functions), vitamins and hormones.

CELLS

1.1 The Cell: the basic unit of life

A cell is defined as the smallest, basic building blocks of all living things. A cell is the structural and fundamental unit of life. (Fig 1.1)

The study of cell has been made possible with the help of light microscope. Robert Hooke (1665) with the help of light microscope discovered that a section of cork is made up of small cavities surrounded by firm walls. He used the term "cell" for the first time to describe his investigations on the "texture of a piece of cork".

Cells are the **structural, functional, and biological** units of all living beings. A cell can replicate itself independently. Hence, they are known as the **building blocks of life.** They provide structure for the body, take in nutrients from food, convert those nutrients into energy, and carry out specialized functions. Organisms, such as most bacteria, are unicellular (consist of a single cell). Other organisms, such as humans, are multicellular. Humans have about 100 trillion cells

Each cell contains a **fluid** called the **cytoplasm**, which is enclosed by a **membrane**. Also present in the cytoplasm are several **biomolecules like proteins, nucleic acids and lipids**.

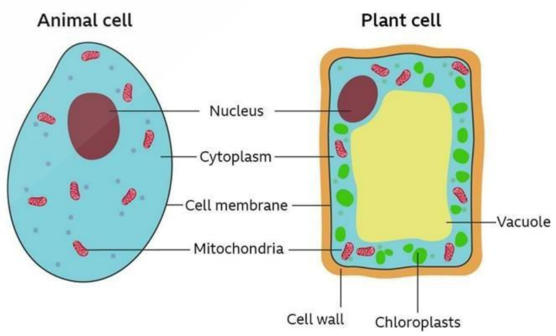

Fig 1.1 Cell

1.1.1 Cell Theory

- All living things are made of one or more cells.
- Cells are the basic unit of structure and function in living things.
- Living cells come only from other living cells.

1.2 Structure and functions of a cell

The cell structure comprises individual components with specific functions essential to carry out life's processes. These components include- cell wall, cell membrane, cytoplasm, nucleus, and cell organelles.

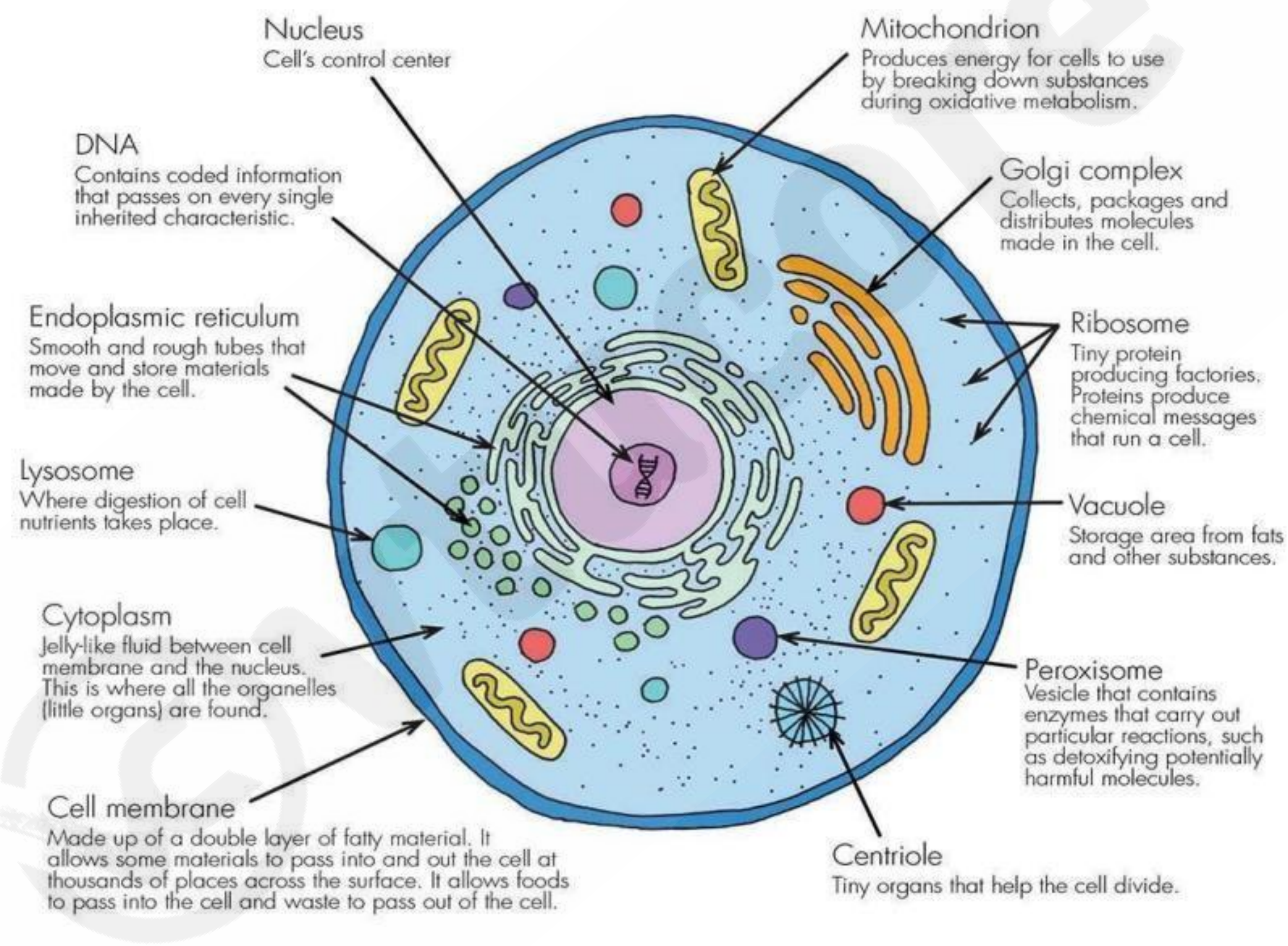

Fig 1.2 Detailed structure of cell

1.2.1 Cell Membrane

• The cell membrane supports and protects the cell. It controls the movement of substances in and out of the cells. It separates the cell from the external environment. The cell membrane is present in all the cells.

• The cell membrane is the outer covering of a cell within which all other organelles, such as the cytoplasm and nucleus, are enclosed. It is also referred to as the **plasma membrane**.

• By structure, it is a porous membrane (with pores) which permits the movement of selective substances in and out of the cell. Besides this, the cell membrane also protects the cellular component from damage and leakage.

• Membrane is created out of a lipid bilayer and proteins, present in both plant and animal cells

• Plants are immobile, so their cell structures are well-adapted to protect them from external factors. The cell wall helps to reinforce this function.

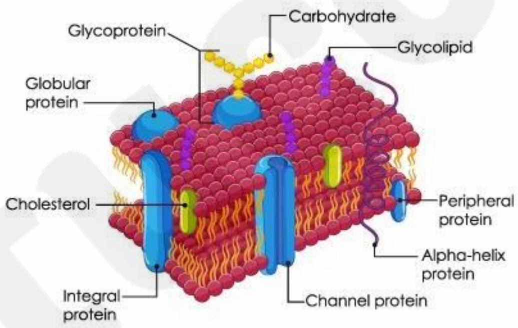

Fig. 1.3 Cell Membrane

1.2.2 Cell Wall

• The cell wall is the most prominent part of the plant's cell structure. It is made up of cellulose, hemicellulose and pectin.

• The cell wall is present exclusively in plant cells. It protects the plasma membrane and other cellular components. The cell wall is also the outermost layer of plant cells.

• It is a rigid and stiff structure surrounding the cell membrane.

• It provides shape and support to the cells and protects them from mechanical shocks and injuries.

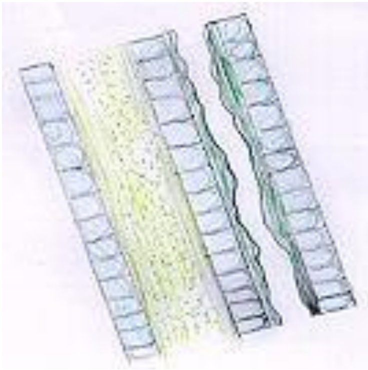

Fig. 1.4 Cell Wall

1.2.3 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 endoplasmic reticulum, vacuoles, mitochondria, ribosomes, are suspended in this cytoplasm.

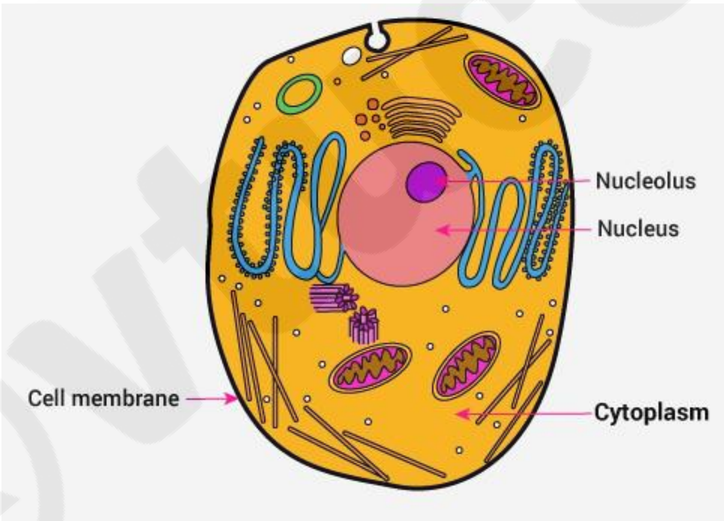

Fig 1.5 Cell with cytoplasm

1.2.4 Nucleus

The nucleus contains all the genetic material of the cell. It is circular in shape and dark in color having a double membrane. Nuclear membranes are also selectively permeable. They help in cellular transport. Nuclear pores are present over the nuclear membrane which help in the transport of proteins and transcription factors. The nuclear membrane differentiates the nucleoplasm from the cytoplasm.

Within the nucleus, a small spherical body is presently known as the **nucleolus**, which contains the chromosomes. They are the thin thread-like structure that contains the gene. Gene is the hereditary unit i.e., all the information from the parent to the offspring is transferred via gene. The key function of the nucleus is to maintain the cell and its metabolic activities.

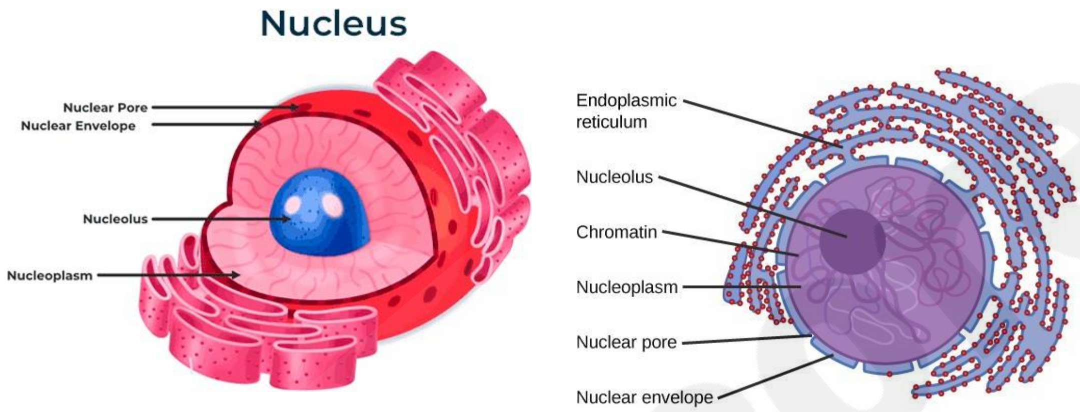

Fig 1.6 Nucleus

- 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.

