Biyani's Think Tank

Concept based notes

Cell Biology & Genetics

[B.Sc. Part-I]

Shikha Mathur
and
Abhilasha sharma
Lecturer
Deptt. of Science
Biyani Girls College, Jaipur

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Sector-3, Vidhyadhar Nagar,
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Ph : 0141-2338371, 2338591-95 Fax : 0141-2338007
E-mail : acad@biyanicolleges.org
Website :www.gurukpo.com; www.biyanicolleges.org

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Preface

I am glad to present this book, especially designed to serve the needs of the students. The book has been written keeping in mind the general weakness in understanding the fundamental concepts of the topics. The book is self-explanatory and adopts the "Teach Yourself" style. It is based on question-answer pattern. The language of book is quite easy and understandable based on scientific approach.

Any further improvement in the contents of the book by making corrections, omission and inclusion is keen to be achieved based on suggestions from the readers for which the author shall be obliged.

I acknowledge special thanks to Mr. Rajeev Biyani, *Chairman* & Dr. Sanjay Biyani, *Director* (*Acad.*) Biyani Group of Colleges, who are the backbones and main concept provider and also have been constant source of motivation throughout this Endeavour. They played an active role in coordinating the various stages of this Endeavour and spearheaded the publishing work.

I look forward to receiving valuable suggestions from professors of various educational institutions, other faculty members and students for improvement of the quality of the book. The reader may feel free to send in their comments and suggestions to the under mentioned address.

Author

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Section A

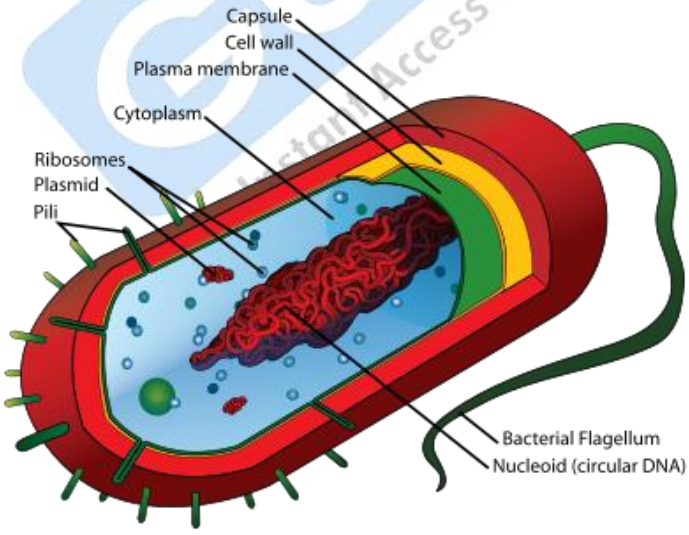
Cell Structure

Q-1 Write down about structure and function of the animal cell.

Ans. The cell is the basic structural and functional unit of all known living organisms. It is the smallest unit of life that is classified as a living thing, and is often called the building block of life. Organisms can be classified as unicellular (consisting of a single cell; including most bacteria) or multicellular (including plants and animals). Humans contain about 10 trillion (10^{13}) cells. Most plant and animal cells are between 1 and 100 µm and therefore are visible only under the microscope.

The word *cell* comes from the Latin *cellula*, meaning "a small room". The descriptive term for the smallest living biological structure was coined by Robert Hooke in a book he published in 1665 when he compared the cork cells he saw through his microscope to the small rooms monks lived in.

