Lecture 1

Cell Biology

Introduction:

Cells are the basic building blocks that build of all organisms. They are the smallest unit of a living organism whether made of one cell like bacteria or many cells like human. Cell biology means studying the structure and function of cells. Cells that cannot be seen by naked eyes and we need use microscope. In general, cells grouped into two categories: prokaryotic and eukaryotic cells. Prokaryotic cells involve bacteria but eukaryotic cells involve both animal and plant cells.

In 1665, term "cell" used for the first time by Robert Hooke when he observed box-like structure of cork tissue by using a lens. Furthermore, in the 1670s, Van Leeuwenhoek discovered bacteria and protozoa. By the late 1830s, botanist Matthias Schleiden and zoologist Theodor Schwann were studying tissues and proposed the unified cell theory. The unified cell theory states that: all living things are composed of one or more cells; the cell is the basic unit of life; and new cells arise from existing cells. Later, Rudolf Virchow had added important contributions to this theory.

Cell theory:

1- The cell is the fundamental unit of structure and function in organisms.
2- All organisms are made up of one or more cells.
3- Cells arise from other cells through cellular division.
4- Cells carry genetic material passed to daughter cells during cellular division.
5- All cells are essentially the same in chemical composition.

Types of cells:

All cells that exist on earth belong to one of two categories: prokaryotic and eukaryotic cells. Prokaryotic cells are unicellular cells consisting of a single cell for example bacteria. Eukaryotic cells are multicellular cells or have many cells for example human.

Prokaryotic cells

The word prokaryote comes from Greek (pro) means before and (karyote) means nucleus. Prokaryotic cells are smaller and more simple than eukaryotic cells such as bacteria and cyanobacteria (blue green algae). They do not have nucleus and instead they have free-genetic material (DNA) floating in the area of the cytoplasm called nucleoid. They also lack the intracellular organelles.

Eukaryotic cells

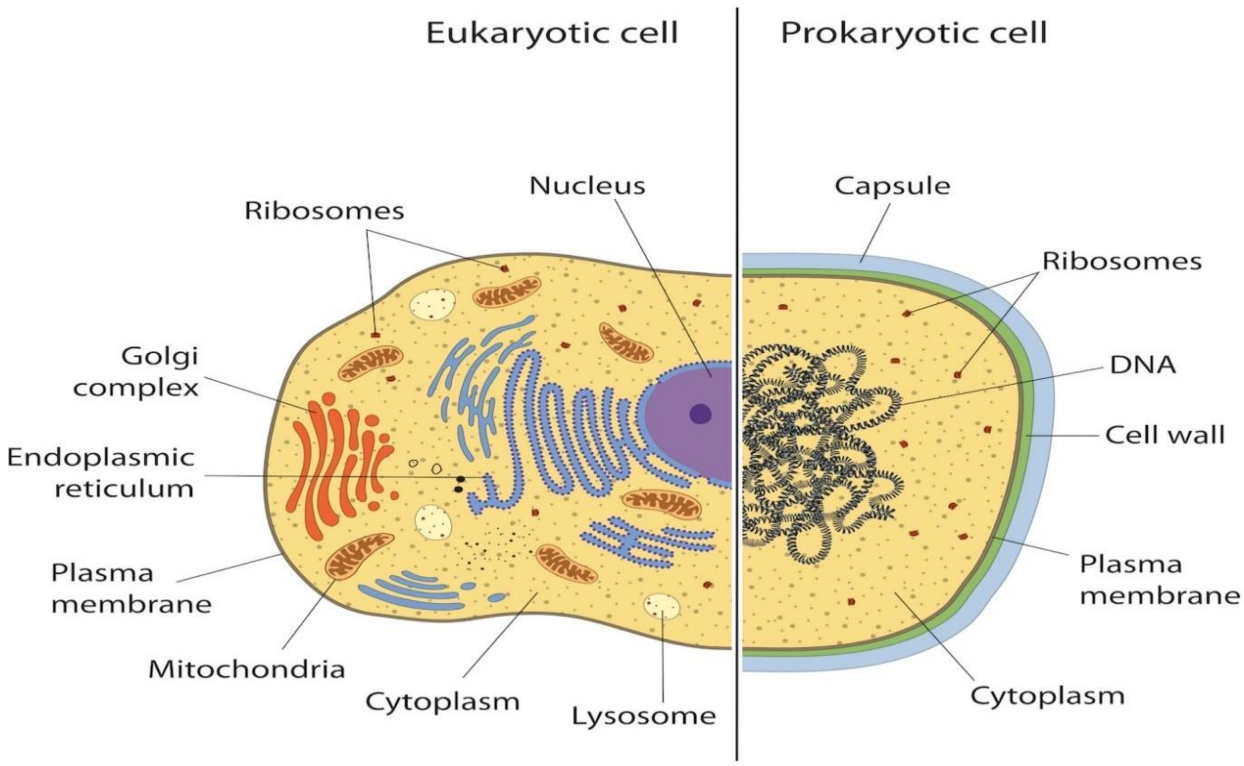
The word eukaryote comes from Greek (eu) means true and (karyote) means nucleus. Eukaryotic cells have complex cells and the genetic material (DNA) located in the nucleus. They have the intracellular organelles. Cells of human, animals, plants, fungi and protists are example of eukaryotic cells.

Prokaryotic and eukaryotic cells share some common features, including the following:

1- **DNA**: Genetic coding that determines all the characteristics of living things.
2- **Cell (or plasma) membrane**: Outer layer that separates the cell from the surrounding environment and acts as a selective barrier for incoming and outgoing materials.
3- **Cytoplasm**: Jelly-like fluid within a cell that is composed primarily of water, salts and proteins.
4- **Ribosomes**: Organelles that make proteins.

Following are the substantial difference between Prokaryotic Cells and Eukaryotic Cell:

Characteristics	**Prokaryotic cells**	**Eukaryotic cells**
Organisms	Bacteria and cyanobacteria (blue green algae)	Human, animal, plant, fungi and protists
Organization	Unicellular	Multicellular
Cell size	Small (0.1 – 10 µm)	Larger (10-100 µm)
Membrane – bound organelles	Absent	Present
DNA	Circular located in the nucleoid	Linear located in the nucleus
Ribosomes	70S	80S



Lecture 2

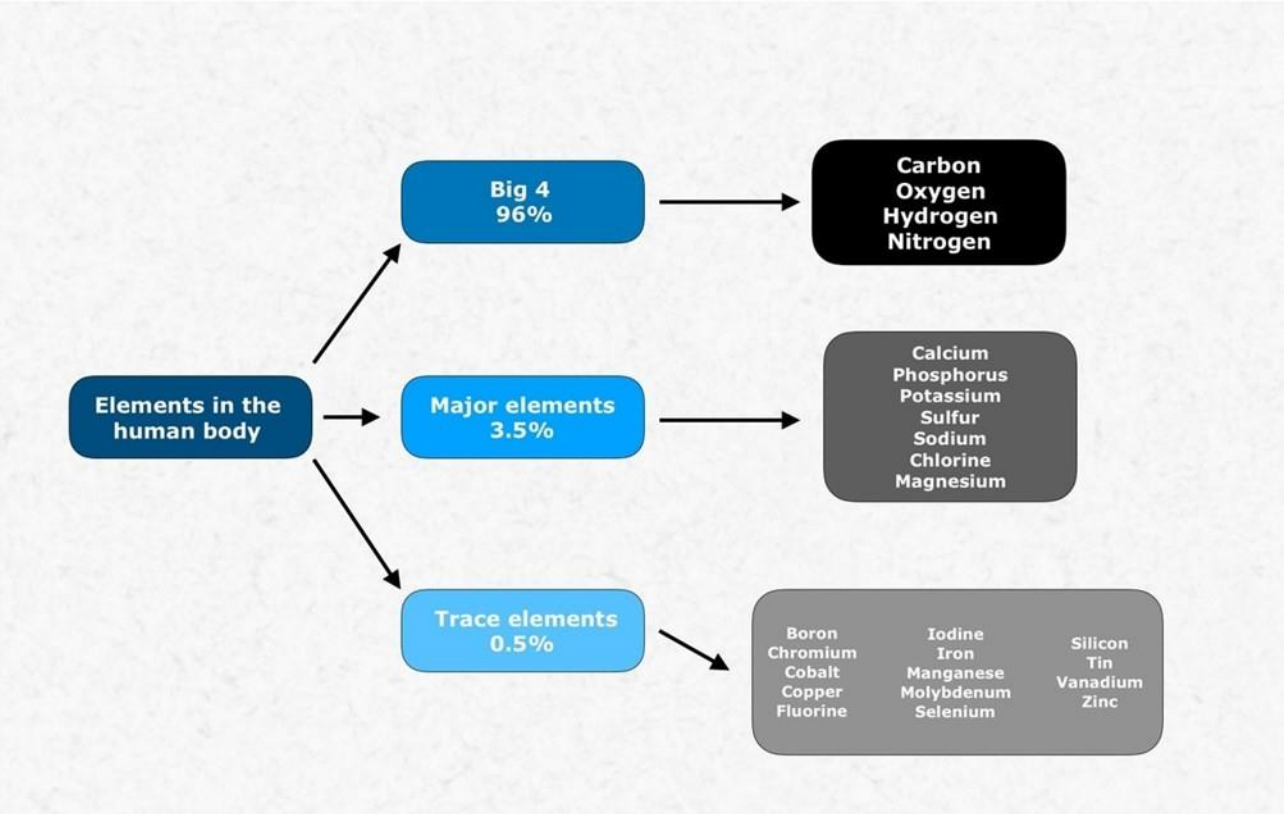
Chemical composition of Cell

All living organisms, prokaryotic and eukaryotic cells, are composed of chemical substances. **Elements** are the basic or pure chemical substances that cannot be broken down into other substances by chemical means. For example, Carbon, oxygen, hydrogen, nitrogen, sulfur, calcium, sodium and iron and they perform the same general tasks. About 25 elements are essential to life and these elements are divided into three groups depending on the amount needed:

1- 4 of these elements—oxygen (O), carbon (C), hydrogen (H), and nitrogen (N)—make up about 96% and called **big elements**.