1.2.5 Cell Organelles

Cells are composed of various cell organelles that perform certain specific functions to carry out life's processes. The different cell organelles, along with its principal functions, are as follows:

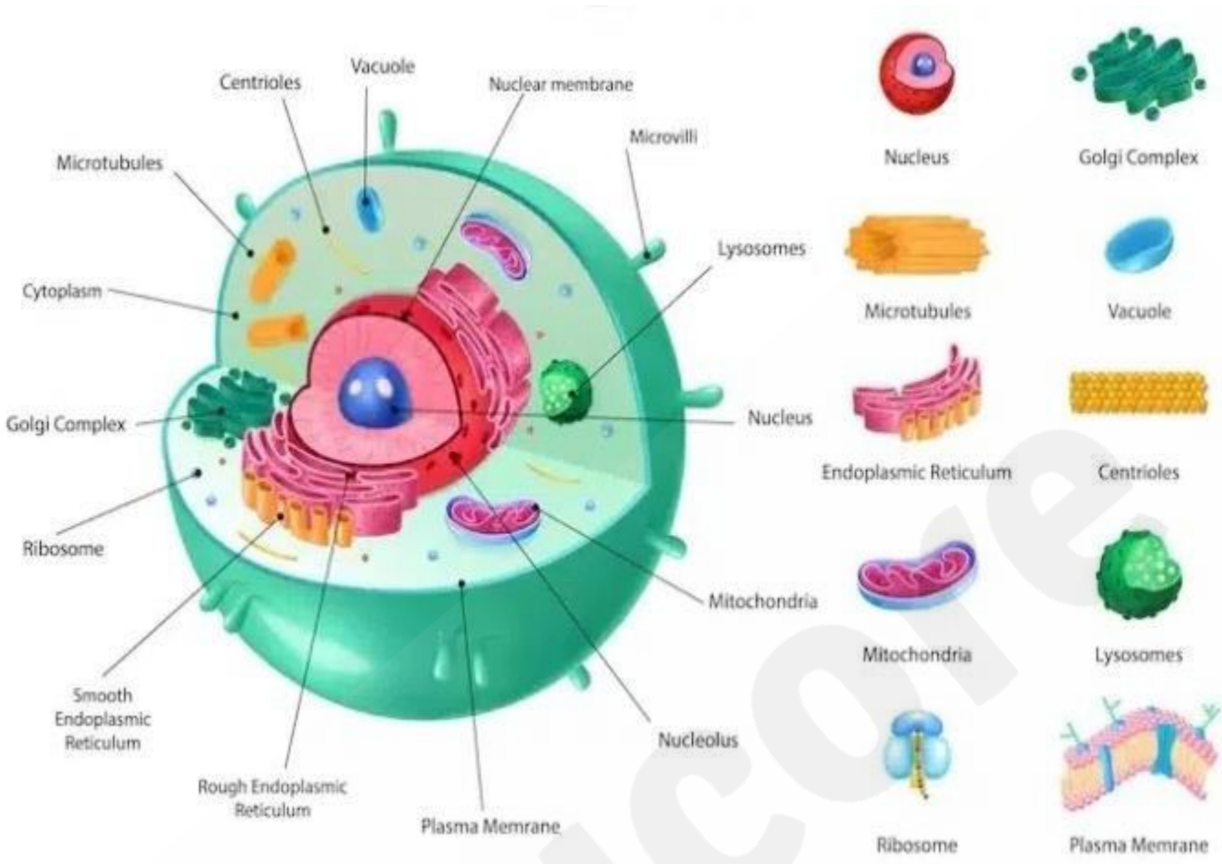

Fig 1.7 Cell Organelles

i) Nucleolus: The nucleolus is the site of ribosome synthesis. Also, it is involved in controlling cellular activities and cellular reproduction.

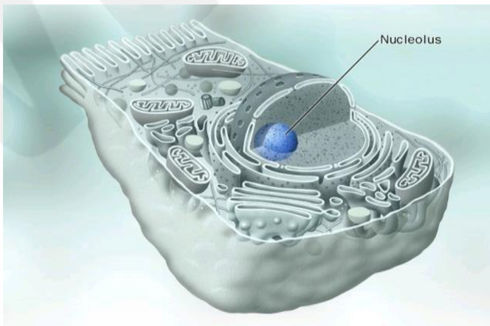

Fig 1.8 Nucleolus

- Cell may have 1 to 3 nucleoli
- Inside nucleus
- Disappears when cell divides
- Makes ribosomes that make proteins

ii) Nuclear membrane: The nuclear membrane protects the nucleus by forming a boundary between the nucleus and other cell organelles.

- Surrounds nucleus
- Made of two layers
- Openings allow material to enter and leave nucleus

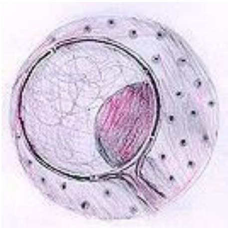

Fig 1.9 Nuclear membrane

iii) Chromosomes: Chromosomes play a crucial role in determining the sex of an individual. Each human cell contains 23 pairs of chromosomes.

- Placed in nucleus
- Made of DNA
- Contain instructions for traits & characteristics

Fig 1.10 Chromosomes

iv) Endoplasmic reticulum:

Endoplasmic reticulum membranes form continuous folds, eventually joining the outer layer of the nuclear membrane. Except for sperm cells and red blood cells, the endoplasmic reticulum is observed in every other type of eukaryotic cell.

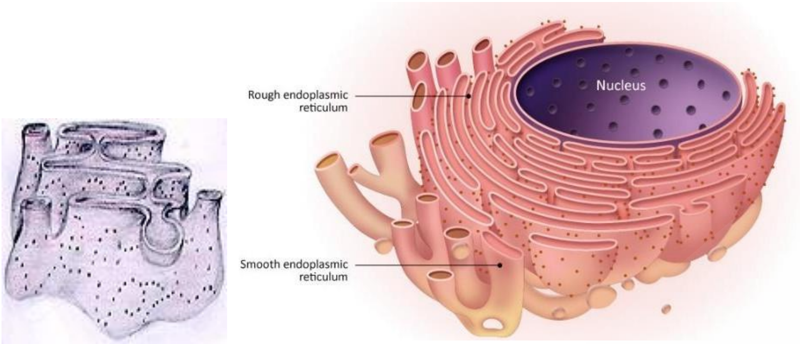

Fig 1.11 Endoplasmic reticulum

It can be divided into two distinct types: rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). The RER is studded with ribosomes to synthesize membrane and secreted proteins and has some continuity with the nuclear membrane lumen. No ribosomes are associated with the SER, which is involved in lipid metabolism. Soluble proteins are transported from the ER to the Golgi apparatus by way of vesicles for further modification, and are subsequently released from the Golgi in vesicles destined to fuse with the cell membrane. They are the transport system of the cell, involved in transporting materials throughout the cell.

a) Smooth Endoplasmic Reticulum Function:

- Smooth ER is responsible for the synthesis of essential lipids such as phospholipids and cholesterol.
- Smooth ER is also responsible for the production and secretion of steroid hormones.
- It is also responsible for the metabolism of carbohydrates.
- The smooth ER store and releases calcium ions. These are quite important for the nervous system and muscular systems.

b) Rough Endoplasmic Reticulum Function:

- The majority of the functions of rough ER is associated with protein synthesis.
- The rough endoplasmic reticulum also plays a vital role in protein folding.
- Also ensures quality control (regarding correct protein folding).
- The second most important function after protein synthesis and protein folding is protein sorting.

vi) Golgi Bodies: (or Golgi Apparatus / Golgi Complex) Golgi bodies are called the cell's post office as it is involved in the transportation of materials within the cell. It is a membrane-bound organelle, which is mainly composed of a series of flattened, stacked pouches called cisternae. This cell organelle is primarily responsible for transporting, modifying, and packaging proteins and lipids to targeted destinations. Golgi Apparatus is found within the cytoplasm of a cell and is present in both plant and animal cells.

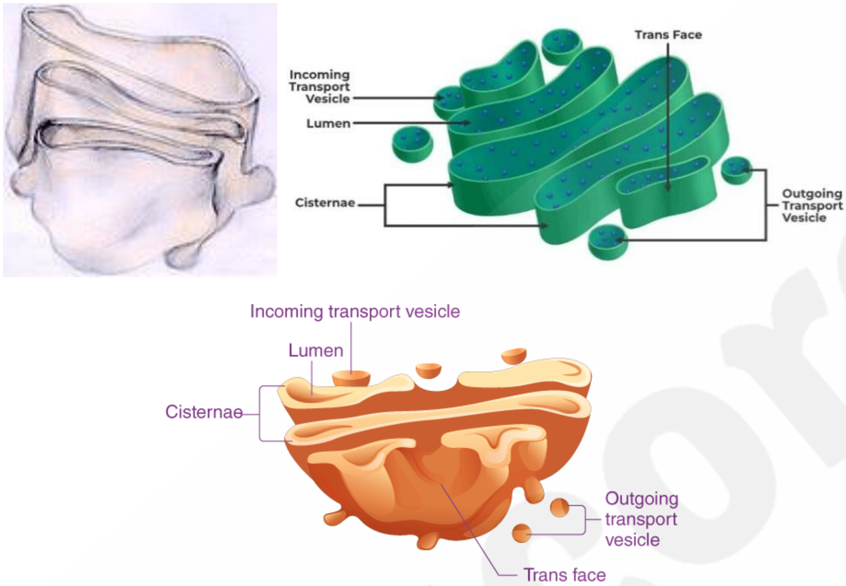

Fig 1.12 Golgi Bodies

- Protein packaging plant
- Move materials within the cell
- Move materials out of the cell

vii) Ribosome: Ribosomes are the protein synthesisers of the cell. (structures that combine amino acids to create proteins.)

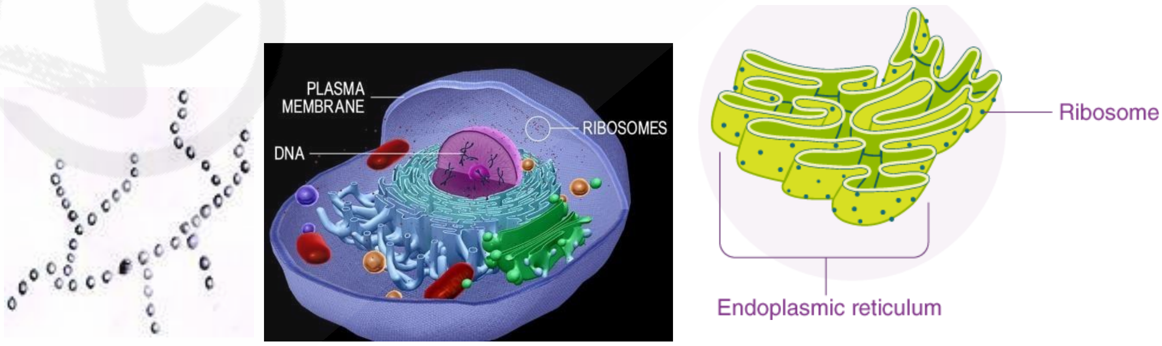

Fig 1.13 Ribosome

vii) Mitochondria: Mitochondria are called the powerhouses of the cell as they produce energy-rich molecules for the cell. The mitochondrial genome is inherited maternally in several organisms. It is a double membrane-bound, sausage-shaped organelle, found in almost all eukaryotic cells.

The double membranes divide its lumen into two distinct aqueous compartments. The inner compartment is called a 'matrix' which is folded into cristae whereas the outer membrane forms a continuous boundary with the cytoplasm. They usually vary in their size and are found either round or oval in shape. Mitochondria are the sites of aerobic respiration in the cell, produces energy in the form of ATP and helps in the transformation of the molecules.

For instance, glucose is converted into adenosine triphosphate – ATP. Mitochondria have their own circular DNA, RNA molecules, ribosomes (the 70s), and a few other molecules that help in protein synthesis.

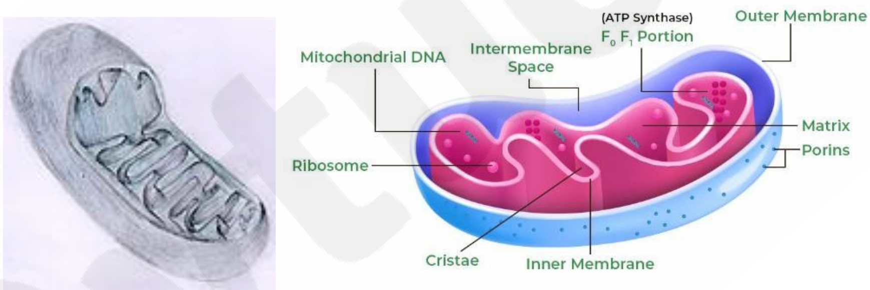

Fig 1.14 Mitochondria

- The mitochondrion is called "the powerhouse of the cell." It is called so because it produces ATP – the cell's energy currency.
- Produces energy through chemical reactions – breaking down fats & carbohydrates
- Controls level of water and other materials in cell
- Recycles and decomposes proteins, fats, and carbohydrates

ix) Lysosomes: Lysosomes protect the cell by engulfing the foreign bodies entering the cell and help in cell renewal. Therefore, they are known as the cell's suicide bags.