Prokaryotic cells



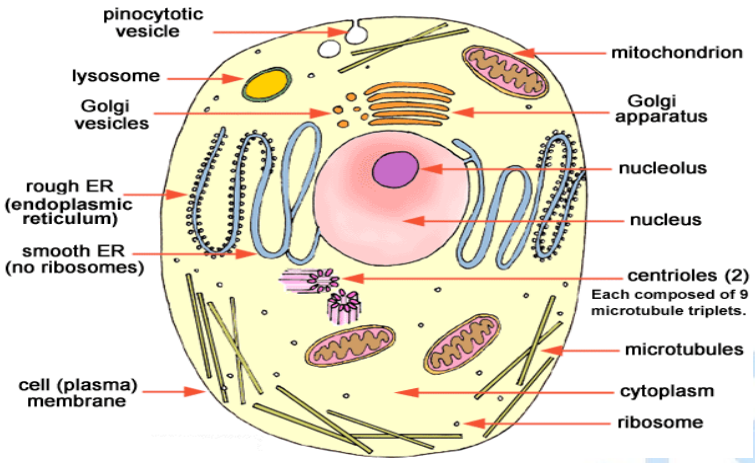
The prokaryote cell is simpler, and therefore smaller, than a eukaryote cell, lacking a nucleus and most of the other organelles of eukaryotes. There are two kinds of prokaryotes: bacteria and archaea; these share a similar structure.

Nuclear material of prokaryotic cell consist of a single chromosome that is in direct contact with cytoplasm. Here, the undefined nuclear region in the cytoplasm is called nucleoid.

A prokaryotic cell has three architectural regions:

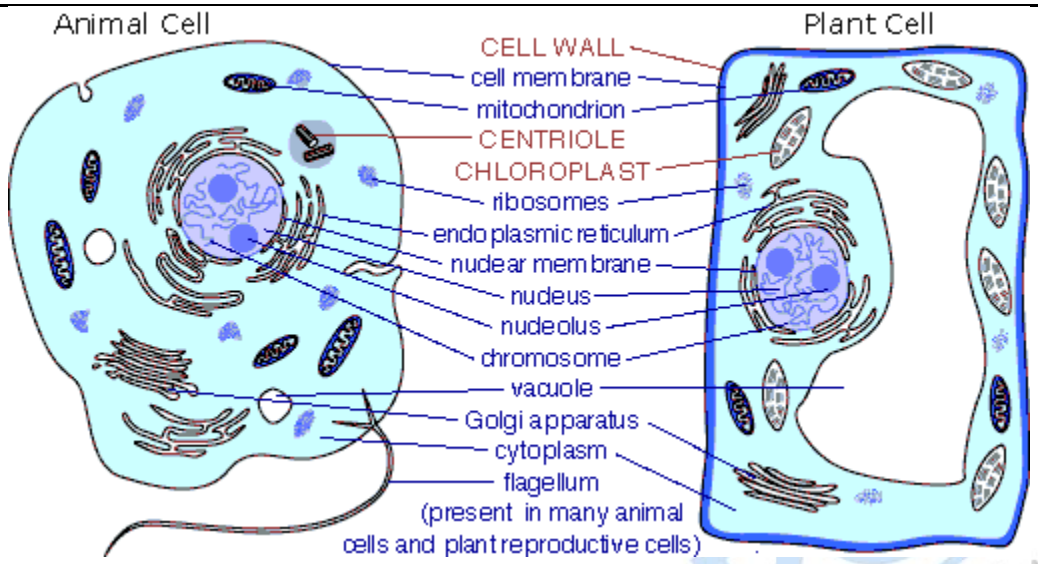
- On the outside, flagella and pili project from the cell's surface. These are structures (not present in all prokaryotes) made of proteins that facilitate movement and communication between cells;
- Enclosing the cell is the cell envelope – generally consisting of a cell wall covering a plasma membrane though some bacteria also have a further covering layer called a capsule. The envelope gives rigidity to the cell and separates the interior of the cell from its environment, serving as a protective filter. Though most prokaryotes have a cell wall, there are exceptions such as *Mycoplasma* (bacteria) and *Thermoplasma* (archaea). The cell wall consists of *peptidoglycan* in bacteria, and acts as an additional barrier against exterior forces. It also prevents the cell from expanding and finally bursting (cytolysis) from osmotic pressure against a hypotonic environment. Some eukaryote cells (plant cells and fungi cells) also have a cell wall;
- Inside the cell is the cytoplasmic region that contains the cell genome (DNA) and ribosomes and various sorts of inclusions. A prokaryotic chromosome is usually a circular molecule (an exception is that of the bacterium *Borrelia burgdorferi*, which causes Lyme disease). Though not forming a *nucleus*, the DNA is condensed in a *nucleoid*. Prokaryotes can carry extrachromosomal DNA elements called *plasmids*, which are usually circular. Plasmids enable additional functions, such as antibiotic resistance.