2- Calcium (Ca), phosphorus (P), potassium (K), sulfur (S), sodium (Na), chlorine (Cl) and magnesium (Mg) make up about 3.5% and called **major elements**.

3- 14 elements such as copper (Cu), iodine (I), iron (Fe), zinc (Zn) and a few other elements make up about 0.5% and called **trace elements**.



Two or more elements are covalently bonded to form **Molecules**. Molecules are divided into organic and inorganic compounds:

1- **Organic compounds** always contain carbon such as carbohydrates, fats, proteins and nucleic acids.

2- **Inorganic compounds** not contain carbon such as water and ions (salts, acids and bases).

Water

Water accounts for approximately 70% of the mass of a cell. Water plays an important role in the maintenance of biological systems (**Functions of water**):

1- Temperature regulation: in humans, the sweat glands produce sweat which cools the body as it evaporates from the body surface in a process called perspiration. In a similar way, plants are cooled by the loss of water vapour from their leaves, in a process called transpiration.

2- Form and support: water is an important constituent of the body and plays an important role in providing form and support in animals and plants. Animals, such as worms and jellyfish, use water in special chambers in their body to give their bodies support. This use of water pressure to provide body form, and enable movement is called a hydrostatic skeleton. Plants grow upright and keep their shape due to the pressure of water (turgor pressure*)* inside the cells.

3- Transport medium: water transports substances around the body. For example, water is the main constituent of blood and enables blood cells, hormones and dissolved gases, electrolytes and nutrients to be transported around the body.

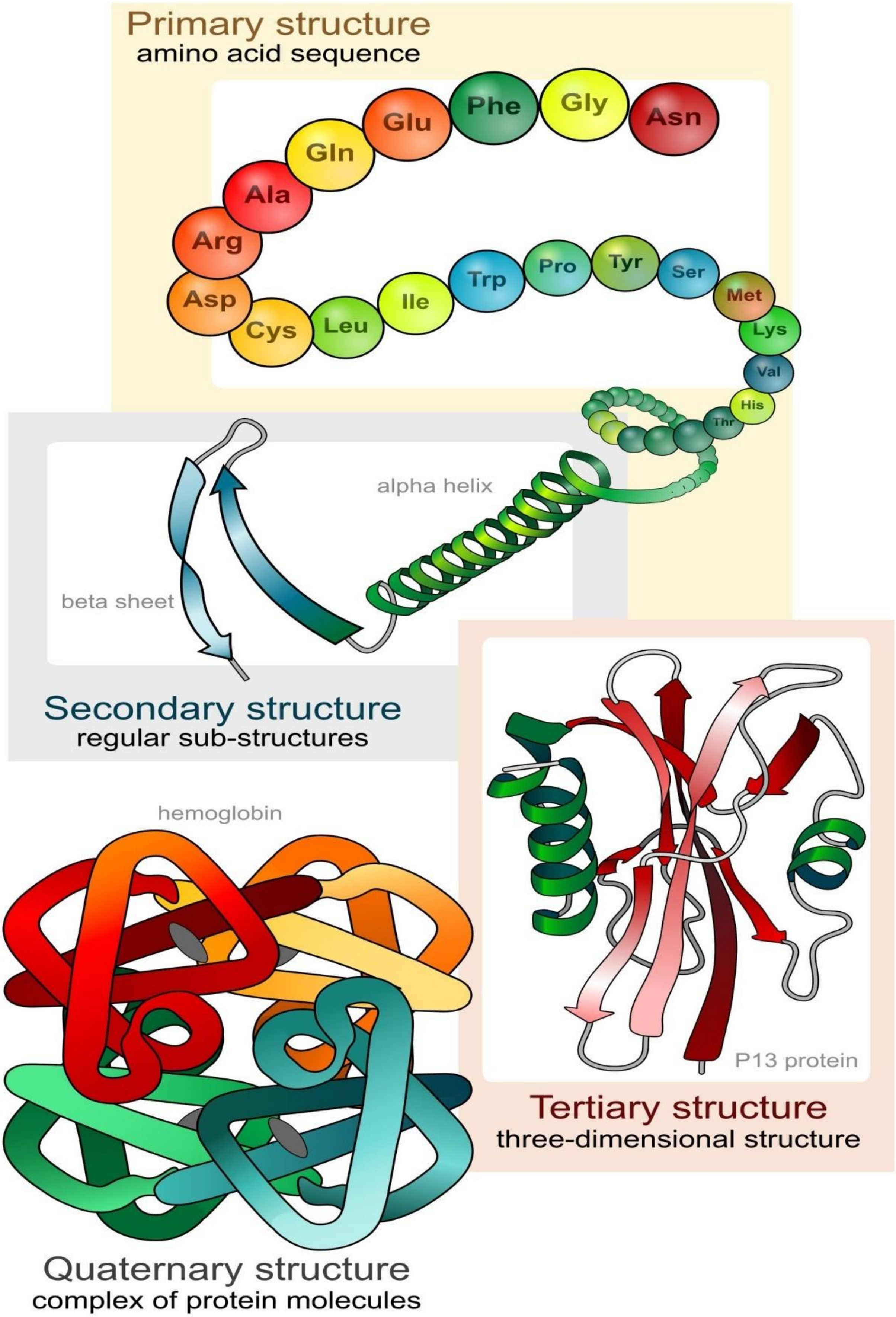
4- Lubricating agent: water is the main constituent of saliva which helps chewing and swallowing and also allows food to pass easily along the alimentary canal. Water is also the main constituent of tears which help keep the eyes lubricated.

5- **Solvent for biological chemicals**: the liquid in which substances dissolve is called a solvent. Water is known as the universal solvent as more substances dissolve in water than in any other liquid.
6- **Medium in which chemical reactions occur**: all chemical reactions in living organisms take place in water.

Protein

Proteins are made of **amino acids**. There are 20 common amino acids from which all proteins in living organisms are made. Nine of them are considered **essential amino acids**, as they cannot by synthesised in the body from other compounds, and must be obtained from the diet. Amino acids are bonded together by **peptide bonds** to form **peptides**. A long peptide chain forms a protein, which folds into a very specific three-dimensional shape. This three-dimensional shape is completely determined by the identity and order of the amino acids in the peptide chain. We often refer to **four different levels** of protein structure:

- **Primary structure**: This refers to the sequence of amino acids joined together by peptide bonds to form a polypeptide chain.
- **Secondary structure**: This is the first level of three dimensional folding. It is driven completely by hydrogen bonding.
- **Tertiary structure**: This is the second level of three dimensional folding and is the overall final shape of the protein molecule. The secondary structures and unstructured regions of the chain further fold into a globular shape, driven by hydrophobic interactions (non-polar regions trying to escape the water in the cell environment) and electrostatic interactions (polar and charged regions wanting to interact with the water environment and each other).
- **Quaternary structure**: Some proteins are complex: two or more peptide chains fold into their tertiary structures, then these complete structures associate together by hydrophobic and electrostatic interactions to form the final protein.


Primary structure
amino acid sequence
Phe
Gly
Glu
Asn
Gln
Ala
Arg
Asp
Cys
Leu
Ile
Trp
Pro
Tyr
Ser
Met
Lys
Val
His
Thr
alpha helix
beta sheet
Secondary structure
regular sub-structures
hemoglobin
Tertiary structure
three-dimensional structure
P13 protein
Quaternary structure
complex of protein molecules

Proteins are important in several crucial biological functions. Proteins are found in hair, skin, bones, muscles, tendons, ligaments and other structures and perform key structural and mechanical functions. **Proteins are also important in cell communication and in the immune system. Proteins can also act as an energy reserve when broken down through digestive processes.** Certain proteins called **enzymes** are important in catalysing cellular reactions that form part of metabolism.

Enzymes are biological molecules (typically proteins) that significantly **speed up the rate of virtually all of the chemical reactions that take place within cells.**

They are vital for life and serve a wide range of important functions in the body, such as aiding in digestion and metabolism.

Some enzymes help break large molecules into smaller pieces that are more easily absorbed by the body. Other enzymes help bind two molecules together to produce a new molecule. Enzymes are highly selective catalysts, meaning that each enzyme only speeds up a specific reaction.

Carbohydrates

Carbohydrates form about 2% of body mass

1- Carbohydrates are made up of monomers known as **monosaccharides**. The monosaccharide that makes up most carbohydrates is glucose. Other monosaccharides include fructose, galactose and deoxyribose.
2- These monomers can be joined together by **glycosidic** bonds. When two monosaccharides are chemically bonded together, they form **disaccharides**. An example of a disaccharide is sucrose (table sugar), which is made up of glucose and fructose. Other dissacharides include lactose, made up of glucose and galactose, and maltose, made up of two glucose molecules.
3- Several monosaccharides join together to form **polysaccharides**. Examples of polysaccharides include glycogen, starch and cellulose.

The main function of carbohydrates is as energy storage molecules and as substrates (starting material) for energy production. Carbohydrates are broken down by living organisms to release energy. **Starch** and **glycogen** are both storage polysaccharides and thus act as a store for energy in living organisms. Starch is a storage polysaccharide in plants and glycogen is the storage polysaccharide for animals. Cellulose is found in plant cell walls and helps gives plants strength.