Fig 1.15 Lysosomes

- Digestive 'plant' for proteins, fats, and carbohydrates
- Transports undigested material to cell membrane for removal
- Cell breaks down if lysosome explodes

x) Chloroplast: Chloroplasts are the primary organelles for photosynthesis. It contains the pigment called chlorophyll.

Chloroplasts are double membrane-bound organelles, which usually vary in their shape – from a disc shape to spherical, discoid, oval and ribbon. They are present in mesophyll cells of leaves, which store chloroplasts and other carotenoid pigments. These pigments are responsible for trapping light energy for photosynthesis. The inner membrane encloses a space called the stroma. Flattened disc-like chlorophyll-containing structures known as thylakoids are arranged in a stacked manner like a pile of coins. Each pile is called a granum (plural: grana) and the thylakoids of different grana are connected by flat membranous tubules known as stromal lamella. Just like the mitochondrial matrix, the stroma of chloroplast also contains a double-stranded circular DNA, 70S ribosomes, and enzymes which are required for the synthesis of carbohydrates and proteins.

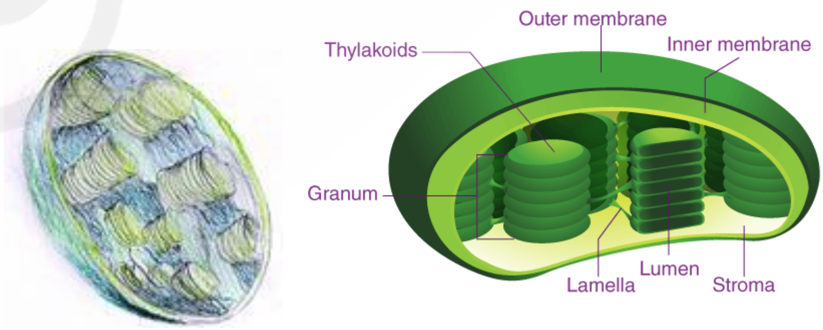

Fig 1.16 Chloroplast

- Usually found in plant cells
- Contains green chlorophyll
- Where photosynthesis takes place

xi) Vacuoles: Vacuoles are mostly defined as storage bubbles of irregular shapes which are found in cells. They are fluid-filled organelles enclosed by a membrane. The vacuole stores the food or a variety of nutrients that a cell might need to survive. In addition to this, it also stores waste products. The waste products are eventually thrown out by vacuoles. Thus, the rest of the cell is protected from contamination. The animal and plant cells have different size and number of vacuoles. Compared to the animals, plant cells have larger vacuoles.

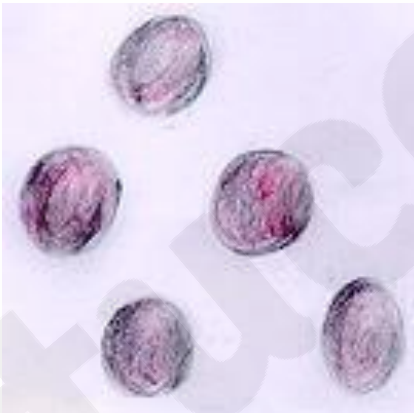

Fig 1.17 Vacuoles

- Membrane-bound sacs for storage, digestion, and waste removal
- Store food, water, and other waste materials in the cell.
- Contains water solution
- Help plants maintain shape

Cell Organelles	Structure	Functions
Cell membrane	A double membrane composed of lipids and proteins. Present both in plant and animal cells.	Provides shape, protects the inner organelles of the cell and acts as a selectively permeable membrane.
Centrosomes	Composed of centrioles and found only in the animal cells.	It plays a major role in organizing the microtubule and cell division.
Chloroplasts	Present only in plant cells and contains a green-coloured pigment known as chlorophyll.	Sites of photosynthesis.
Cytoplasm	A jelly-like substance, which consists of water, dissolved nutrients and waste products of the cell.	Responsible for the cell's metabolic activities.
Endoplasmic Reticulum	A network of membranous tubules, present within the cytoplasm of a cell.	Forms the skeletal framework of the cell, involved in the detoxification, production of lipids and proteins.
Golgi apparatus	Membrane-bound, sac-like organelles, present within the cytoplasm of the eukaryotic cells.	It is mainly involved in secretion and intracellular transport.
Lysosomes	A tiny, circular-shaped, single membrane-bound organelles, filled with digestive enzymes.	Helps in the digestion and removes wastes and digests dead and damaged cells. Therefore, it is also called as the "suicidal bags".
Mitochondria	An oval-shaped, membrane-bound organelle, also called as the "Powerhouse of The Cell".	The main site of cellular respiration and also involved in storing energy in the form of ATP molecules.
Nucleus	The largest, double membrane-bound organelles, which contains all the cell's genetic information.	Controls the activity of the cell, helps in cell division and controls the hereditary characters.
Peroxisome	A membrane-bound cellular organelle presents in the cytoplasm, which contains the reducing enzyme.	Involved in the metabolism of lipids and catabolism of long-chain fatty acids.
Plastids	Double membrane-bound organelles. There are 3 types of plastids: **Leucoplast** –Colourless plastids. 1. **Chromoplast**–Blue, red, and yellow colour plastids. 2. **Chloroplast** – Green coloured plastids.	Helps in the process of photosynthesis and pollination, imparts colour to leaves, flowers, fruits and stores starch, proteins and fats.
Ribosomes	Non-membrane organelles, found floating freely in the cell's cytoplasm or embedded	Involved in the synthesis of proteins.

Table 1.1 A Brief Summary on Cell Organelles

	within the endoplasmic reticulum.	
Vacuoles	A membrane-bound, fluid-filled organelle found within the cytoplasm.	Provide shape and rigidity to the plant cell and help in digestion, excretion, and storage of substances.

1.2.6 Functions of Cell

A cell performs major functions essential for the growth and development of an organism. Important functions of cell are as follows:

i) Provides Support and Structure

All the organisms are made up of cells. They form the structural basis of all the organisms. The cell wall and the cell membrane are the main components that function to provide support and structure to the organism. For eg., the skin is made up of a large number of cells. Xylem present in the vascular plants is made of cells that provide structural support to the plants.

ii) Facilitate Growth Mitosis

In the process of mitosis, the parent cell divides into the daughter cells. Thus, the cells multiply and facilitate the growth in an organism.

iii) Allows Transport of Substances

Various nutrients are imported by the cells to carry out various chemical processes going on inside the cells. The waste produced by the chemical processes is eliminated from the cells by active and passive transport. Small molecules such as oxygen, carbon dioxide, and ethanol diffuse across the cell membrane along the concentration gradient. This is known as passive transport. The larger molecules diffuse across the cell membrane through active transport where the cells require a lot of energy to transport the substances.

iv) Energy Production

Cells require energy to carry out various chemical processes. This energy is produced by the cells through a process called photosynthesis in plants and respiration in animals.

v) Aids in Reproduction

A cell aids in reproduction through the processes called mitosis and meiosis. Mitosis is termed as the asexual reproduction where the parent cell divides to form daughter cells. Meiosis causes the daughter cells to be genetically different from the parent cells.

1.3 Types of Cell

All organisms are made of cells. Cells vary in their shape, size as well as functions. Based on the presence or absence of a membrane bound nucleus and other organelles, organisms are classified as **Eukaryotes** or **Prokaryotes**.

1.3.1 Prokaryote Cell

Prokaryotes are unicellular organisms that lack membrane-bound structures, the most noteworthy of which is the nucleus. Prokaryotic cells tend to be small, simple cells, measuring around 0.1-5 µm in diameter.

While prokaryotic cells **do not have membrane-bound structures**, they do have distinct cellular regions. In prokaryotic cells, **DNA bundles together in a region called the nucleoid**.

Prokaryotes can be split into two domains, bacteria and archaea.

In prokaryotes, molecules of protein, DNA and metabolites are all found together, floating in the cytoplasm. Primitive organelles, found in bacteria, do act as micro-compartments to bring some sense of organization to the arrangement.

- **Prokaryotic cell features**

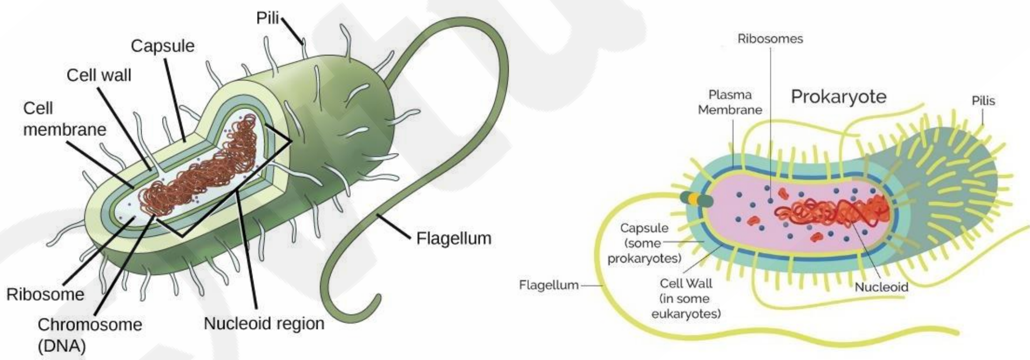

Fig 1.18 Prokaryotic cell

- Nucleoid: A central region of the cell that contains its DNA.
- Ribosome: Ribosomes are responsible for protein synthesis.
- Cell wall: The cell wall provides structure and protection from the outside environment. Most bacteria have a rigid cell wall made from carbohydrates and proteins called peptidoglycans.
- Cell membrane: Every prokaryote has a cell membrane, also known as the plasma membrane, that separates the cell from the outside environment.

- Capsule: Some bacteria have a layer of carbohydrates that surrounds the cell wall called the capsule. The capsule helps the bacterium attach to surfaces.
- Fimbriae: Fimbriae are thin, hair-like structures that help with cellular attachment.
- Pili: Pili are rod-shaped structures involved in multiple roles, including attachment and DNA transfer.
- Flagella: Flagella are thin, tail-like structures that assist in movement.

Examples of prokaryotes

Bacteria and archaea are the two types of prokaryotes.

1.3.2 Eukaryote definition

Eukaryotes are organisms whose cells have a nucleus and other organelles enclosed by a plasma membrane. Organelles are internal structures responsible for a variety of functions, such as energy production and protein synthesis.

Eukaryotic cells are large (around 10-100 μm) and complex. While most eukaryotes are multicellular organisms, there are some single-cell eukaryotes.

Eukaryotic cell features

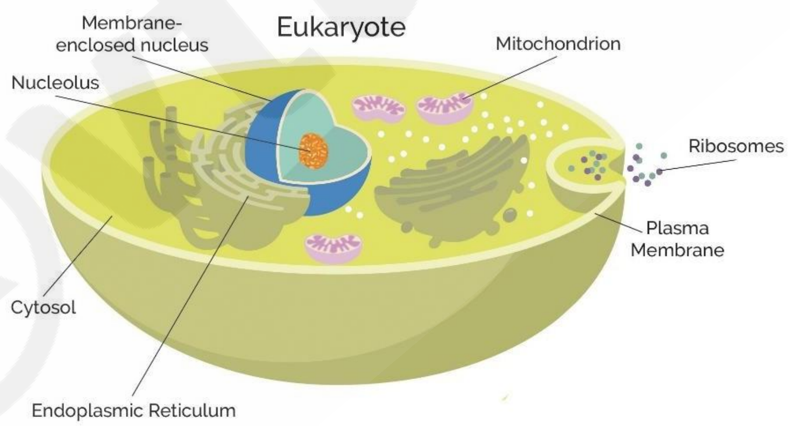

Fig 1.19 Eukaryotic cell

Within a eukaryotic cell, each membrane-bound structure carries out specific cellular functions.

- Nucleus: The nucleus stores the genetic information in chromatin form.
- Nucleolus: Found inside of the nucleus, the nucleolus is the part of eukaryotic cells where ribosomal RNA is produced.