Eukaryotic cells



Plants, animals, fungi, slime moulds, protozoa, & algae are all Eukaryotic. These cells are about 15 times wider than a typical prokaryote and can be as much as 1000 times greater in volume. The major difference between prokaryotes and eukaryotes is that eukaryotic cells contain membrane-bound compartments in which specific metabolic activities take place. Most important among these is a cell nucleus, a membrane-delineated compartment that houses the eukaryotic cell's DNA. This nucleus gives the eukaryote its name, which means "true nucleus." Other differences include:

- The plasma membrane resembles that of prokaryotes in function, with minor differences in the setup. Cell walls may or may not be present.
- The eukaryotic DNA is organized in one or more linear molecules, called chromosomes, which are associated with histone proteins. All chromosomal DNA is stored in the *cell nucleus*, separated from the cytoplasm by a membrane. Some eukaryotic organelles such as mitochondria also contain some DNA.
- Many eukaryotic cells are ciliated with *primary cilia*. Primary cilia play important roles in chemosensation, mechanosensation, and thermosensation. Cilia may thus be "viewed as sensory cellular antennae that coordinate a large number of cellular signaling pathways, sometimes coupling the signaling to ciliary motility or alternatively to cell division and differentiation."[5]
- Eukaryotes can move using *motile cilia* or *flagella*. The flagella are more complex than those of prokaryotes.



Structure of a typical plant cell

Table 2: Comparison of structures between animal and plant cells

	Typical animal cell	Typical plant cell

Organelles	• Nucleus
	  ○ Nucleolus (within nucleus)
	• Rough endoplasmic reticulum (ER)
	• Smooth ER
	• Ribosomes
	• Cytoskeleton
	• Golgi apparatus
	• Cytoplasm
	• Mitochondria
	• Vesicles
	• Lysosomes
	• Centrosome
	  ○ Centrioles
		• Nucleus
		  ○ Nucleolus (within nucleus)
		• Rough ER
		• Smooth ER
		• Ribosomes
		• Cytoskeleton
		• Golgi apparatus (dictiosomes)
		• Cytoplasm
		• Mitochondria
		• Plastids and its derivatives
		• Vacuole(s)
		• Cell wall

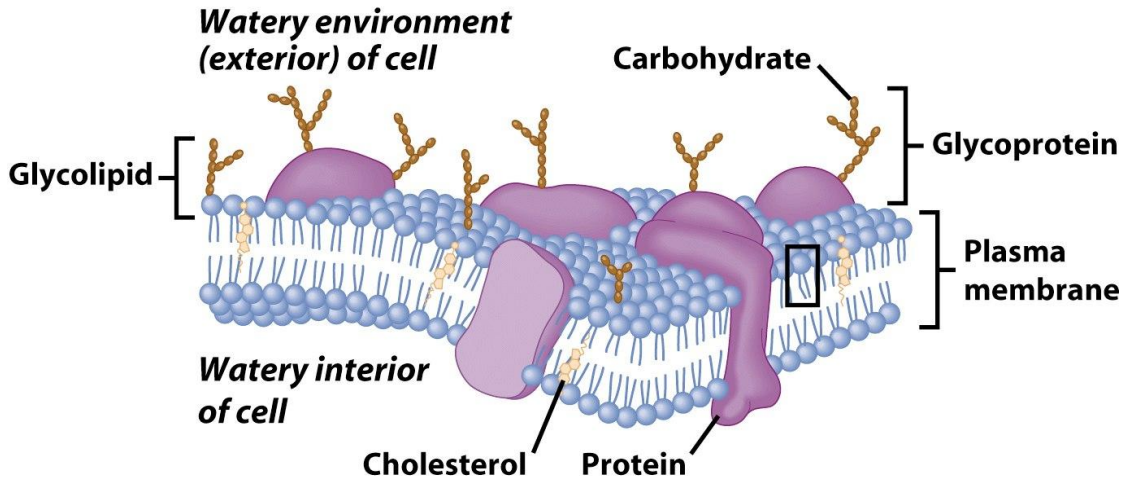
Subcellular components

All cells, whether prokaryotic or eukaryotic, have a membrane that envelops the cell, separates its interior from its environment, regulates what moves in and out (selectively permeable), and maintains the electric potential of the cell. Inside the membrane, a salty cytoplasm takes up most of the cell volume. All cells possess