Lipids

Triglycerides are one of the most common types of lipids. Triglyceride molecules are made up of glycerol and three fatty acids. The fatty acid tails are made up of many carbons joined together. **Functions of fatty acids are**:

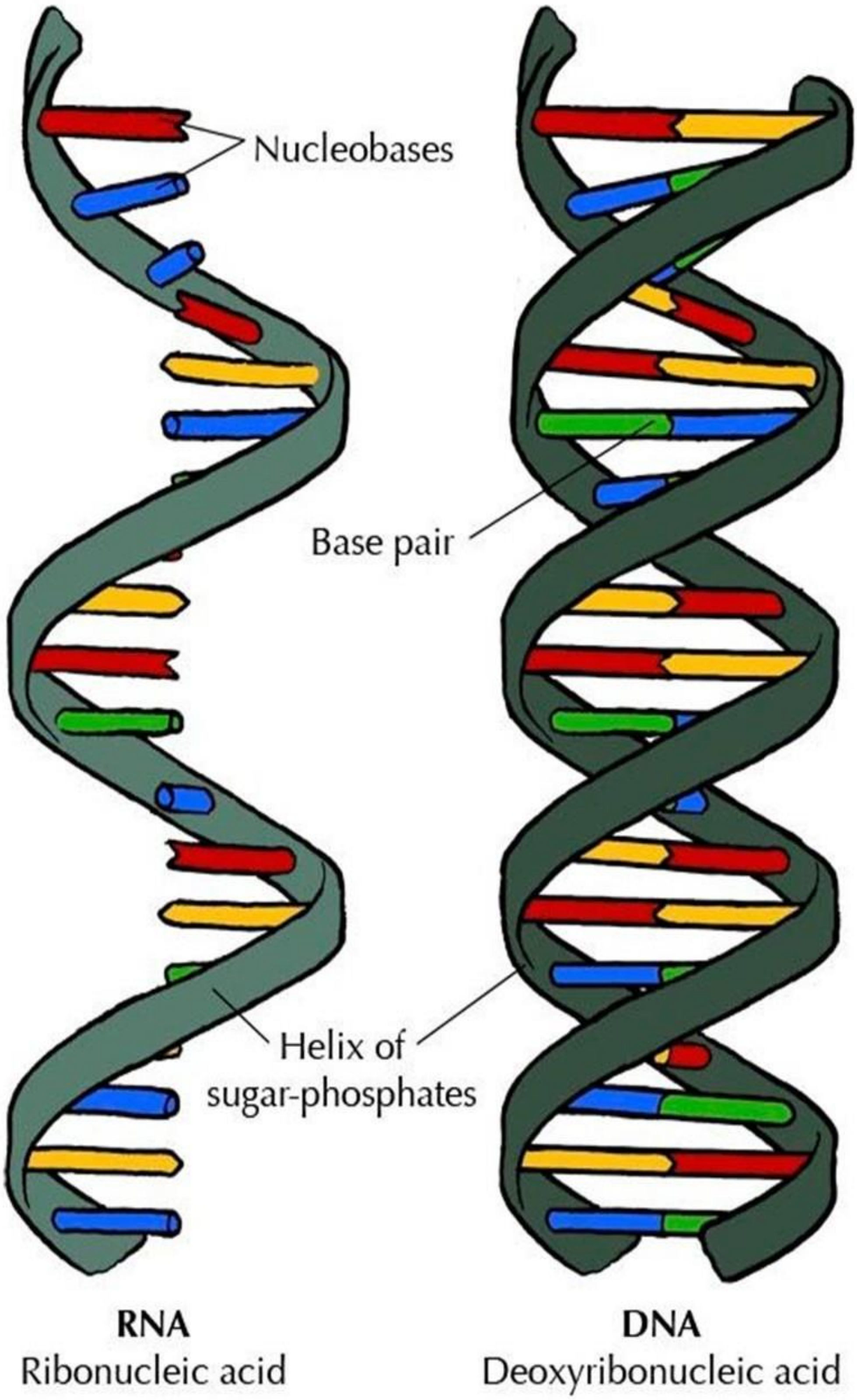
1- Lipids are an important energy reserve. Triglyceride lipids are broken down to release glycerol and fatty acids.
2- Glycerol can be converted to glucose and used as a source of energy, however the majority of energy provided by lipids comes from the breakdown of the fatty acid chains.
3- Lipids are important for the digestion and transport of essential vitamins, help insulate body organs against shock and help to maintain body temperature.
4- Lipids also play an important role in cell membranes.

Nucleic acids

Nucleic acids, such as DNA and RNA, are large organic molecules that are key to all living organisms. The building blocks of nucleic acids are called **nucleotides**. Each nucleotide is made up of a sugar, a phosphate and a nitrogenous base. Nucleotides are joined together by **phosphodiester** bonds, which join the phosphate of one nucleotide to the sugar of the next. The phosphate-sugar-phosphate-sugar strands form a "backbone" upon which the nitrogen-containing bases are exhibited. DNA is a double-stranded polymer, due to hydrogen bonding between the nitrogenous bases of two complementary strands. RNA is a single-stranded polymer. Nucleic acids do not need to be obtained from the diet because they are synthesised using intermediate products of carbohydrate and amino acid metabolism.

Nucleic acids include:

- Deoxyribonucleic acid (**DNA**): which contains the 'instructions' for the synthesis of proteins in the form of genes. DNA is found in the nucleus of every cell, and is also present in smaller amounts inside mitochondria and chloroplasts.
- Ribonucleic acid (**RNA**): is important in transferring genetic information from DNA to form proteins. It is found on ribosomes, in the cytoplasm and in the nucleus.


Nucleobases
Base pair
Helix of
sugar-phosphates
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid

Lecture 3

The cell membrane structure

The cell membrane

The **cell membrane** also known as the **plasma membrane** or **cytoplasmic membrane.** The cell's organelles and its intracellular solutes (some inorganic and some organic) are contained within the cell by its membrane. The membrane has limited and selective permeability; it maintains the intracellular concentration of electrolytes and biologic compounds that is distinctly different from that of the extracellular fluid. Cell membrane function is thus an essential one for the health and survival of the cell.

Historical view

1- The first insights into the chemical nature of the outer boundary layer of a cell were obtained by **Ernst Overton** of the University of Zürich during the 1890s. Overton knew that nonpolar solutes dissolved more readily in nonpolar solvents than in polar solvents, and that polar solutes had the opposite solubility.

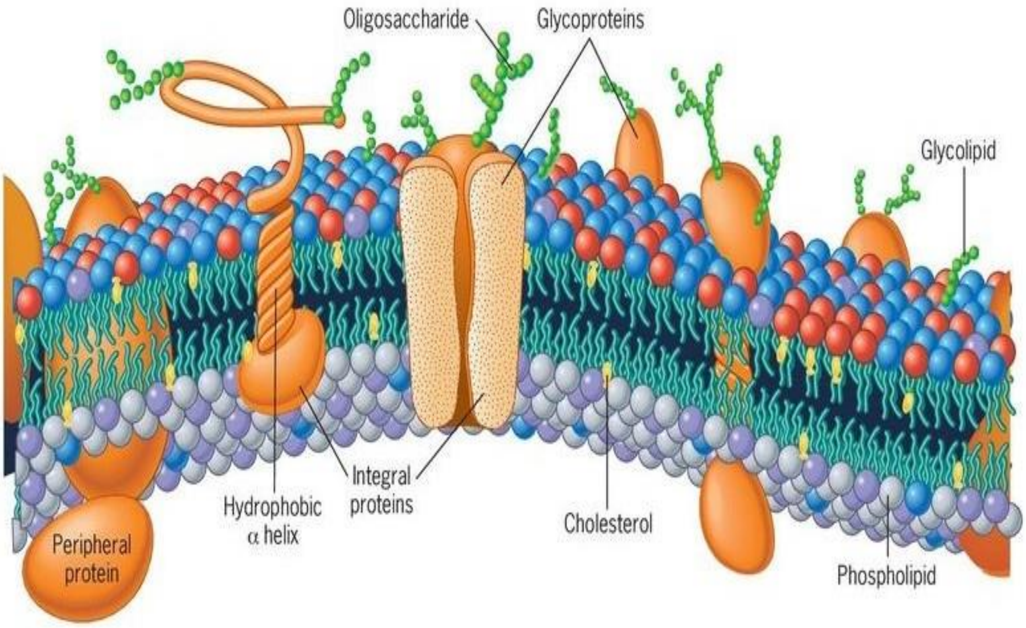
2- The first proposal that cellular membranes might contain a lipid bilayer was made in 1925 by two Dutch scientists, **E. Gorter and F. Grendel**. These researchers extracted the lipid from human red blood cells and measured the amount of surface area the lipid would cover when spread over the surface of water. Since mature mammalian red blood cells lack both nuclei and cytoplasmic organelles, the plasma membrane is the only lipid-containing structure in the cell. Consequently, all of the lipids extracted from the cells can be assumed to have resided in the cells' plasma membranes.

3- In the 1920s and 1930s, cell physiologists obtained evidence that there must be more to the structure of membranes than simply a lipid bilayer.