- Plasma membrane: The plasma membrane is a phospholipid bilayer that surrounds the entire cell and encompasses the organelles within.
- Cytoskeleton or cell wall: The cytoskeleton or cell wall provides structure, allows for cell movement, and plays a role in cell division.
- Ribosomes: Ribosomes are responsible for protein synthesis.
- Mitochondria: Mitochondria, also known as the powerhouses of the cell, are responsible for energy production.
- Cytoplasm: The cytoplasm is the region of the cell between the nuclear envelope and plasma membrane.
- Cytosol: Cytosol is a gel-like substance within the cell that contains the organelles.
- Endoplasmic reticulum: The endoplasmic reticulum is an organelle dedicated to protein maturation and transportation.
- Vesicles and vacuoles: Vesicles and vacuoles are membrane-bound sacs involved in transportation and storage.
- Other common organelles found in many, but not all, eukaryotes include the Golgi apparatus, chloroplasts and lysosomes.

Examples of eukaryotes

Animals, plants, fungi, algae and protozoans are all eukaryotes.

1.3.3 Comparing prokaryotes and eukaryotes

The primary distinction between these two types of organisms is that eukaryotic cells have a membrane-bound nucleus and prokaryotic cells do not. The nucleus is where eukaryotes store their genetic information. In prokaryotes, DNA is bundled together in the nucleoid region, but it is not stored within a membrane-bound nucleus.

The nucleus is only one of many membrane-bound organelles in eukaryotes. Prokaryotes, on the other hand, have no membrane-bound organelles. Another important difference is the DNA structure. Eukaryote DNA consists of multiple molecules of double-stranded linear DNA, while that of prokaryotes is double-stranded and circular.

Similarity: All cells, whether prokaryotic or eukaryotic, share these four features:

1. DNA
2. Plasma membrane
3. Cytoplasm
4. Ribosomes

Table 1.2 Key differences between prokaryotes and eukaryotes

	Prokaryote	Eukaryote
Nucleus	Absent	Present
Membrane-bound organelles	Absent	Present
Cell structure	Unicellular	Mostly multicellular; some unicellular
Cell size	Smaller (0.1-5 μm)	Larger (10-100 μm)
Complexity	Simpler	More complex
DNA Form	Circular	Linear
Examples	Bacteria, archaea	Animals, plants, fungi, protists

1.3.4 The Plant Cell and animal cell

The cells of plants and animals are both eukaryotic, meaning that they have a membrane-bound nucleus. However, there are some major differences between the two types of cells. For example, plant cells typically have larger vacuoles than animal cells. Plant cells also have cell walls made of cellulose, while animal cells do not. Additionally, plant cells can undergo photosynthesis to produce their food, while animal cells cannot.

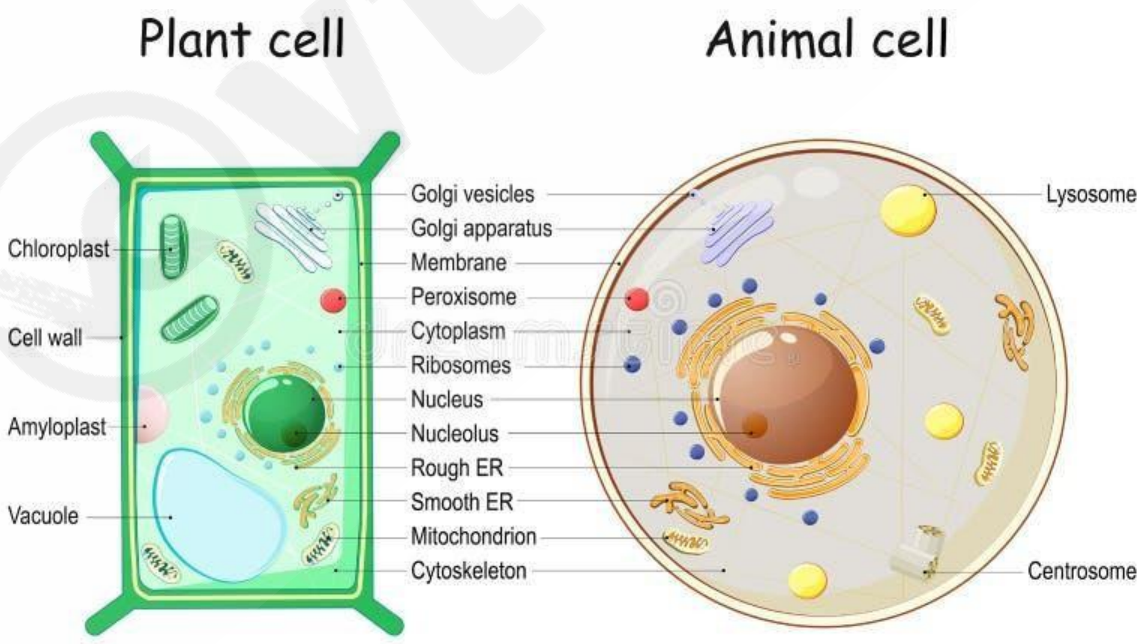

Fig 1.20 Plant Cell and animal cell

i) Plant Cell

A plant cell is a type of eukaryotic cell that is unique in several ways. For starters, plant cells have a cell wall made of cellulose. This cell wall provides structural support and protection for the plant cell. Additionally, plant cells have large vacuoles that help to store water and other materials. Finally, many plant cells can undergo photosynthesis, a process in which the plant cell produces its food.

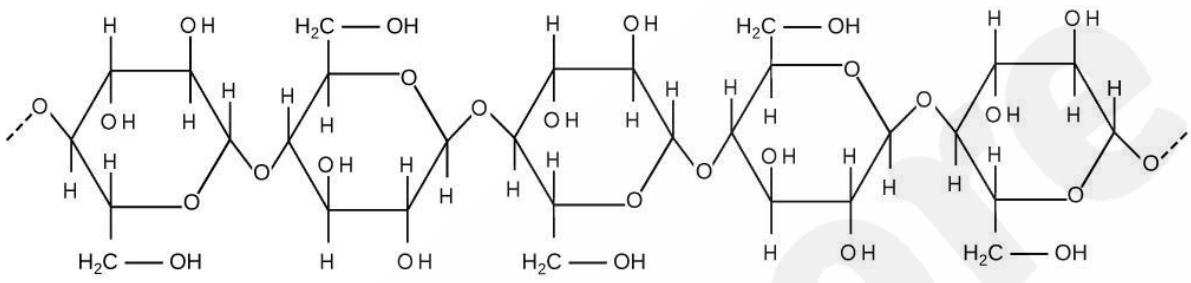

Fig 1.21 Cellulose is a long chain of β-glucose molecules

Parts of a plant cell

- Cell Membrane: The cell membrane is a thin layer of protein that surrounds the plant cell.
- Nucleus: The nucleus is a large organelle that contains the cell's DNA.
- Cytoplasm: The cytoplasm is a gel-like substance that fills the plant cell.
- Ribosomes: Ribosomes are small organelles that help to create proteins.
- Endoplasmic Reticulum: The endoplasmic reticulum is a system of membranes that helps to transport materials within the cell.
- Golgi Body: The Golgi body is an organelle that helps to package and ship materials within the cell.
- Lysosomes: Lysosomes are small organelles that help to break down food and other materials.
- Plant cells also have a few unique organelles that animal cells do not. These include:
- Chloroplasts: Chloroplasts are organelles that help the plant cell to undergo photosynthesis.

- Vacuoles: Vacuoles are large, sac-like organelles that store water and other materials.
- Cell Wall: The cell wall is a tough, protective layer that surrounds the plant cell.

ii) Animal Cell

Animal cells are also eukaryotic cells, but they differ from plant cells in a few key ways. Animal cells do not have a cell wall made of cellulose. Instead, their cell walls are made of a different type of protein. Additionally, animal cells have smaller vacuoles than plant cells. Finally, animal cells cannot undergo photosynthesis.

Parts of an animal cell

- Cell Membrane: The cell membrane is a thin layer of protein that surrounds the animal cell.
- Nucleus: The nucleus is a large organelle that contains the cell's DNA.
- Cytoplasm: The cytoplasm is a gel-like substance that fills the animal cell.
- Ribosomes: Ribosomes are small organelles that help to create proteins.
- Endoplasmic Reticulum: The endoplasmic reticulum is a system of membranes that helps to transport materials within the cell.
- Golgi Body: The Golgi body is an organelle that helps to package and ship materials within the cell.
- Lysosomes: Lysosomes are small organelles that help to break down food and other materials.

Difference between a plant cell and an animal cell

Plant cells have a few key features that animal cells do not. For example, plant cells have a cell wall made of cellulose, while animal cells do not. Additionally, plant cells have large vacuoles that help to store water and other materials. Finally, many plant cells can undergo photosynthesis, while animal cells cannot.

Animal cells are more complex than plant cells because they have several organelles that help them carry out specific tasks. Plant cells do not have all of the same organelles as animal cells, but they do have some specialized structures that allow them to perform important functions.

While both plant cells and animal cells are eukaryotic, there are some major differences between the two.

- **Functioning**: Plant cells can undergo photosynthesis to produce their food, while animal cells cannot.
- **Structural**: Plant cells have a cell wall made of cellulose, while animal cells do not. Animal cells have smaller vacuoles than plant cells.
- **Materials**: Large vacuoles in plant cells help store water and other materials.

Table 1.3 Plant Cell Vs Animal cells

Plant cells	Animal cells
The plant cells are larger than animal cells.	Animal cells are usually smaller in size.
The plant cells are rectangular shaped.	Animal cells usually have irregular shapes.
An outer envelope covers the plasma membrane of the plant cell called a cell wall.	Animal cell lacks a cell wall, and the plasma membrane is the outer membrane.
Plastid, a membrane-bound cell organelle, is present in a plant cell.	Except for *Eugelena*, animal cells lack plastids.
The vacuole in the plant cell is single, large, and centrally located.	Animal cells have numerous vacuoles and are small in size.
Plant cells have many simpler units of Golgi apparatus called dictyosomes.	Animal cells have a single highly complex and prominent Golgi apparatus.
Plant cells lack centrosomes and centrioles.	Animal cells have centrosomes and centrioles.
The number of mitochondria are fewer.	The number of mitochondria are more than that of plant cell.
Plant cells do not have cilia.	Animal cells have cilia.
Lysosomes are very rare in plant cells.	Animal cells have lysosomes.

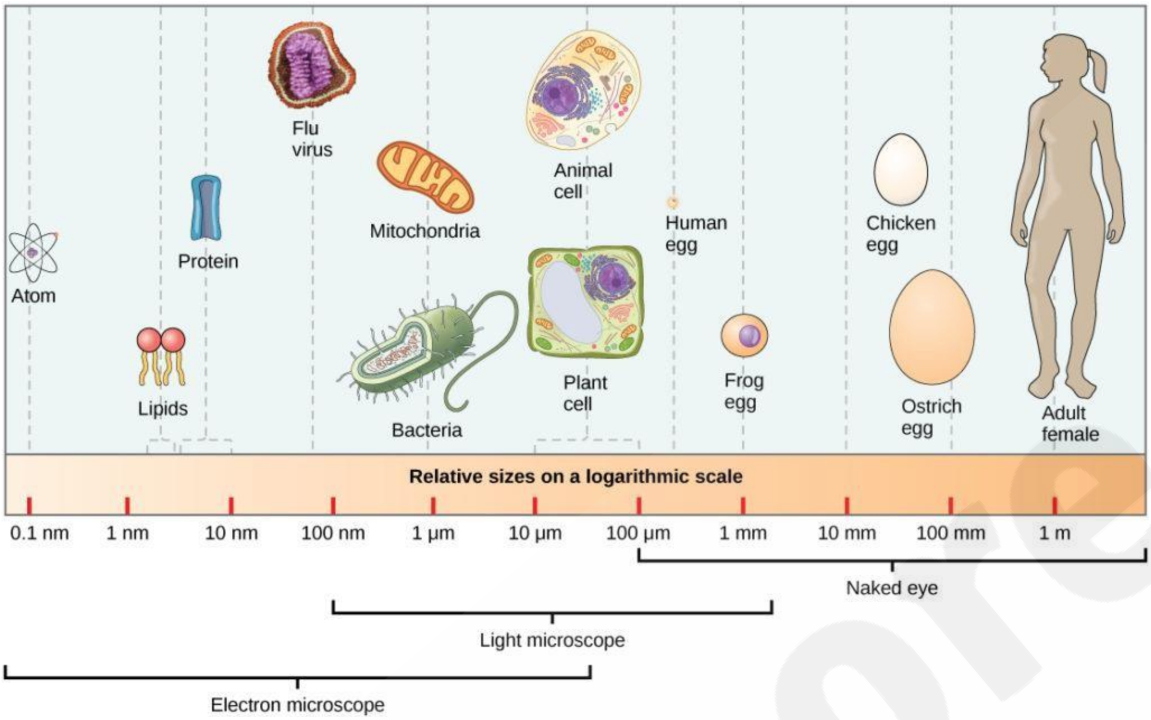

Fig 1.22 Cell size

1.4 Stem cells and their application.

Stem cells are cells that do not yet have a specific role and can become almost any cell that is required. They can also regenerate damaged tissue under the right conditions.