DNA, the hereditary material of genes, and RNA, containing the information necessary to build various proteins such as enzymes, the cell's primary machinery. There are also other kinds of biomolecules in cells. This article lists these primary components of the cell, then briefly describe their function.

Membrane

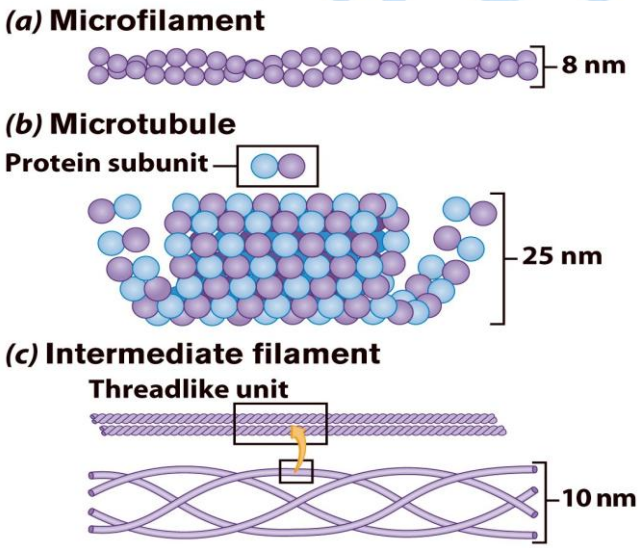
The cytoplasm of a cell is surrounded by a cell membrane or *plasma membrane*. The plasma membrane in plants and prokaryotes is usually covered by a cell wall. This membrane serves to separate and protect a cell from its surrounding environment and is made mostly from a double layer of lipids (hydrophobic fat-like molecules) and hydrophilic phosphorus molecules. Hence, the layer is called a phospholipid bilayer. It may also be called a fluid mosaic membrane. Embedded within this membrane is a variety of protein molecules that act as channels and pumps that move different molecules into and out of the cell. The membrane is said to be 'semi-permeable', in that it can either let a substance (molecule or ion) pass through freely, pass through to a limited extent or not pass through at all. Cell surface membranes also contain receptor proteins that allow cells to detect external signaling molecules such as hormones.



Cytoskeleton

Bovine Pulmonary Artery Endothelial cell: nuclei stained blue, mitochondria stained red, and F-actin, an important component in microfilaments, stained green. Cell imaged on a fluorescent microscope.

The cytoskeleton acts to organize and maintain the cell's shape; anchors organelles in place; helps during endocytosis, the uptake of external materials by a cell, and cytokinesis, the separation of daughter cells after cell division; and moves parts of the cell in processes of growth and mobility. The eukaryotic cytoskeleton is composed of microfilaments, intermediate filaments and microtubules. There is a great number of proteins associated with them, each controlling a cell's structure by directing, bundling, and aligning filaments. The prokaryotic cytoskeleton is less well-studied but is involved in the maintenance of cell shape, polarity and cytokinesis.[6]