4- In 1935, **Hugh Davson and James Danielli** proposed that the plasma membrane was composed of a lipid bilayer that was lined on both its inner and outer surface by a layer of globular proteins. They revised their model in the early 1950s to account for the selective permeability of the membranes they had studied.
5- Experiments conducted in the late 1960s led to a new concept of membrane structure, as detailed in the fluidmosaic model proposed in 1972 by **S. Jonathan Singer and Garth Nicolson** of the University of California, San Diego

The Chemical Composition of Membranes

Membranes are lipid–protein assemblies in which the components are held together in a thin sheet by noncovalent bonds. The lipid bilayer serves primarily as a structural backbone of the membrane and provides the barrier that prevents random movements of water-soluble materials into and out of the cell. The proteins of the membrane, on the other hand, carry out most of the specific functions. Each type of differentiated cell contains a unique complement of membrane proteins, which contributes to the specialized activities of that cell type. The ratio of lipid to protein in a membrane varies, depending on the type of cellular membrane (plasma vs. endoplasmic reticulum vs.Golgi), the type of organism (bacterium vs. plant vs. animal), and the type of cell (cartilage vs. muscle vs. liver). For example, the inner mitochondrial membrane has a very high ratio of protein/lipid in comparison to the red blood cell plasma membrane, which is high in comparison to the membranes of the myelin sheath that form a multilayered wrapping around a nerve cell. To a large degree, these differences can be correlated with the basic functions of these membranes. The inner mitochondrial membrane contains the protein carriers of the electron-transport chain, and relative to other membranes, lipid is diminished. In contrast, the myelin sheath acts primarily as electrical insulation for the nerve cell it encloses, a function that is best carried out by a thick lipid layer of high electrical resistance with a minimal content of protein. Membranes also contain carbohydrates, which are attached to the lipids and proteins.



Cell membrane Structure

Membrane Lipids

Membranes contain a wide diversity of lipids, all of which are **amphipathic**. They contain both hydrophilic and hydrophobic regions. The hydrophilic (polar) region is their globular head; the hydrophobic (nonpolar) regions are their fatty acid tails. There are three main types of membrane lipids: phosphoglycerides, sphingolipids, and cholesterol.

1- **Phosphoglycerides** Most membrane lipids contain a phosphate group, which makes them phospholipids. Because most membrane phospholipids are built on a glycerol backbone, they are called phosphoglycerides
2- **Sphingolipids** A less abundant class of membrane lipids, called sphingolipids, are derivatives of sphingosine, an amino alcohol that contains a long hydrocarbon chain. Sphingolipids consist of sphingosine linked to a fatty acid by its amino group.
3- **Cholesterol** Another lipid component of certain membranes is the sterol cholesterol, which in certain animal cells may constitute up to 50 percent of the

lipid molecules in the plasma membrane. Plant cells contain cholesterol-like sterols, but biologists disagree as to whether or not they completely lack cholesterol.

Membrane protein

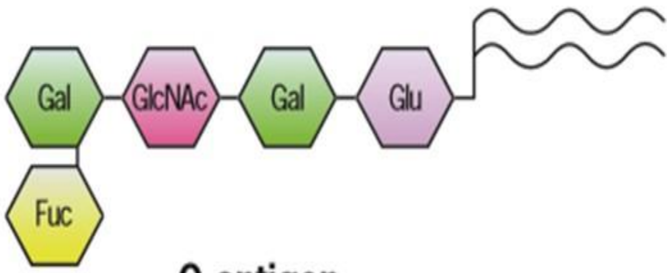
Depending on the cell type and the particular organelle within that cell, a membrane may contain hundreds of different proteins. Each membrane protein has a defined orientation relative to the cytoplasm, so that the properties of one surface of a membrane are very different from those of the other surface. Membrane proteins can be grouped into three distinct classes distinguished by the intimacy of their relationship to the lipid bilayer

1- **Integral proteins** that penetrate the lipid bilayer. Integral proteins are transmembrane proteins. They pass entirely through the lipid bilayer and thus have domains that protrude from both the extracellular and cytoplasmic sides of the membrane.
2- **Peripheral proteins** that are located entirely outside of the lipid bilayer, on either the cytoplasmic or extracellular side, yet are associated with the surface of the membrane by noncovalent bonds.
3- **Lipid-anchored proteins** that are located outside the lipid bilayer, on either the extracellular or cytoplasmic surface, but are covalently linked to a lipid molecule that is situated within the bilayer.

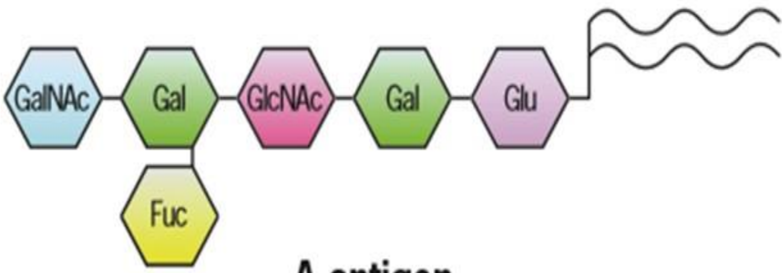
Membrane Carbohydrates

The plasma membranes of eukaryotic cells also contain carbohydrate. Depending on the species and cell type, the carbohydrate content of the plasma membrane ranges between 2 and 10 percent by weight. More than 90 percent of the membrane’s carbohydrate is covalently linked to proteins to form **glycoproteins**; the remaining carbohydrate is covalently linked to lipids to form **glycolipids.**

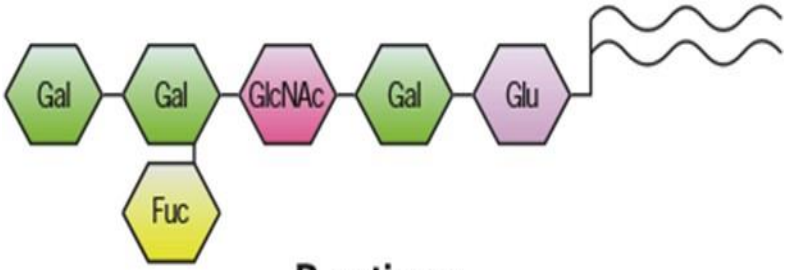
The carbohydrates of the glycolipids of the red blood cell plasma membrane determine whether a person’s blood type is A, B, AB, or O. A person having blood type A has an enzyme that adds an Nacetylgalactosamine to the end of the chain, whereas a person with type B blood has an enzyme that adds galactose to the chain terminus. These two enzymes are encoded by alternate versions of the same gene, yet they recognize different substrates. People with AB blood type possess both enzymes, whereas people with O blood type lack enzymes capable of attaching either terminal sugar. The function of the ABO blood-group antigens remains a mystery.



O antigen



A antigen



B antigen

Lecture 4

Cell membrane functions

All cell membranes have the following functions:

1- **Providing a selectively permeable barrier:** Membranes prevent the unrestricted exchange of molecules from one side to the other. At the same time, membranes provide the means of communication between the compartments they separate.

2- **Transporting solutes:** The plasma membrane contains the machinery for physically transporting substances from one side of the membrane to another, often from a region where the solute is present at low concentration into a region where that solute is present at much higher concentration.

3- **Responding to external stimuli:** The plasma membrane plays a critical role in the response of a cell to external stimuli, a process known as **signal transduction**. Membranes possess **receptors** that combine with specific molecules (**ligands**) or respond to other types of stimuli such as light or mechanical tension.

4- **Intercellular interaction:** Situated at the outer edge of every living cell, the plasma membrane of multicellular organisms mediates the interactions between a cell and its neighbors.

5- **Energy transduction:** Membranes are intimately involved in the processes by which one type of energy is converted to another type (**energy transduction**).

Protein functions:

Integral proteins serve as **(1) channels**, which permit the passage of selected ions through the membrane; **(2) carriers (or transporters)**, which translocate substances across the membrane by binding to them; **(3) pumps**, which are carriers that split adenosine triphosphate (ATP) and use the energy derived for membrane transport of substrates; **(4) receptors** (located on the outside), which bind to specific molecules and generate a chemical signal initiating intracellular reactions; and **(5) enzymes catalyzing reactions** at the membrane surfaces, both outer and inner.

Peripheral proteins serve as **(1) cell adhesion molecules (CAMs)** that anchor cells to neighboring cells and to the basal lamina. **(2) They also contribute to the cytoskeleton** when present on the cytoplasmic side of the membrane.

Membrane Transport

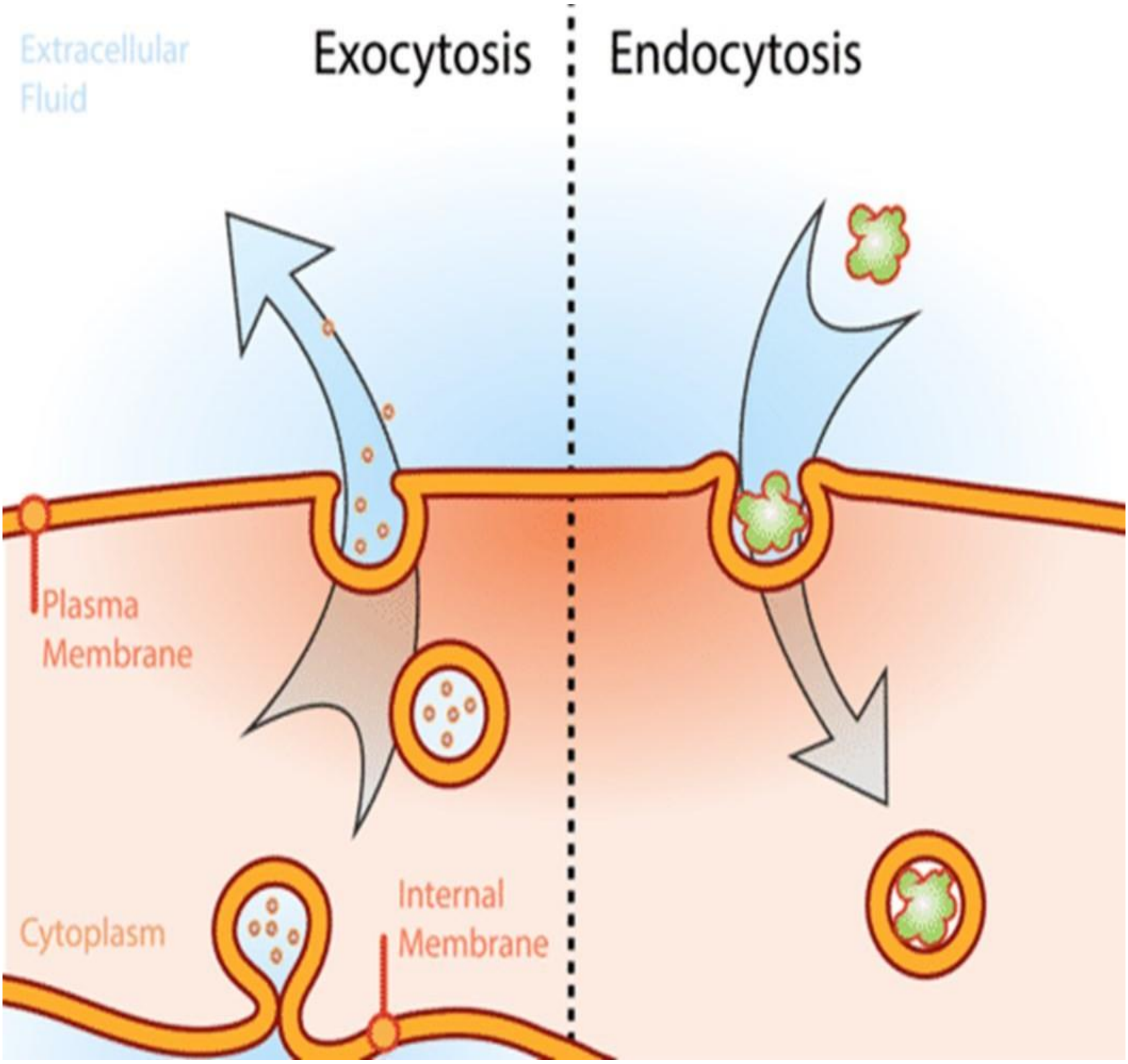
Simple Diffusion: It can occur only from a region of high solute concentration to a region of low solute concentration and no needs energy. Simple diffusion is the result of the random motion of molecules, and it occurs in both directions across the membrane. The membrane permeability to a substance depends on the molecule's size, lipid solubility, and electrical charge.