Stem cells are undifferentiated cells that can turn into specific cells, as the body needs them.

Stem cells are special human cells that can develop into many different types of cells, from muscle cells to brain cells.

Stem cells also have the ability to repair damaged cells. These cells have strong healing power. They can evolve into any type of cell. Research on stem cells is going on, and it is believed that stem cell therapies can cure ailments like paralysis and Alzheimer's as well.

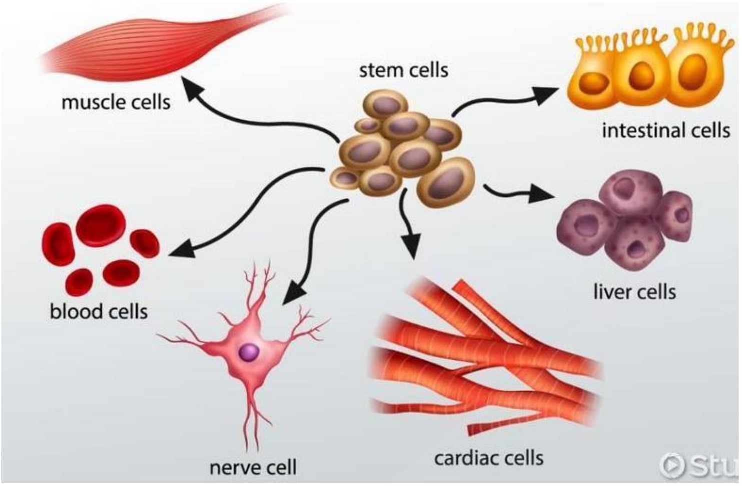

Fig 1.23 Stem cells

1.4.1 Types of Stem cells

- Embryonic Stem Cells
- Adult Stem Cells
- Induced Pluripotent Stem Cells
- Mesenchymal stem cells

Embryonic Stem Cells

The fertilized egg begins to divide immediately. All the cells in the young embryo are totipotent cells. These cells form a hollow structure within a few days. Cells in one region group together to form the inner cell mass. This contains pluripotent cells that make up the developing foetus.

The embryonic stem cells can be further classified as:

- **Totipotent Stem Cells:** These can differentiate into all possible types of stem cells.
- **Pluripotent Stem Cells:** These are the cells from an early embryo and can differentiate into any cell type.
- **Multipotent Stem Cells:** These differentiate into a closely related cell type. E.g., the hematopoietic stem cells differentiate into red blood cells and white blood cells.
- **Oligopotent Stem Cells:** Adult lymphoid or myeloid cells are oligopotent. They can differentiate into a few different types of cells.

- **Unipotent Stem Cells:** They can produce cells only of their own type. Since they have the ability to renew themselves, they are known as unipotent stem cells. E.g., Muscle stem cells.

Adult Stem Cells

These stem cells are obtained from developed organs and tissues. They can repair and replace the damaged tissues in the region where they are located. For eg., hematopoietic stem cells are found in the bone marrow. These stem cells are used in bone marrow transplants to treat specific types of cancers.

Induced Pluripotent Stem Cells

These cells have been tested and arranged by converting tissue-specific cells into embryonic cells in the lab. These cells are accepted as an important tool to learn about the normal development, onset and progression of the disease and are also helpful in testing various drugs. These stem cells share the same characteristics as embryonic cells do. They also have the potential to give rise to all the different types of cells in the human body.

Mesenchymal Stem Cells

These cells are mainly formed from the connective tissues surrounding other tissues and organs, known as the stroma. These mesenchymal stem cells are accurately called stromal cells. The first mesenchymal stem cells were found in the bone marrow that is capable of developing bones, fat cells, and cartilage.

There are different mesenchymal stem cells that are used to treat various diseases as they have been developed from different tissues of the human body. The characteristics of mesenchymal stem cells depend on the organ from where they originate.

1.4.2 Applications of Stem Cells

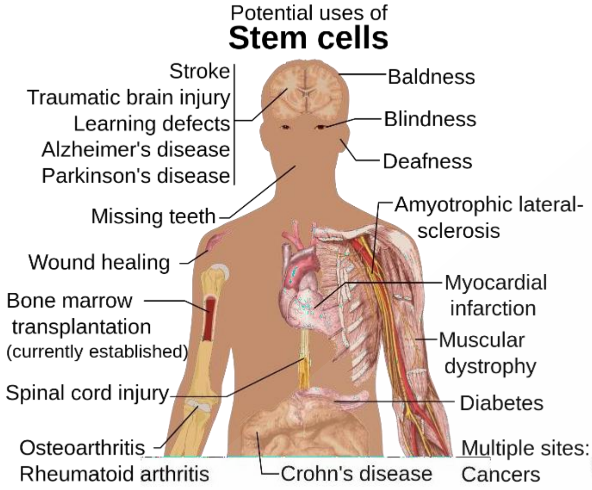

Fig 1.24 Stem cells applications

Following are the important 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. The doctors have already used the stem cells from beneath the epidermis to develop skin tissue that can repair severe burns or other injuries by tissue grafting.

- **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. Researchers have tried to differentiate embryonic stem cells into these types of cells and make it possible to treat diseases.

- **Blood Disease Treatment**

  The 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.

- **Sources of Stem Cells**

  Stem Cells originate from different parts of the body. Adult stem cells can be found in specific tissues in the human body. Matured cells are specialized to conduct various functions. Generally, these cells can develop the kind of cells found in tissues where they reside.

  Embryonic Stem Cells are derived from 5-day-old blastocysts that develop into embryos and are pluripotent in nature. These cells can develop any type of cell and tissue in the body. These cells have the potential to regenerate all the cells and tissues that have been lost because of any kind of injury or disease.

Biomolecules

1.1 Biomolecules

Biomolecules are the most essential organic molecules, which are involved in the maintenance and metabolic processes of living organisms. These non-living molecules are the actual foot-soldiers of the battle of sustenance of life. They range from small molecules such as primary and secondary metabolites and hormones to large macromolecules like proteins, nucleic acids, carbohydrates, lipids etc.

1.1.1 Types of Biomolecules

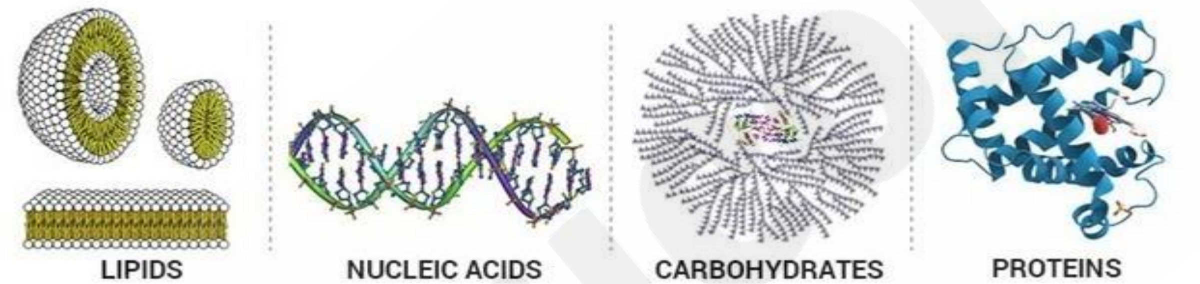

Fig. 1.1 Types of Biomolecules

There are four major classes of Biomolecules – **Carbohydrates, Proteins, Nucleic acids and Lipids**. Each of them is discussed below.

1.2 Carbohydrates

Carbohydrates are chemically defined as polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis. In layman’s terms, we acknowledge carbohydrates as sugars or substances that taste sweet. They are collectively called as saccharides (Greek: sakcharon = sugar). Depending on the number of constituting sugar units obtained upon hydrolysis, they are classified as monosaccharides (1 unit), oligosaccharides (2-10 units) and polysaccharides (more than 10 units). They have multiple functions’ viz. they’re the most abundant dietary source of energy; they are structurally very important for many living organisms as they form a major structural component, e.g. cellulose is an important structural fibre for plants. Carbohydrates are macronutrients and are one of the three main ways by which our body obtains its energy.

They are called carbohydrates as they comprise **carbon**, **hydrogen** and **oxygen** at their chemical level. Carbohydrates are essential nutrients which include sugars, fibers and starches. They are found in grains, vegetables, fruits and in milk and other dairy products. They are the basic food groups which play an important role in a healthy life.

The food containing carbohydrates are converted into glucose or blood sugar during the process of digestion by the digestive system.

Our body utilizes this sugar as a source of energy for the cells, organs and tissues. The extra amount of energy or sugar is stored in our muscles and liver for further requirement. The term 'carbohydrate' is derived from a French term '**hydrate de carbone**'meaning 'hydrate of carbon'. The general formula of this class of organic compounds is $\mathbf{C_n(H_2O)_n}$.

Fig. 1.2 Carbohydrates food

1.2.1 Classification of Carbohydrates

The carbohydrates are further classified into simple and complex which is mainly based on their chemical structure and degree of polymerization.

a) Simple Carbohydrates (Monosaccharides, Disaccharides and Oligosaccharides)

Simple carbohydrates have one or two sugar molecules. In simple carbohydrates, molecules are digested and converted quickly resulting in a rise in the blood sugar levels. They are abundantly found in milk products, beer, fruits, refined sugars, candies, etc. These carbohydrates are called empty calories, as they do not possess fiber, vitamins and minerals.

Plants, being producers, synthesize glucose ($C_6H_{12}O_6$) using raw materials like carbon dioxide and water in the presence of sunlight. This process of photosynthesis converts solar energy to chemical energy. Consumers feed on plants and harvest energy stored in the bonds of the compounds synthesized by plants.

i) Monosaccharides

Glucose is an example of a carbohydrate monomer or monosaccharide. Other examples of monosaccharides include mannose, galactose, fructose, etc. The structural organization of monosaccharides is as follows:

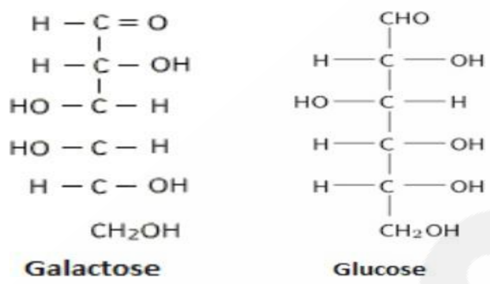

Fig. 1.3 Structural organization of monosaccharides

Monosaccharides may be further classified depending on the number of carbon atoms:

- **Trioses ($C_3H_6O_3$):** These have three carbon atoms per molecule. Example: Glyceraldehyde
- **Tetroses ($C_4H_6O_4$):** These monosaccharides have four carbon atoms per molecule. Example: Erythrose.
- **Pentoses**,
- **Hexoses,** and
- **Heptoses**
- **Disaccharides**

Two monosaccharides combine to form a disaccharide. Examples of carbohydrates having two monomers include- Sucrose, Lactose, Maltose, etc.