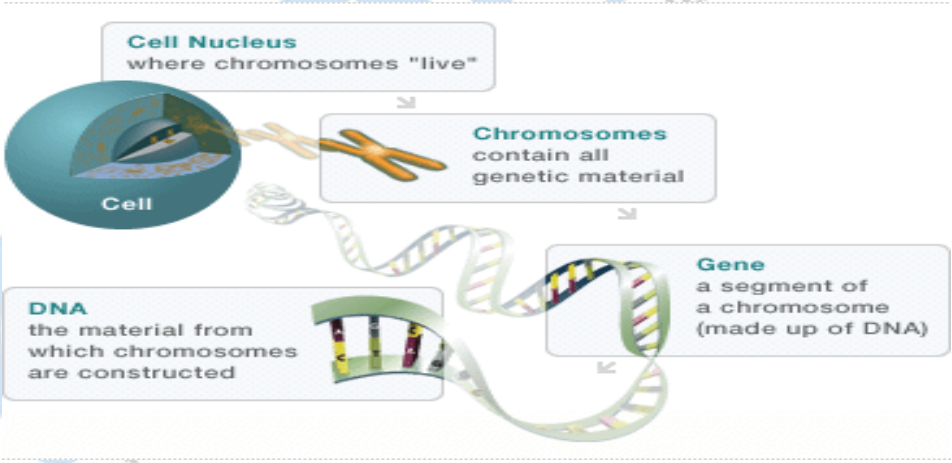
Genetic material

Two different kinds of genetic material exist: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Most organisms use DNA for their long-term information storage, but some viruses (e.g., retroviruses) have RNA as their genetic material. The biological information contained in an organism is encoded in its DNA or RNA sequence. RNA is also used for information transport (e.g., mRNA) and enzymatic functions (e.g., ribosomal RNA) in organisms that use DNA for the genetic code itself. Transfer RNA (tRNA) molecules are used to add amino acids during protein translation.

Prokaryotic genetic material is organized in a simple circular DNA molecule (the bacterial chromosome) in the nucleoid region of the cytoplasm. Eukaryotic genetic material is divided into different, linear molecules called chromosomes inside a discrete nucleus, usually with additional genetic material in some organelles like mitochondria and chloroplasts (see endosymbiotic theory).

A human cell has genetic material contained in the cell nucleus (the nuclear genome) and in the mitochondria (the mitochondrial genome). In humans the nuclear genome is divided into 23 pairs of linear DNA molecules called chromosomes. The mitochondrial genome is a circular DNA molecule distinct from the nuclear DNA. Although the mitochondrial DNA is very small compared to nuclear chromosomes, it codes for 13 proteins involved in mitochondrial energy production and specific tRNAs.

Foreign genetic material (most commonly DNA) can also be artificially introduced into the cell by a process called transfection. This can be transient, if the DNA is not inserted into the cell's genome, or stable, if it is. Certain viruses also insert their genetic material into the genome.

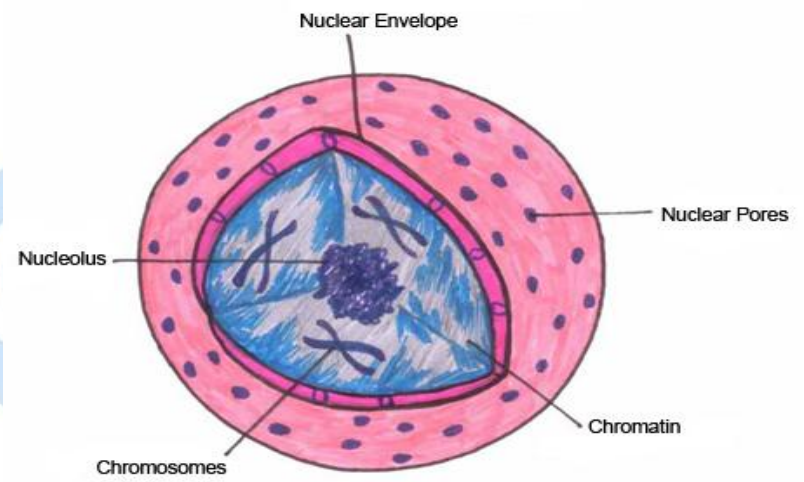


Organelles

The human body contains many different organs, such as the heart, lung, and kidney, with each organ performing a different function. Cells also have a set of "little organs," called organelles, that are adapted and/or specialized for carrying out one or more vital functions. Both eukaryotic and prokaryotic cells have organelles but organelles in eukaryotes are generally more complex and may be membrane bound.

There are several types of organelles in a cell. Some (such as the nucleus and golgi apparatus) are typically solitary, while others (such as mitochondria, peroxisomes and lysosomes) can be numerous (hundreds to thousands). The cytosol is the gelatinous fluid that fills the cell and surrounds the organelles.