Carrier-mediated Transport Membrane: transport can also occur through carrier•mediated transport, which employs certain integral membrane proteins as carriers or transporters for specific substrates. It may occur without any energy expenditure (**facilitated diffusion**) or may involve energy expenditure (**active transport).**

Endocytosis: Endocytosis is the process by which cells take up macromolecules and large particles from the extracellular environment. The process requires ATPase, $Ca2^{+}$, and microfilaments. Endocytosis of cells, bacteria, viruses, or debris is called **phagocytosis.** Endocytosis of water, nutrient molecules, and parts of the cell membrane is called **pinocytosis.**

Exocytosis: Exocytosis is the process for release of macromolecules formed in the cell to the exterior.

Endocytosis and exocytosis processes are active transport processes, requiring energy.



Lecture 5

Junctions between cells

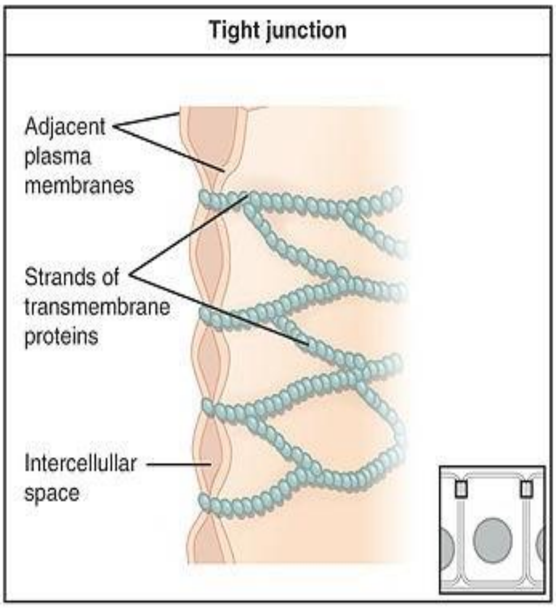
Intercellular junctions are structures which provide adhesion and communication between cells. They are mostly present in epithelial cells that are especially characterized by their strong attachment one to another and to extracellular matrix. The different multiprotein complexes each of these junctions have, allow also intercellular transport with the neighboring cells.

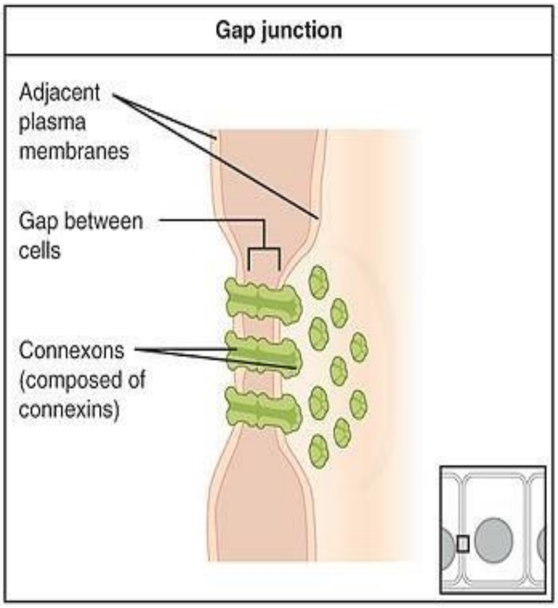
Three different types of intercellular junctions can be distinguished according to their function:

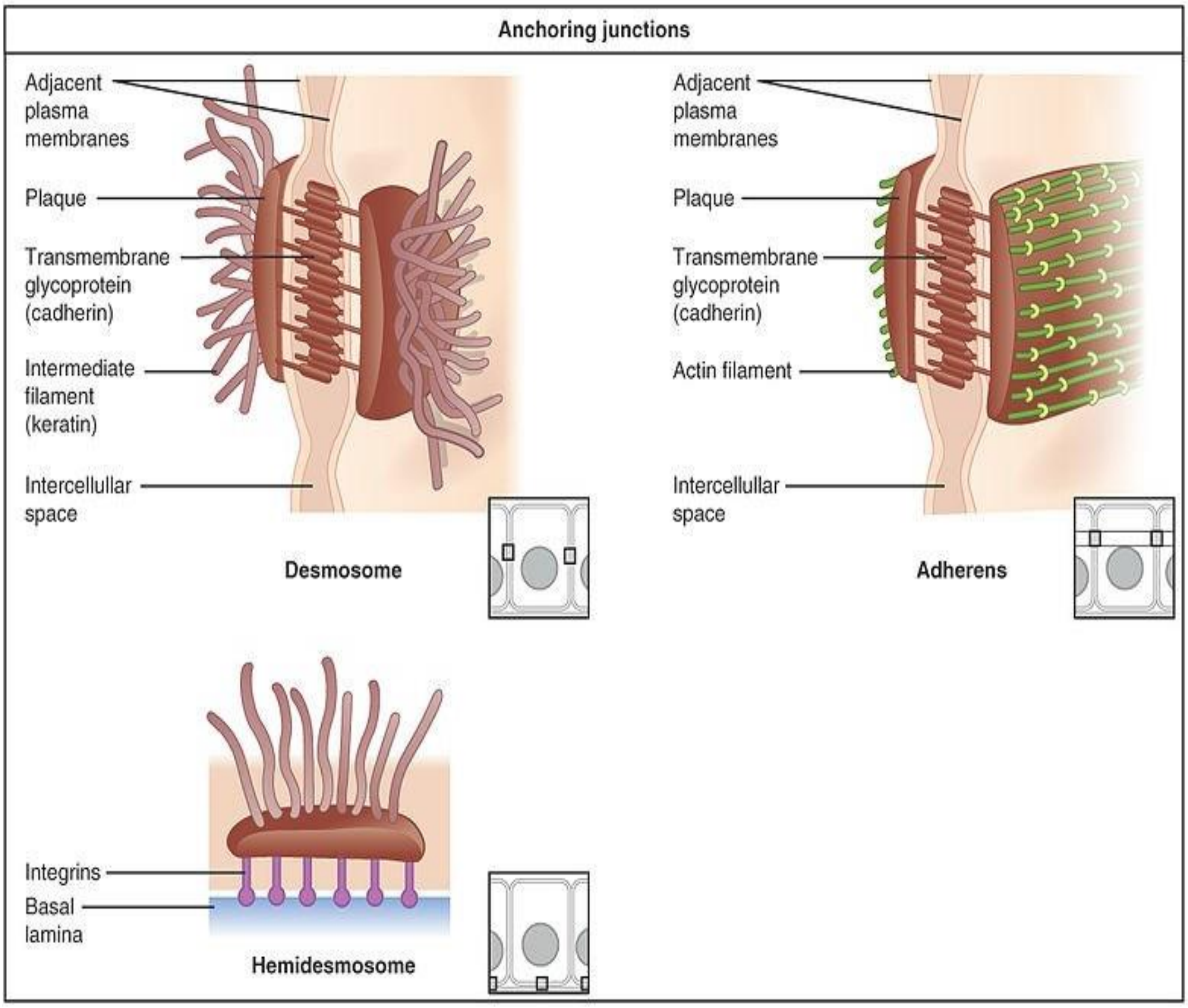
1- **Tight or occluding junctions:** provide transcellular and paracellular transport of molecules, but prevent passive flow between cells.

2- **Adherent or anchoring junctions, including desmosomes and hemidesmosomes:** provide strengthening and stabilizing the circular occluding bands. Another important function is the linking cytoskeletons of adjacent cells.

3- **Gap junctions:** The major function of gap junctions is the direct transfer and exchange of nutrients and signal molecules between the cells.