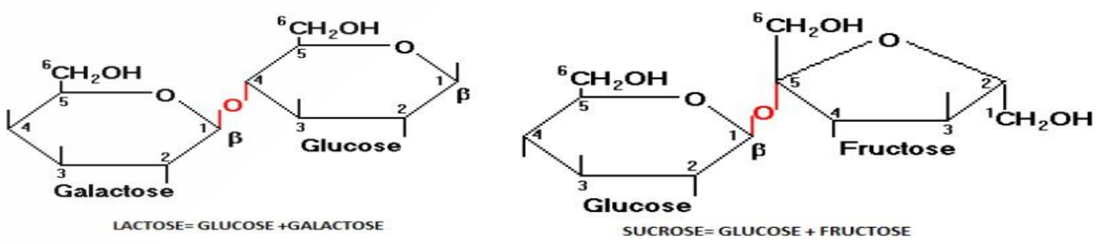

Fig. 1.4 Structural organization of two monosaccharides

iii) Oligosaccharides

Carbohydrates formed by the condensation of 2-9 monomers are called oligosaccharides. By this convention, trioses, pentoses, hexoses are all oligosaccharides.

b) Complex Carbohydrates (Polysaccharides)

Complex carbohydrates have two or more sugar molecules, hence they are referred to as starchy foods. In complex carbohydrates, molecules are digested and converted slowly compared to simple carbohydrates. They are abundantly found in lentils, beans, peanuts, potatoes, peas, corn, whole-grain bread, cereals, etc.

Polysaccharides are complex carbohydrates formed by the polymerization of a large number of monomers. Examples of polysaccharides include starch, glycogen, cellulose, etc. which exhibit extensive branching and are homopolymers – made up of only glucose units.

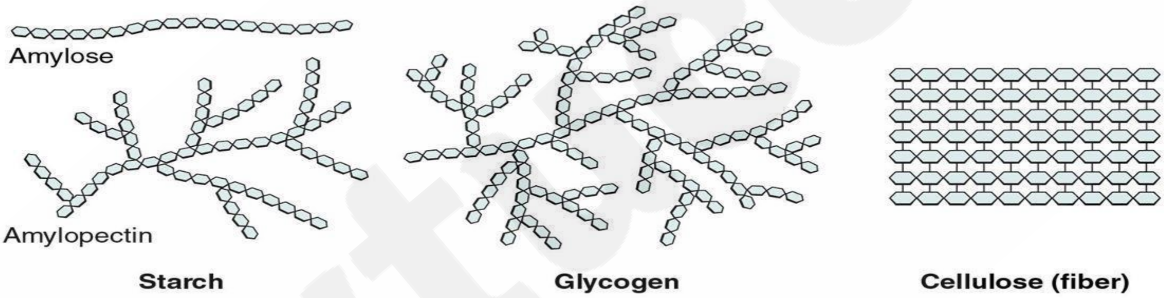

Fig. 1.5 Polysaccharides

- Starch is composed of two components- amylose and amylopectin. Amylose forms the linear chain and amylopectin is a much-branched chain.
- Glycogen is called animal starch. It has a structure similar to starch, but has more extensive branching.
- Cellulose is a structural carbohydrate and is the main structural component of the plant cell wall. It is a fibrous polysaccharide with high tensile strength. In contrast to starch and glycogen, cellulose forms a linear polymer.

1.2.2 Functions of Carbohydrates

The main function of carbohydrates is to provide energy and food to the body and to the nervous system.

- Carbohydrates are known as one of the basic components of food, including sugars, starch, and fibre which are abundantly found in grains, fruits and milk products.
- Carbohydrates are also known as starch, simple sugars, complex carbohydrates and so on.
- It is also involved in fat metabolism and prevents ketosis.
- Inhibits the breakdown of proteins for energy as they are the primary source of energy.
- An enzyme by name amylase assists in the breakdown of starch into glucose, finally to produce energy for metabolism.

1.2.3 Sources of Carbohydrates

- Simple sugars are found in the form of fructose in many fruits.
- Galactose is present in all dairy products.
- Lactose is abundantly found in milk and other dairy products.
- Maltose is present in cereal, beer, potatoes, processed cheese, pasta, etc.
- Sucrose is naturally obtained from sugar and honey containing small amounts of vitamins and minerals.

These simple sugars that consist of minerals and vitamins exist commonly in milk, fruits, and vegetables. Many refined and other processed foods like white flour, white rice, and sugar, lack important nutrients and hence, they are labelled "**enriched**." It is quite healthy to use vitamins, carbohydrates and all other organic nutrients in their normal forms.

1.2.4 Carbohydrate Foods

Eating too much sugar results in an abnormal increase in calories, which finally leads to obesity and in turn low calories leads to malnutrition. Therefore, a well-balanced diet needs to be maintained to have a healthy life. That is the reason a balanced diet is stressed so much by dietitians.

Table 1.1 Differences between the good and bad carbohydrates.

Good Carbohydrates	Bad Carbohydrates
High in Nutrients	Low in nutrients
Moderate in calories	High in calories
Low in sodium and saturated fats	High in sodium and saturated fats
Low in trans-fat and cholesterol	High in trans-fat and cholesterol
They are complex carbs. For instance: Legumes, vegetables, whole grains, fruits, and beans.	Foods considered bad carbs rarely have any nutritional value. Some of the foods include white flour, rice, pastries, sodas and processed foods.

Examples of Carbohydrates

Following are the important examples of carbohydrates:

- Glucose
- Galactose
- Maltose
- Fructose
- Sucrose
- Lactose
- Starch
- Cellulose
- Chitin

1.3 Proteins

Proteins are another class of indispensable biomolecules, which make up around 50per cent of the cellular dry weight. Proteins are polymers of **amino acids** arranged in the form of polypeptide chains. The structure of proteins is classified as primary, secondary, tertiary and quaternary in some cases. These structures are based on the level of complexity of the folding of a polypeptide chain. Proteins play both structural and dynamic roles. Myosin is the protein that allows movement by contraction of muscles. Most enzymes are proteinaceous in nature.

1.3.1 Protein Structure

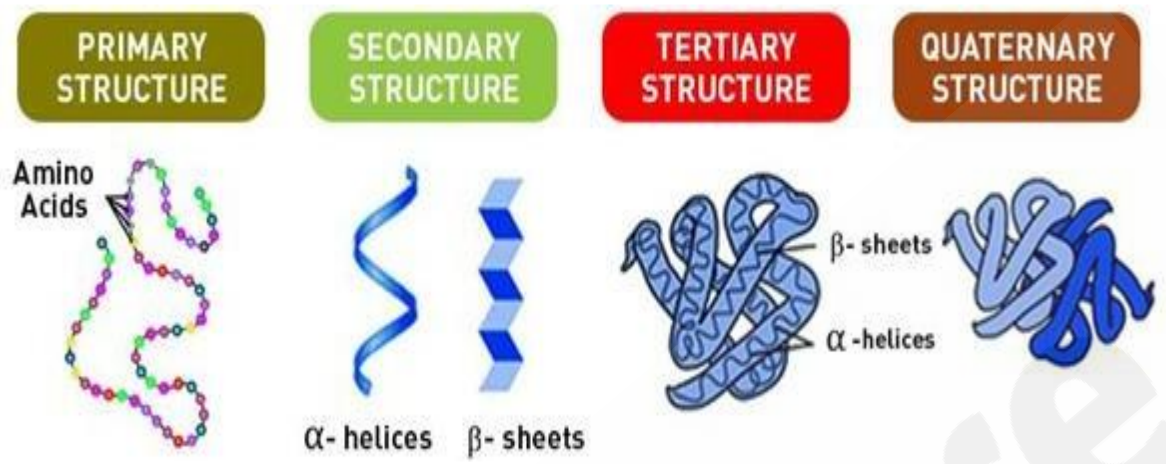

Fig. 1.7 Protein Structure

In general, they are two types of protein molecules fibrous proteins and globular proteins. Fibrous proteins are insoluble and elongated. Globular proteins are soluble and compact. Fibrous and Globular proteins may comprise one or four types of protein structures and they include primary, secondary, tertiary and quaternary structure.

- **Primary Structure:** It is a specific sequence of amino acids. The order of amino acids bonded together is detected by information stored in genes.
- **Secondary Structure:** It is a three-dimensional form of a local segment of proteins. They are formed by hydrogen bonds between the atoms along the backbone of the polypeptide chain.
- **Tertiary Structure:** It is determined by R-groups. It is a three-dimensional shape of a protein. Many numbers of tertiary structure fold to form Quaternary Structure.
- **Quaternary Structure:** It is the arrangement of multiple folded protein subunits in a multi-subunit complex.

1.3.2 Types of Proteins and Their Functions

Although there are debates about the intake of carbohydrates and fats in order to maintain a proper health, a minimum amount of daily protein intake is always a doctor's first recommendation. The common examples of proteins in biology are eggs, almond, chicken, oats, fish and seafood, soy, beans and pulses, cottage cheese, Greek yogurt, milk, broccoli, and quinoa.

Functions of Proteins

1. **Enzymes:** Enzymes mostly carry out all numerous chemical reactions which take place within a cell. They also help in regenerating and creating DNA molecules and carry out complex processes.
2. **Hormones:** Proteins are involved in the creation of various types of hormones which help in balancing the components of the body. For example hormones like insulin, which helps in regulating blood sugar and secretin. It is also involved in the digestion process and formation of digestive juices.
3. **Antibody:** Antibody also known as an immunoglobulin. It is a type of protein which is majorly used by the immune system to repair and heal the body from foreign bacteria. They often work together with other immune cells to identify and separate the antigens from increasing until the white blood cells destroy them completely.
4. **Energy:** Proteins are the major source of energy that helps in the movements of our body. It is important to have the right amount of protein in order to convert it into energy. Protein, when consumed in excess amounts, gets used to create fat and becomes part of the fat cells.

Table 1.2 Functions of Proteins.

Aspect	**Functions of Proteins in Human Body**	**Examples**
Storage	Legume Storage, albumin, and proteins.	Supplies food during the early stage of the seedling or embryo.
Hormone Signalling	Counterpart activities of different body parts.	Glucagon and Insulin.
Transport	It transport substances throughout the body through lump or blood cells.	Hemoglobin.
Contraction	To carry out muscle contraction.	Myosin.
Digestive Enzyme	Breaks down nutrients present in the food into smaller portions so that it can be easily absorbed	Pepsin, Amylase, and Lipase

1.4 Nucleic Acids

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, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The main function of nucleic acid is the transfer of genetic information and synthesis of proteins by processes known as translation and transcription. The monomeric unit of nucleic acids is known as nucleotide and is composed of a nitrogenous base, pentose sugar, and phosphate. The nucleotides are linked by a 3' and 5' phosphodiester bond. The nitrogen base attached to the pentose sugar makes the nucleotide distinct. There are 4 major nitrogenous bases found in DNA: adenine, guanine, cytosine, and thymine. In RNA, thymine is replaced by uracil. The DNA structure is described as a double-helix or double-helical structure which is formed by hydrogen bonding between the bases of two antiparallel polynucleotide chains. Overall, the **DNA structure** looks similar to a twisted ladder.

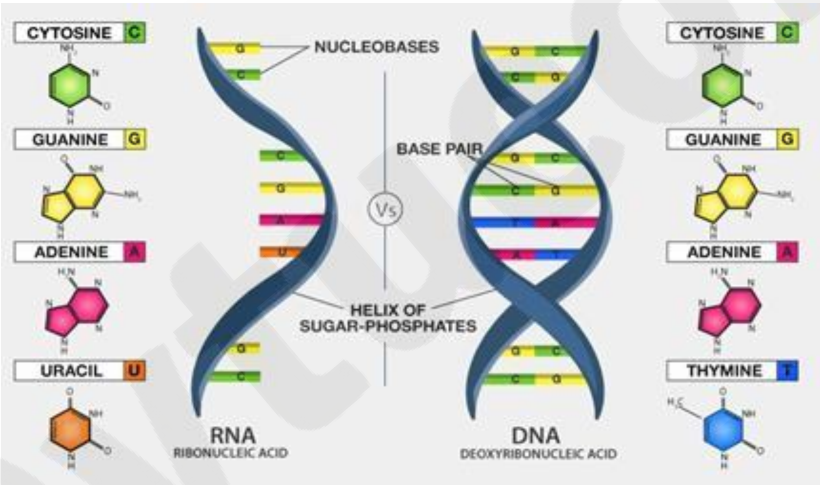

Fig. 1.10 Plant based Protein

Table 1.3 DNA and RNA Difference

DNA (Deoxyribonucleic acid)	**RNA (Ribonucleic acid)**
Definition	
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.
Location	

It is located in the nucleus of a cell and in the mitochondria.	It is found in the cytoplasm, nucleus and in the ribosome.
Sugar portion	
It has 2-deoxyribose.	It has Ribose.
Function	
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.
Predominant Structure	
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.
Propagation	
DNA replicates on its own, it is self-replicating.	RNA does not replicate on its own. It is synthesized from DNA when required.
Nitrogenous Bases and Pairing	
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).