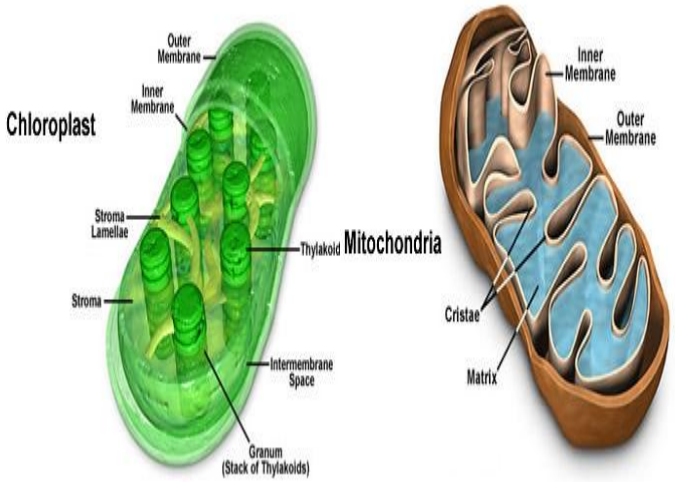
- **Cell nucleus** – eukaryotes only - A cell's information center, the cell nucleus is the most conspicuous organelle found in a eukaryotic cell. It houses the cell's chromosomes, and is the place where almost all DNA replication and RNA synthesis (transcription) occur. The nucleus is spherical and separated from the cytoplasm by a double membrane called the nuclear envelope. The nuclear envelope isolates and protects a cell's DNA from various molecules that could accidentally damage its structure or interfere with its processing. During processing, DNA is transcribed, or copied into a special RNA, called messenger RNA (mRNA). This mRNA is then transported out of the nucleus, where it is translated into a specific protein molecule. The nucleolus is a specialized region within the nucleus where ribosome subunits are assembled. In prokaryotes, DNA processing takes place in the cytoplasm.



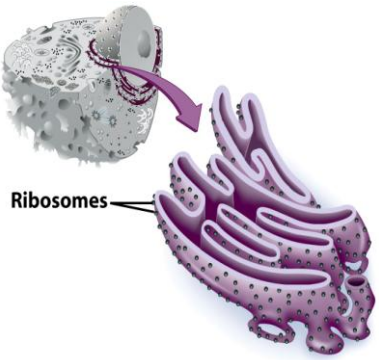
Cell Nucleus Diagram

- **Mitochondria and Chloroplasts** – eukaryotes only - the power generators: Mitochondria are self-replicating organelles that occur in various numbers, shapes, and sizes in the cytoplasm of all eukaryotic cells. Mitochondria play a critical role in generating energy in the eukaryotic cell. Mitochondria generate

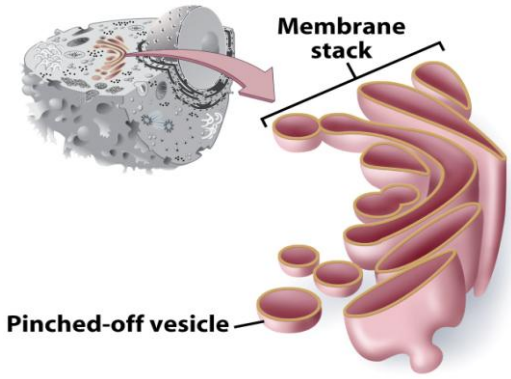
the cell's energy by oxidative phosphorylation, using oxygen to release energy stored in cellular nutrients (typically pertaining to glucose) to generate ATP. Mitochondria multiply by splitting in two. Respiration occurs in the cell mitochondria.



- **Endoplasmic reticulum** – eukaryotes only: The endoplasmic reticulum (ER) is the transport network for molecules targeted for certain modifications and specific destinations, as compared to molecules that float freely in the cytoplasm. The ER has two forms: the rough ER, which has ribosomes on its surface and secretes proteins into the cytoplasm, and the smooth ER, which lacks them. Smooth ER plays a role in calcium sequestration and release.