Tight junction
Adjacent plasma membranes
Strands of transmembrane proteins
Intercellullar space


Gap junction
Adjacent plasma membranes
Gap between cells
Connexons (composed of connexins)


Anchoring junctions
Adjacent plasma membranes
Plaque
Transmembrane glycoprotein (cadherin)
Intermediate filament (keratin)
Intercellullar space
Desmosome
Adjacent plasma membranes
Plaque
Transmembrane glycoprotein (cadherin)
Actin filament
Intercellullar space
Adherens
Integrins
Basal lamina
Hemidesmosome

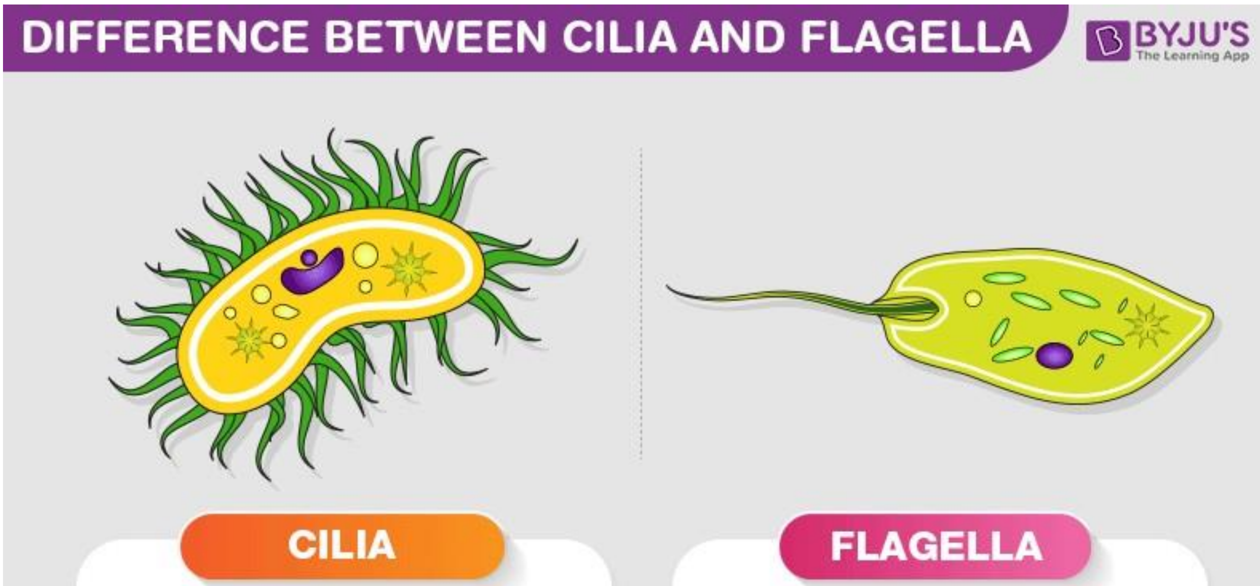
Appendages on Cell membrane

1- **Cilia -** short, hairlike, motile cellular extensions that occur on the surfaces of certain cells; ex. **some protozoa (called Ciliates) use cilia for motility & feeding.**
2- **Flagella** - in humans, the single, long, hairlike cellular extension that occurs in sperm cells; beat in waves (prokaryotic flagella rotate!); **some protozoans use flagella for motility.**

Cilia and flagella are cell organelles that are structurally similar but different in the length and functions. Cilia are present in organisms such as paramecium while flagella can be found in bacteria and sperm cells. Cilia are shorter and numerous than flagella. **The difference between cilia and flagella are summarized below:**

Difference Between Cilia And Flagella

Cilia	Flagella
The number of cilia is comparatively more (typically ranges in the thousands)	The number of flagella is comparatively less (usually ranges from 1 to 8)
Cilia is usually shorter in length	Flagella is comparatively longer in length
Beating pattern of cilia is very complicated – Can move in a wide range of motions	Beating pattern of Flagella involves circular, wave-like or propeller-like motion
Found in Eukaryotic cells	Found in prokaryotic cells and eukaryotic cells
Cilia are of two types: Non-motile cilia and Motile cilia	Flagella are of three types: Bacterial flagella, Archaeal flagella and Eukaryotic flagella



3- **Stereocilia**: are also organelle of cells, but typically of hair cells. Because it is mechano-sensing function, these are present in the inner ear, epididymis and ductus deferens.
4- **Microvilli**: is the protrusions of cellular membrane in eukaryotic cells. The role of Microvilli is to facilitate cellular adhesion, secretion, absorption and mechanco-transduction. These are non-motile organelle and present in the sensory organs like nose, mouth and ears.

Lecture 6

cellular organelles

We will now look at the key organelles that make up the cell. It is important to bear in mind that structure and function are closely related in all living systems.

Cytoplasm

The cytoplasm is the jelly-like substance that fills the cell. It consists of up to 90% water. It also contains dissolved nutrients and waste products. Its main function is to hold together the organelles which make up the cytoplasm. It also nourishes the cell by supplying it with salts and sugars and provides a medium for metabolic reactions to occur.

All the contents of prokaryotic cells are contained within the cytoplasm. In eukaryotic cells, all the organelles are contained within the cytoplasm except the nucleolus which is contained within the nucleus.

Functions of the cytoplasm

1- **The cytoplasm provides mechanical support** to the cell by exerting pressure against the cell's membrane which helps keep the shape of the cell. This pressure is known as **turgor pressure**.

2- **It is the site of most cellular activities** including metabolism, cell division and protein synthesis.

3- **The cytoplasm contains ribosomes** which assist in the synthesis of protein.

4- **The cytoplasm acts a storage** area for small carbohydrate, lipid and protein molecules.

5- **The cytoplasm suspends and can transport organelles around the cell**.

Type of cellular organelles

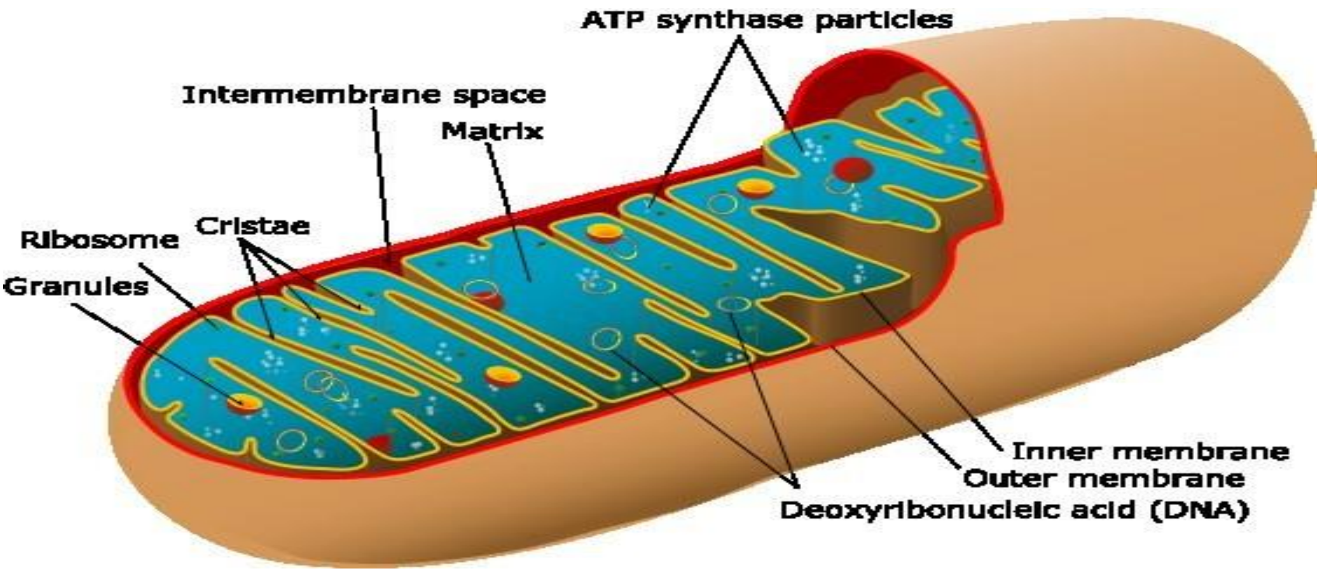
Mitochondria

A mitochondrion is a membrane bound organelle found in eukaryotic cells. This organelle generates the cell's supply of chemical energy by releasing energy stored in molecules from food and using it to produce ATP (adenosine triphosphate). ATP is a special type of "energy carrying" molecule.

Structure and function of the mitochondrion

Mitochondria contain two phospholipid bilayers: there is an outer membrane, and an inner membrane. The inner membrane contains many folds called cristae which contain specialised membrane proteins that enable the mitochondria to synthesise ATP. Inside the inner membrane is a jelly-like matrix. Listed from the outermost layer to the innermost compartment, the compartments of the mitochondrion, are:

1- Outer mitochondrial membrane
2- Intermembrane space
3- Inner mitochondrial membrane
4- Cristae (folds of the inner membrane)
5- matrix (jelly-like substance within the inner membrane)



The table below relates each structure to its function.