1.4.1 DNA

In cells, DNA (Deoxyribonucleic acid) is the nucleic acid that functions as the original blueprint for the synthesis of proteins. DNA contains the sugar deoxyribose, phosphates and a unique sequence of the nitrogenous bases adenine (A), guanine (G), cytosine (C) and thymine (T).

Brief Insight into the Structure and Composition of DNA

- The DNA molecules contain instructions a living entity requires to grow, develop and reproduce. These instructions are present inside each cell and are inherited from the parents to their offspring.

- It is made up of nucleotides which contain a nitrogenous group, a phosphate group, and a sugar group. The order of the nitrogenous bases – thymine(T), guanine(G), cytosine(C), and adenine(A), is crucial in determining the genetic code.
- Genes are formed by the order of the nitrogenous bases present in the DNA which is crucial for protein synthesis. RNA is another nucleic acid that translates genetic information into proteins from DNA.
- The nucleotides are linked together for the formation of two long strands which spiral to produce a structure known as the double-helix which resembles that of a ladder wherein the sugar and phosphate molecules form the sides while the rungs are formed by the bases.
- The bases located on one strand pair up with the bases on the other strand, as in – **guanine** pairs with **cytosine** and **adenine** pairs with **thymine**.
- The DNA molecules are extremely long and hence without the right packaging, they cannot fit into cells. Thus, DNA is tightly coiled to produce formations referred to as **chromosomes**. Every chromosome has a single DNA molecule. In humans, there are 23 pairs of chromosomes that are present within the nucleus of the cells.

1.4.2 Types of DNA

- **A-DNA:** It is found at a relative humidity of 75%. In an environment where there is a higher salt concentration or ionic concentrations, such as $K+$, $Na+$, $Cs+$ or in a state of dehydration it endures in a form that contains 11 nucleotide pairs with a rise of 2.56Å vertically per base pair. It has the broadest helical diameter amongst all DNA forms – 23Å DNA which is a typical helix that is right-handed with a rotation of 32.7^0 per base pair.
- **B-DNA:** The most common form, present in most DNA at neutral pH and physiological salt concentrations, is B-form. It has 10 base pairs per turn from the helix axis. There is a distance of 3.4Å with a helical diameter of 20Å. Watson-Crick's double helix model is defined as a B-form of DNA.
- **C-DNA:** It is observed at a relative humidity of 66% and in the occupancy of a few ions such as Lithium($Li+$). It closely has 9.33 base pairs for every turn. The diameter of the helix is about 19Å and the vertical rise for every base pair for the right-handed helix is 3.320.
- **D-DNA:** It is observed rarely as an extreme variant. The 8 base pairs are titled negatively from the helix axis with an axial rise of about 3.03Å

- **Z-DNA:** It is found in an environment with a very high salt concentration. Unlike the A, B, and C types of DNA, it is a left-handed helical structure. The backbone is arranged in a zig-zag pattern formed by the sugar-phosphate linkage wherein the recurrent monomer is the dinucleotide in contrast to the mononucleotide, which is observed in alternate forms.

1.4.3 RNA

Ribonucleic acid (RNA) is a nucleic acid which is directly involved in protein synthesis. Ribonucleic acid is an important nucleotide with long chains of nucleic acid present in all living cells. Its main role is to act as a messenger conveying instructions from DNA for controlling protein synthesis.

RNA contains the sugar ribose, phosphates, and the nitrogenous bases adenine (A), guanine (G), cytosine (C), and uracil (U). DNA and RNA share the nitrogenous bases A, G, and C. Thymine is usually only present in DNA and uracil is usually only present in RNA.

1.4.4 Types of RNA

Only some of the genes in cells are expressed into RNA. The following are the types of RNA wherein each type is encoded by its own type of gene:

- **tRNA**– The transfer RNA or the tRNA carries amino acids to ribosomes while translation
- **mRNA** – The messenger RNA or the mRNA encodes amino acid sequences of a polypeptide
- **rRNA** – The ribosomal RNA or the rRNA produces ribosomes with the ribosomal proteins that are organelles responsible for the translation of the mRNA.
- **snRNA** – The small nuclear RNA forms the complexes along with proteins which are utilized in RNA processing in the eukaryotes.

- With an estimated global mortality of about 50,000 per year, rabies has been identified as one of the major causes of human death from infectious diseases. According to estimates, one person dies due to rabies every 15 minute, and 300 people are exposed to the risk, during the same period. More than 99% rabies deaths occur in the developing countries of Asia and Africa. The disease manifests itself as a progressive fatal encephalomyelitis, and results from infection with viruses of the genus Lyssavirus in the family Rhabdoviridae.

Infection is usually acquired from transcutaneous or mucosal exposure to virus-laden saliva of a rabid animal. All warm blooded animals are susceptible, though companion animals, especially dogs, constitute the major vector in most developing countries.

- Limited access to healthcare facilities and the high costs and complex schedules of rabies biologics often hamper human rabies prophylaxis in the developing countries. The cell culture vaccines, though 100% effective when combined with appropriate wound care and use of immunoglobulins, are expensive, require multiple doses over at least 3 weeks, and demand cold chain maintenance. Canine rabies control is critical in prevention of human rabies in the endemic countries; but faces greater challeges—logistics of mass vaccination drivesever-expanding population of unowned dogs, difficulties in locating the dogs for repeat doses, disrespect of vaccine cold chain, poor immune responses in malnourished and sick animals etc. A cheaper, easily producible vaccine that requires single or a few doses, and reasonably stable at room temperature would be highly desirable in endemic countries, at least for veterinary vaccination. In this context, a DNA vaccine could be a suitable option.

1.5 Lipids

Lipids are organic substances that are insoluble in water, soluble in organic solvents, are related to fatty acids and are utilized by the living cell. They include fats, waxes, sterols, fat-soluble vitamins, mono-, di- or triglycerides, phospholipids, etc. Unlike carbohydrates, proteins, and nucleic acids, lipids are not polymeric molecules. Lipids play a great role in the cellular structure and are the chief source of energy.

"Lipids are organic compounds that contain hydrogen, carbon, and oxygen atoms, which form the framework for the structure and function of living cells."

- **What are Lipids?**

These organic compounds are nonpolar molecules, which are soluble only in nonpolar solvents and insoluble in water because water is a polar molecule. In the human body, these molecules can be synthesized in the liver and are found in oil, butter, whole milk, cheese, fried foods and also in some red meats.

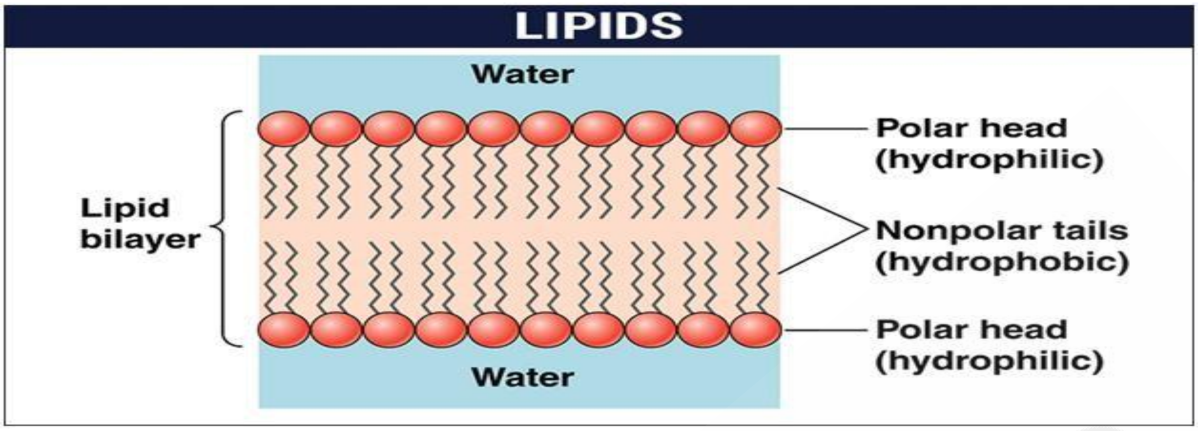

Fig. 1.11 Lipids

1.5.1 Properties of Lipids

Lipids are a family of organic compounds, composed of fats and oils. These molecules yield high energy and are responsible for different functions within the human body. Listed below are some important characteristics of Lipids.

- Lipids are oily or greasy nonpolar molecules, stored in the adipose tissue of the body.
- Lipids are a heterogeneous group of compounds, mainly composed of hydrocarbon chains.
- Lipids are energy-rich organic molecules, which provide energy for different life processes.
- Lipids are a class of compounds characterised by their solubility in nonpolar solvents and insolubility in water.
- Lipids are significant in biological systems as they form a mechanical barrier dividing a cell from the external environment known as the cell membrane.

1.5.2 Lipid Structure

Lipids are the polymers of fatty acids that contain a long, non-polar hydrocarbon chain with a small polar region containing oxygen. The lipid structure is explained in the diagram below:

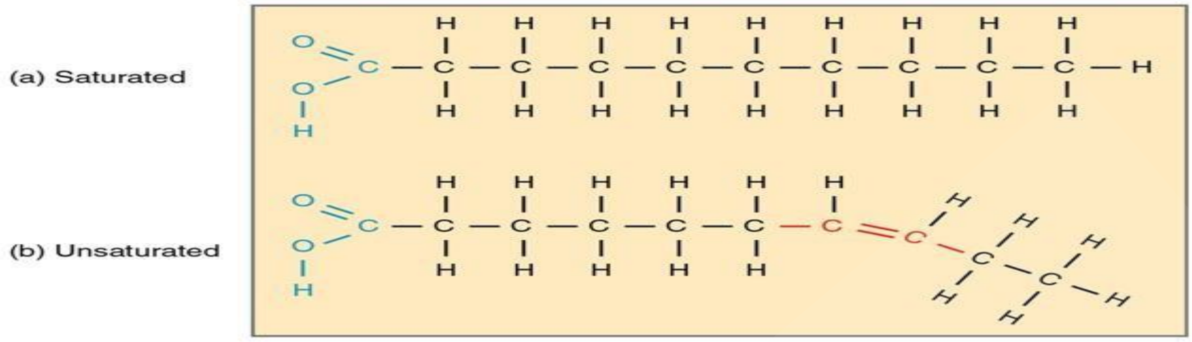

Fig. 1.12 Lipid Structure – Saturated and Unsaturated Fatty Acids

1.5.3 Classification of Lipids

Lipids can be classified into two main classes:

- Nonsaponifiable lipids
- Saponifiable lipids

a) Nonsaponifiable Lipids

A nonsaponifiable lipid cannot be disintegrated into smaller molecules through hydrolysis. Nonsaponifiable lipids include cholesterol, prostaglandins, etc

b) Saponifiable Lipids

A saponifiable lipid comprises one or more ester groups, enabling it to undergo hydrolysis in the presence of a base, acid, or **enzymes,** including waxes, triglycerides, sphingolipids and phospholipids.

Further, these categories can be divided into non-polar and polar lipids.

Nonpolar lipids, namely triglycerides, are utilized as fuel and to store energy.

Polar lipids, that could form a barrier with an external water environment, are utilized in membranes. Polar lipids comprise sphingolipids and glycerophospholipids.

Fatty acids are pivotal components of all these lipids.

1.5.4 Types of Lipids

Within these two major classes of lipids, there are numerous specific types of lipids, which are important to life, including fatty acids, triglycerides, glycerophospholipids, sphingolipids and steroids. These are broadly classified as simple lipids and complex lipids.

a) Simple Lipids

Esters of fatty acids with various alcohols.

- **Fats:** Esters of fatty acids with glycerol. Oils are fats in the liquid state
- **Waxes**: Esters of fatty acids with higher molecular weight monohydric alcohols

b) Complex Lipids

Esters of fatty acids containing groups in addition to alcohol and fatty acid.