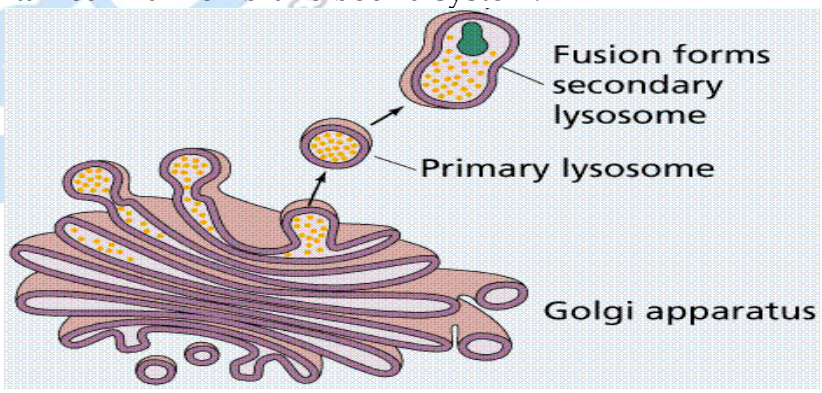


- **Golgi apparatus** – eukaryotes only : The primary function of the Golgi apparatus is to process and package the macromolecules such as proteins and lipids that are synthesized by the cell.



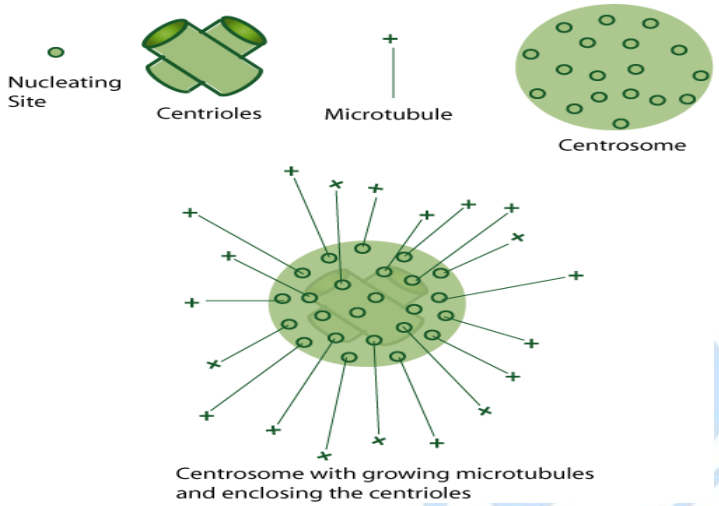
- **Ribosomes**: The ribosome is a large complex of RNA and protein molecules. They each consist of two subunits, and act as an assembly line where RNA from the nucleus is used to synthesise proteins from amino acids. Ribosomes can be found either floating freely or bound to a membrane (the rough endoplasmatic reticulum in eukaryotes, or the cell membrane in prokaryotes).

- **Lysosomes and Peroxisomes** – eukaryotes only: Lysosomes contain digestive enzymes (acid hydrolases). They digest excess or worn-out organelles, food particles, and engulfed viruses or bacteria. Peroxisomes have enzymes that rid the cell of toxic peroxides. The cell could not house these destructive enzymes if they were not contained in a membrane-bound system.



- **Centrosome** – the cytoskeleton organiser: The centrosome produces the microtubules of a cell – a key component of the cytoskeleton. It directs the transport through the ER and the Golgi apparatus. Centrosomes are composed of two centrioles, which separate during cell division and help in the formation of

the mitotic spindle. A single centrosome is present in the animal cells. They are also found in some fungi and algae cells.



- **Vacuoles**: Vacuoles store food and waste. Some vacuoles store extra water. They are often described as liquid filled space and are surrounded by a membrane. Some cells, most notably *Amoeba*, have contractile vacuoles, which can pump water out of the cell if there is too much water. The vacuoles of eukaryotic cells are usually larger in those of plants than animals.

Structures outside the cell membrane

Many cells also have structures which exist wholly or partially outside the cell membrane. These structures are notable because they are not protected from the external environment by the impermeable cell membrane. In order to assemble these structures export processes to carry macromolecules across the cell membrane must be used.