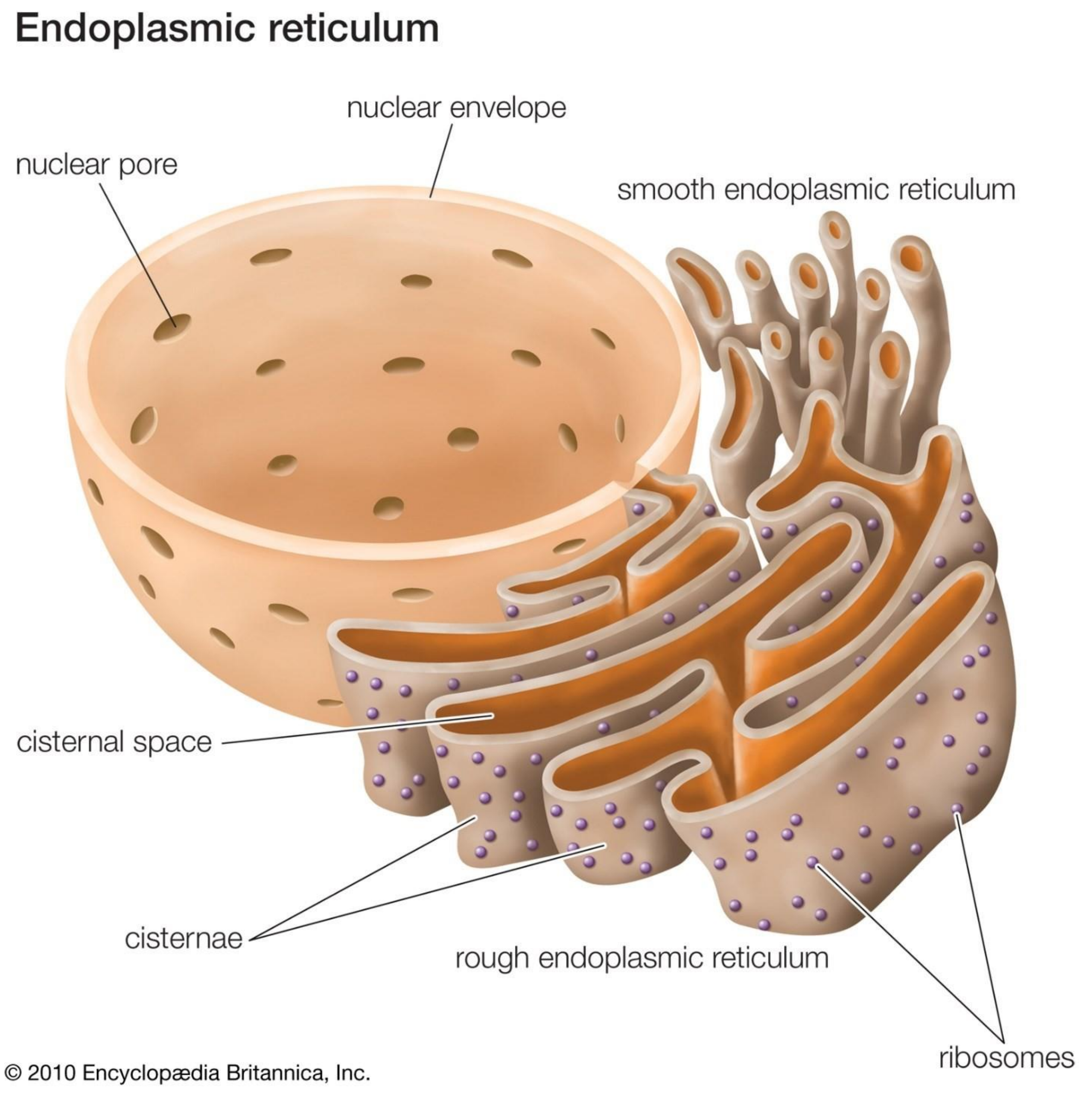
Structure	Function	Adaptation to function
Outer mitochondrial membrane	Transfer of nutrients (e.g lipids) to mitochondrion.	Has large number of channels to facilitate transfer of molecules.
Intermembrane space	Stores large proteins allowing for cellular respiration.	Its position between two selectively permeable membranes allows it to have a unique composition compared to the cytoplasm and the matrix.
Inner membrane	Stores membrane proteins that allow for energy production.	Contains folds known as *cristae* which provide increased surface area, thus enabling production of ATP (chemical potential energy).
Matrix	Contains enzymes that allow for the production of ATP (energy).	The matrix is contains a high quantity of protein enzymes which allow for ATP production.

Endoplasmic reticulum

The endoplasmic reticulum (ER) is an organelle found in eukaryotic cells only. The ER has a double membrane consisting of a network of hollow tubes, flattened sheets, and round sacs. These flattened, hollow folds and sacs are called cisternae. The ER is located in the cytoplasm and is connected to the nuclear envelope. There are two types of endoplasmic reticulum: smooth and rough ER.

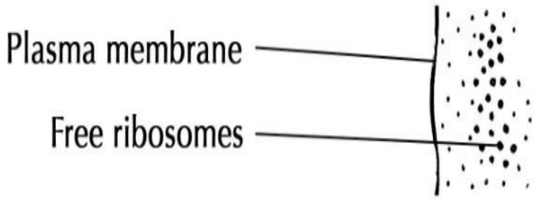
Smooth ER: **does not have any ribosomes attached**. It is involved in the synthesis of lipids, including oils, phospholipids and steroids. It is also responsible for metabolism of carbohydrates, regulation of calcium concentration and detoxification of drugs.

Rough ER: is covered with **ribosomes** giving the endoplasmic reticulum its rough appearance. **It is responsible for protein synthesis** and plays a role in membrane production. The folds present in the membrane increase the surface area allowing more ribosomes to be present on the ER, thereby allowing greater protein production.



Ribosomes

Ribosomes are composed of **RNA and protein**. They occur in the cytoplasm and are the sites where protein synthesis occurs. Ribosomes may occur singly in the cytoplasm or in groups or may be attached to the endoplasmic reticulum thus forming the rough endoplasmic reticulum. Ribosomes are important for protein production. Together with a structure known as messenger RNA (a type of nucleic acid) ribosomes form a structure known as a **polyribosome** which is important in protein synthesis.

Diagram: Free Ribosome	**Diagram**: Polyribosome
 *Figure 2.23: Free ribosomes found within cytoplasm.*	 *Figure 2.24: Diagram of several ribosomes joined together on a strand of mRNA to form a polyribosome.*

Golgi body

The Golgi body is found near the nucleus and endoplasmic reticulum. The Golgi body consists of a stack of flat membrane-bound sacs called cisternae. The cisternae within the Golgi body consist of enzymes which modify the packaged products of the Golgi body (proteins).

Functions of the Golgi body

It is important for proteins to be transported from where they are synthesised to where they are required in the cell. The organelle responsible for this is the Golgi Body. The Golgi body is the sorting organelle of the cell.

Proteins are transported from the rough endoplasmic reticulum (RER) to the Golgi. In the Golgi, proteins are modified and packaged into vesicle. The Golgi body therefore receives proteins made in one location in the cell and transfers these to another location within the cell where they are required. For this reason the Golgi body can be considered to be the 'post office' of the cell.

Lecture 7

cellular organelles

Vesicles and lysosomes

Vesicles are small, membrane-bound spherical sacs which facilitate the metabolism, transport and storage of molecules. Many vesicles are made in the Golgi body and the endoplasmic reticulum, or are made from parts of the cell membrane. Vesicles can be classified according to their contents and function. Transport vesicles transport molecules within the cell.

Lysosomes are formed by the Golgi body and contain powerful digestive enzymes that can potentially digest the cell. Lysosomes are formed by the Golgi body or the endoplasmic reticulum. These powerful enzymes can digest cell structures and food molecules such as carbohydrates and proteins. Lysosomes are abundant in animal cells that ingest food through food vacuoles. When a cell dies, the lysosome releases its enzymes and digests the cell.

Vacuoles

Vacuoles are membrane-bound, fluid-filled organelles that occur in the cytoplasm of most plant cells, but are very small or completely absent from animal cells. Plant cells generally have one large vacuole that takes up most of the cell's volume. A selectively permeable membrane called the **tonoplast**, surround the vacuole. The vacuole contains **cell sap** which is a liquid consisting of water, mineral salts, sugars and amino acids.

Functions of the vacuole

- The vacuole plays an important role in digestion and excretion of cellular waste and storage of water and organic and inorganic substances.
- The vacuole takes in and releases water by osmosis in response to changes in the cytoplasm, as well as in the environment around the cell.

- The vacuole is also responsible for maintaining the shape of plant cells. When the cell is full of water, the vacuole exerts pressure outwards, pushing the cell membrane against the cell wall. This pressure is called turgor pressure.
- If there is not sufficient water, pressure exerted by the vacuole is reduced and the cells become flaccid causing the plant to wilt.

Centrioles

Animal cells contain a special organelle called a centriole. The centriole is a cylindrical tube-like structure that is composed of 9 microtubules arranged in a very particular pattern. Two centrioles arranged perpendicular to each other are referred to as a **centrosome**. The centrosome plays a very important role in cell division. The centrioles are responsible for organising the microtubules that position the chromosomes in the correct location during cell division.