- **Phospholipids**: These are lipids containing, in addition to fatty acids and alcohol, phosphate group. They frequently have nitrogen-containing bases and other substituents, eg, in glycerophospholipids the alcohol is glycerol and in sphingophospholipids the alcohol is sphingosine.
- **Glycolipids (glycosphingolipids)**: Lipids containing a fatty acid, sphingosine and carbohydrate.
- **Other complex lipids**: Lipids such as sulfolipids and amino lipids. Lipoproteins may also be placed in this category.

c) Precursor and Derived Lipids

These include fatty acids, glycerol, steroids, other alcohols, fatty aldehydes, and ketone bodies, hydrocarbons, lipid-soluble vitamins, and hormones. Because they are uncharged, acylglycerols (glycerides), cholesterol, and cholesteryl esters are termed neutral lipids.

These compounds are produced by the hydrolysis of simple and complex lipids.

1.6 Enzyme

Enzymes are a linear chain of amino acids, which give rise to a three-dimensional structure. The sequence of amino acids specifies the structure, which in turn identifies the catalytic activity of the enzyme. Upon heating, the enzyme's structure denatures, resulting in a loss of enzyme activity, which typically is associated with temperature.

Compared to its substrates, enzymes are typically large with varying sizes, ranging from 62 amino acid residues to an average of 2500 residues found in fatty acid synthase. Only a small section of the structure is involved in catalysis and is situated next to the binding sites. The catalytic site and binding site together constitute the enzyme's active site. A small number of ribozymes exist which serve as an RNA-based biological catalyst. It reacts in complex with proteins.

1.6.1 Enzymes Classification

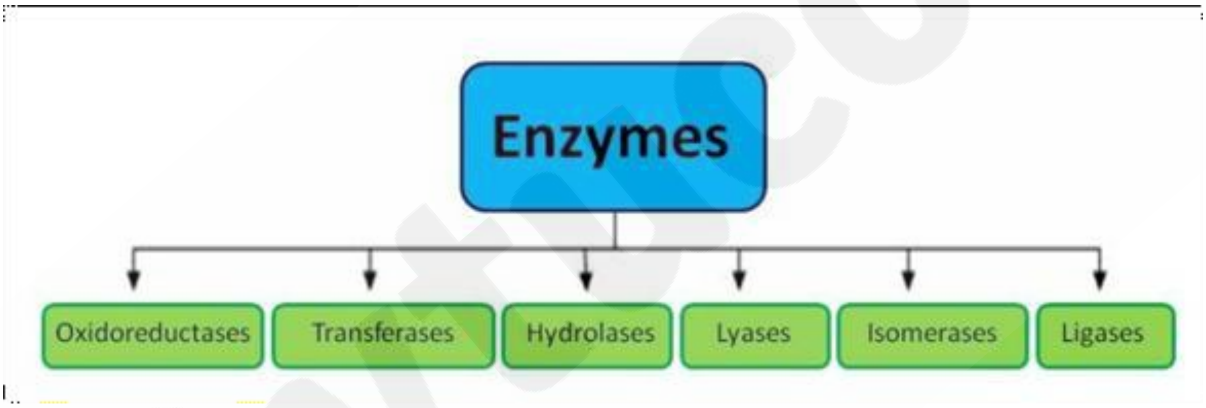

Fig.1.17 Enzymes Classification

Earlier, enzymes were assigned names based on the one who discovered them. With further research, classification became more comprehensive.

According to the International Union of Biochemists (I U B), enzymes are divided into six functional classes and are classified based on the type of reaction in which they are used to catalyze. The six kinds of enzymes are hydrolases, oxidoreductases, lyases, transferases, ligases and isomerases.

Table 1.4 Classification of enzymes

Types	**Biochemical Property**
Oxidoreductases	The enzyme Oxidoreductase catalyzes the oxidation reaction where

	the electrons tend to travel from one form of a molecule to the other.
Transferases	The Transferases enzymes help in the transportation of the functional group among acceptors and donor molecules.
Hydrolases	Hydrolases are hydrolytic enzymes, which catalyze the hydrolysis reaction by adding water to cleave the bond and hydrolyze it.
Lyases	Adds water, carbon dioxide or ammonia across double bonds or eliminate these to create double bonds.
Isomerases	The Isomerases enzymes catalyze the structural shifts present in a molecule, thus causing the change in the shape of the molecule.
Ligases	The Ligases enzymes are known to charge the catalysis of a ligation process.

1.7 Vitamin

A vitamin is an organic molecule other than proteins, carbs, and lipids required for normal growth, nutrition, and health. Vitamins are not utilised to make cells or as a source of energy, but they work as essential catalysts in biological processes, and their lack causes major health disorders.

A vitamin is a chemical compound that is a necessary micronutrient. An organism requires vitamins in little amounts for its metabolism to function properly. Essential nutrients are not produced in the body, either entirely or in adequate amounts, and must be received through food. Most people are acquainted with certain vitamins, such as vitamin B12, Vitamin A and vitamin C. They're also known by several names, such as cobalamins, retinoids and ascorbic acid respectively. Vitamins can also be classified as fat-soluble or water-soluble. These water and fat-soluble properties of vitamins affect whether they can be stored in the body.

1.7.1 Types Of Vitamins

Vitamins are segregated into two broad categories, namely

- Fat-soluble vitamins
- Water-soluble vitamins

There are **4 fat-soluble and 9 water-soluble vitamins** required for the proper functioning of the body. Let's discuss these two types in detail.

- **Fat-soluble vitamins**

Vitamins that are soluble in lipids or body fats are known as fat-soluble vitamins. The human body absorbs these substances through the intestinal tract with the help of dietary fat. These vitamins are then stored in the fatty tissues or liver. Fat-soluble vitamins can be stored in our systems for a long time.

The four fat-soluble vitamins are as follows:

- Vitamin A (retinol)
- Vitamin K (phylloquinone)
- Vitamin D (calciferol)
- Vitamin E (alpha-tocopherol).

- **Water-soluble vitamins**

Water-soluble vitamins, unlike fat-soluble vitamins, cannot be stored in the body for extended periods. Following consumption, these vitamins are eliminated through urine regularly. This is why water-soluble vitamins must be consumed more regularly than fat-soluble vitamins. The water-soluble vitamins are as follows:

Vitamin B1, Vitamin B6, Vitamin B7. Vitamin B3, Vitamin B9, Vitamin B12, Vitamin C
Vitamin B2, Vitamin B5

1.7.2 Functions Of Vitamins

a) Vitamin A

Functions: Vitamin A maintains eye health, muscle and bone growth, strong immunity, healthy skin and teeth. In addition, it is an antioxidant that lowers the risk of certain cancers.

Sources: pumpkins, sweet potatoes, broccoli, carrots, dairy products, eggs, cod liver oil, spinach, etc.

Deficiency causes Night blindness and Xerophthalmia.

b) Vitamin D

Functions: Vitamin D maintains the normal levels of phosphorus and calcium in the blood. It thereby aids in forming bone tissues by assisting the body in absorbing calcium.

Sources: It is the only vitamin the body can adequately synthesise from sunlight. It can also be found in trace amounts in foods such as fish, fish oil, and fish oil.

Deficiency causes Osteoporosis and Rickets.

c) Vitamin E

Functions: Vitamin E is a type of vitamin that aids in producing red blood cells while also lowering oxidative stress. In addition, it is an antioxidant that safeguards vitamin A and lipids against damage.

Sources: Almonds, eggs, vegetable oils, kiwis, and leafy greens are good sources.

Deficiency causes neuropathy and haemolytic anaemia in children.

d) Vitamin K

Functions: Vitamin K helps in blood coagulation or clotting after a wound has formed by stimulating proteins and calcium.

Sources: Milk, tomatoes, eggs, green and leafy vegetables including kale, cabbage, spinach, etc.

Deficiency causes haemorrhage and bleeding diathesis.

e) Vitamin B1

Functions: Vitamin B1 plays a role in synthesising the enzymes involved in converting carbohydrates to energy. It is also essential for muscle, skin, hair, and nerve functions.

Sources: Brown rice, whole grain rye, kale, eggs, potatoes, pork, oranges, etc.

Deficiency causes Beriberi.

f) Vitamin B2

Functions: Vitamin B2 is required for maintaining healthy skin and blood. In addition, this vitamin plays a vital role in food metabolism and the synthesis of erythrocytes (red blood cells).

Sources: Bananas, dairy products, eggs, meat, green beans, asparagus, etc.

Deficiency causes mouth inflammation and fissures.

g) Vitamin B3

Functions: Vitamin B3 aids in digestion and is needed to maintain healthy skin and nerve functions. In addition, at high doses, it exhibits cholesterol regulating effects.

Sources: Salmon, milk, eggs, carrots, nuts, tofu, tomatoes, chicken, lentils, etc.

Deficiency causes Pellagra.

h) Vitamin B5

Functions: Vitamin B5 plays an essential role in food metabolism and hormone production.

Sources: Yoghurt, whole grains, meat, avocado, etc.

Deficiency causes Paresthesia.

i) Vitamin B6

Functions: Vitamin B6 is necessary for the formation of serotonin, the synthesis of red blood cells, and cognitive and immunological functions.

Sources: Beef liver, nuts, chickpeas, bananas, squash.

Deficiency causes anaemia and peripheral neuropathy.

j) Vitamin B7

Functions: Vitamin B7 or Biotin aids in the metabolism of nutrients like the structural protein keratin, which aids in the maintenance of healthy skin, nails, and hair.

Sources: Spinach, liver, broccoli, egg yolk, cheese.

Deficiency causes Dermatitis.

k) Vitamin B9

Functions: Vitamin B9 assists in the normal synthesis of RNA and DNA in foetuses and protects these genetic components against malignant transformation.

Sources: Peas, legumes, liver, sunflower seeds, etc.

Deficiency causes Megaloblastic anaemia. Lower levels of folate may also cause congenital disabilities called spina bifida.

l) Vitamin B12

Functions: Vitamin B12 is an essential vitamin for regulating the body's metabolism. It helps synthesise red blood cells and DNA production and aids fatty acid breakdown. Cobalamin also maintains the proper functioning of the central nervous system.

Sources: Milk and other dairy products, meat, shellfish, fish, eggs, etc.

Deficiency causes different types of anaemia and neuropsychiatric disorders.

m) Vitamin C

Functions: Vitamin C, often known as ascorbic acid, has anti-ageing properties. It is because this vitamin aids in wound healing, blood vessel strengthening, bone-building, iron synthesis, and immune system maintenance by promoting collagen creation.

Sources: Citrus fruits, cabbage, Brussels, spinach, tomatoes, etc.

Deficiency causes Scurvy.

1.8 Hormones

Hormones are chemicals that essentially function as messengers of the body. These chemicals are secreted by special glands known as the endocrine glands. These endocrine glands are distributed throughout the body. These messengers control many physiological functions as well as psychological health. They are also quite important in maintaining homeostasis in the body.

The effects of hormones depend on how they are released. Hence, signalling effects can be classified into the following:

- **Autocrine**: The hormone act on the cell that secreted it.
- **Paracrine**: The hormone act on a nearby cell without having to enter the blood circulation.
- **Intracrine:** The hormone is produced in the cell and acts intracellularly means inside the cell.
- **Endocrine**: The hormone act on the target cells once it is released from the respective glands into the bloodstream.

1.8.1 Types of Hormones

To regulate various functions, different types of hormones are produced in the body. They are classified as follows:

- Peptide Hormones
- Steroid Hormones

a) Peptide Hormones

Peptide hormones are composed of **amino acids** and are soluble in water. Peptide hormones are unable to pass through the cell membrane as it contains a phospholipid bilayer that stops any fat-insoluble molecules from diffusing into the cell. Insulin is an important peptide hormone produced by the pancreas.

b) Steroid Hormones

Unlike peptide hormones, steroid hormones are fat-soluble and are able to pass through a cell membrane. Sex hormones such as testosterone, estrogen and progesterone are examples of steroid hormones.

1.8.2 Functions of Hormones

Following are some important functions of hormones:

- Food metabolism.
- Growth and development.
- Controlling thirst and hunger.
- Maintaining body temperature.
- Regulating mood and cognitive functions.
- Initiating an=d maintaining sexual development and reproduction.