Plastids

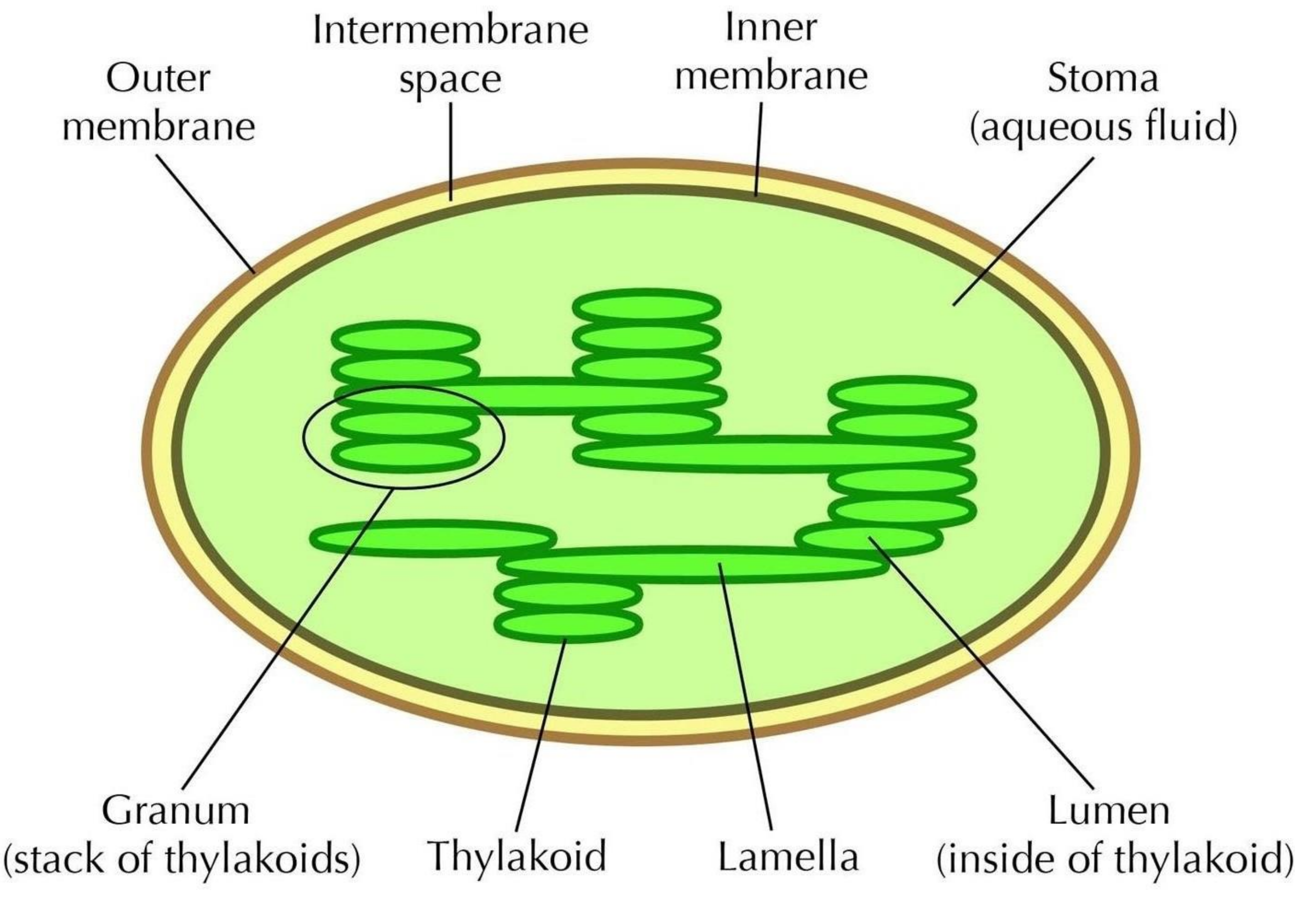
Plastids are organelles found only in plants. There are three different types:

1. **Leucoplasts**: White plastids found in roots.
2. **Chloroplasts**: Green-coloured plastids found in plants and algae.
3. **Chromoplasts**: Contain red, orange or yellow pigments and are common in ripening fruit, flowers or autumn leaves.

Chloroplast

The chloroplast is a double-membraned organelle. Within the double membrane is a gel-like substance called stroma. Stroma contains enzymes for photosynthesis.

Suspended in the stroma are stack-like structures called grana (singular = granum). Each granum is a stack of thylakoid discs. The chlorophyll molecules (green pigments) are found on the surface of the thylakoid discs. Chlorophyll absorbs energy from the sun in order for photosynthesis to take place in the chloroplasts. The grana are connected by lamellae (intergrana). The lamellae keep the stacks apart from each other. The structure of the chloroplast is neatly adapted to its function of trapping and storing energy in plants. For example, chloroplasts contain a high density of thylakoid discs and numerous grana to allow for increased surface area for the absorption of sunlight, thus producing a high quantity of food for the plant. Additionally, the lamellae keeping the thylakoids apart maximise chloroplast efficiency, thus allowing as much light as possible to be absorbed in the smallest surface area.



The differences between plant and animal cells

There are key differences between plant and animal cells. The table below summarises these differences.

Animal Cells	Plant Cells
Do not contain plastids.	Almost all plants cells contain plastids such chloroplasts, chromoplasts and leucoplasts.
No cell wall.	Have a rigid cellulose cell wall in addition to the cell membrane.
Contain centrioles.	Do not contain centrioles.
Animals do not have plasmodesmata or pits.	Contain plasmodesmata and pits.
Few vacuoles (if any).	Large central vacuole filled with cell sap in mature cells.
Nucleus is generally found at the centre of the cytoplasm.	Nucleus is found near the edge of the cell.
No intercellular spaces found between the cells.	Large intercellular air spaces found between some cells.

Lecture 8

Nucleus

The nucleus is the largest organelle in the cell and contains all the cell's genetic information in the form of DNA. The presence of a nucleus is the primary factor that distinguishes eukaryotes from prokaryotes. The structure of the nucleus is described below:

Nuclear envelope: two lipid membranes that are studded with special proteins that separates the nucleus and its contents from the cytoplasm.

Nuclear pores: tiny holes called nuclear pores are found in the nuclear envelope and help to regulate the exchange of materials (such as RNA and proteins) between the nucleus and the cytoplasm.

Chromatin: thin long strands of DNA and protein.

Nucleolus: the nucleolus makes RNA another type of nucleic acid.

During cell division, DNA contracts and folds to form distinct structures called chromosomes. The chromosomes are formed at the start of cell division.

The genetic material of eukaryotic organisms is separated from the cytoplasm by a membrane whereas the genetic material of prokaryotic organisms (like bacteria) is in direct contact with the cytoplasm.

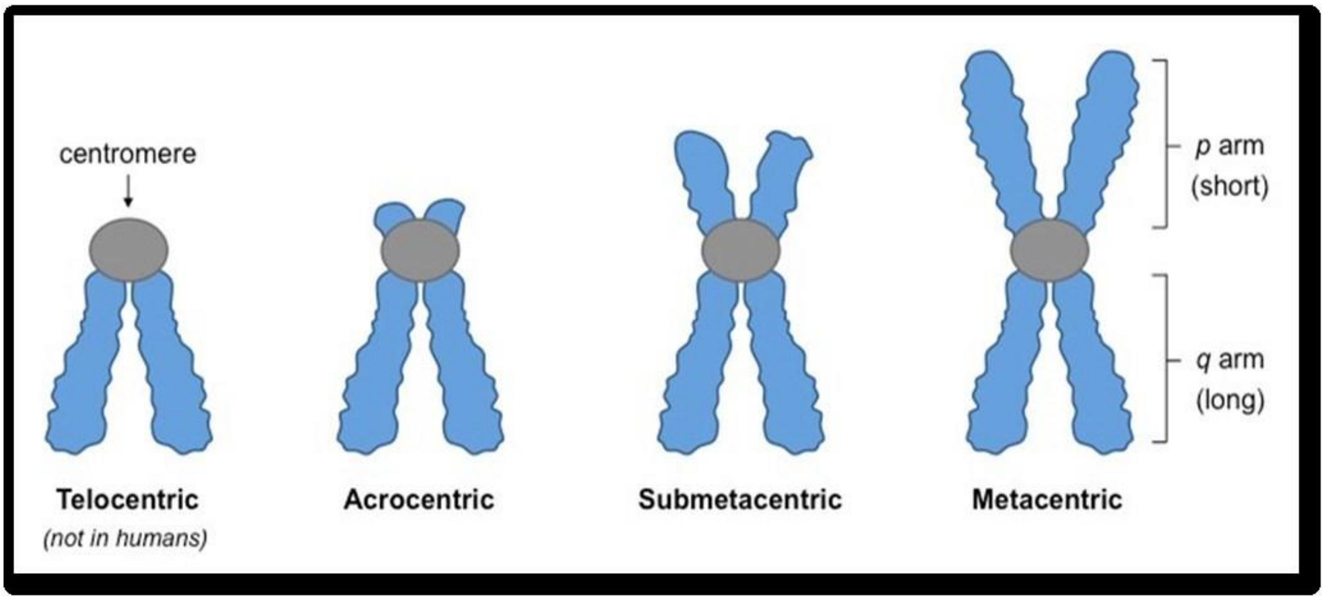
Chromosome part

1- **Telomeres:** the tips part of chromosome
2- **Centromeres:** middle part of chromosome, in this region the spindle fibers attach.
3- **p arm:** the smaller of the two arms
4- **q arm:** the longer of two arms

Chromosome types:

The centromere can be located in different positions and this forms the basis for the four different classes of chromosome:

1. **Metacentric:** centromere is in middle, meaning *p* and *q* arms are of comparable length (e.g. chromosomes 1, 3, 16, 19, 20)
2. **Submetacentric:** centromere off-centre, leading to shorter *p* arm relative to *q* arm (e.g. chromosomes 2, 4 - 12, 17, 18, X)
3. **Acrocentric:** centromere severely off-set from centre, leading to much shorter *p* arm (e.g. chromosomes 13 - 15, 21, 22, Y)
4. **Telocentric:** centromere found at end of chromosome, meaning no *p* armexists (chromosome not found in humans)



Cell cycle

Is the series of events that take place in a cell leading to its division and duplication of its DNA (DNA replication) to produce two daughter cells.

Cell cycle Phases

The cell cycle consists of four distinct phases:

- **G1 phase.** Metabolic changes prepare the cell for division. Cells increase in size in Gap 1. The G_1 *checkpoint* control mechanism ensures that everything is ready for DNA synthesis.
- **S phase**. DNA replication occurs during this phase.. Each chromosome now consists of two sister chromatids.
- **G2 phase.** During the gap between DNA synthesis and mitosis, the cell will continue to grow. The G_2 *checkpoint* control mechanism ensures that everything is ready to enter the M (mitosis) phase and divide.
- **M phase.** A nuclear division (mitosis) followed by a cell division (cytokinesis).