Cell wall

Many types of prokaryotic and eukaryotic cell have a cell wall. The cell wall acts to protect the cell mechanically and chemically from its environment, and is an additional layer of protection to the cell membrane. Different types of cell have cell walls made up of different materials; plant cell walls are primarily made up of pectin, fungi cell walls are made up of chitin and bacteria cell walls are made up of peptidoglycan.

Prokaryotic

Capsule

A gelatinous capsule is present in some bacteria outside the cell membrane and cell wall. The capsule may be polysaccharide as in pneumococci, meningococci or polypeptide as *Bacillus anthracis* or hyaluronic acid as in streptococci. Capsules are not marked by normal staining protocols and can be detected by special stain.

Flagella

Flagella are organelles for cellular mobility. The bacterial flagellum stretches from cytoplasm through the cell membrane(s) and extrudes through the cell wall. They are long and thick thread-like appendages, protein in nature. Are most commonly found in bacteria cells but are found in animal cells as well.

Fimbriae (pili)

They are short and thin hair like filaments, formed of protein called pilin (antigenic). Fimbriae are responsible for attachment of bacteria to specific receptors of human cell (adherence). There are special types of pili called (sex pili) involved in conjunction.[*citation needed*]

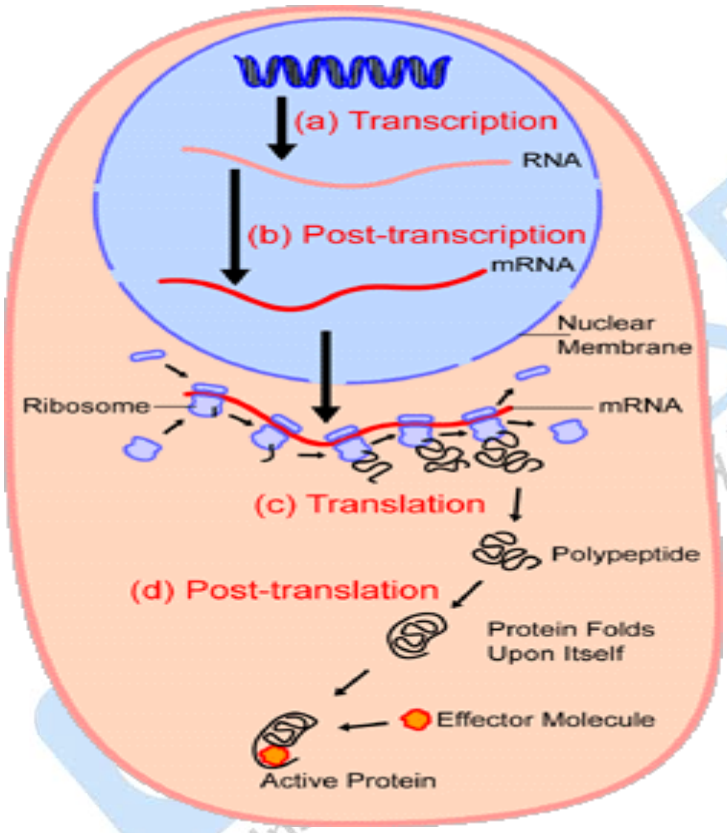
Functions

Growth and metabolism

Between successive cell divisions, cells grow through the functioning of cellular metabolism. Cell metabolism is the process by which individual cells process nutrient molecules. Metabolism has two distinct divisions: catabolism, in which the cell breaks down complex molecules to produce energy and reducing power, and anabolism, in which the cell uses energy and reducing power to construct complex molecules and perform other biological functions. Complex sugars consumed by the organism can be broken down into a less chemically complex sugar molecule called glucose. Once inside the cell, glucose is broken down to make adenosine triphosphate (ATP), a form of energy, through two different pathways.

The first pathway, glycolysis, requires no oxygen and is referred to as anaerobic metabolism. Each reaction is designed to produce some hydrogen ions that can then be used to make energy packets (ATP). In prokaryotes, glycolysis is the only method used for converting energy.

The second pathway, called the Krebs cycle, or citric acid cycle, occurs inside the mitochondria and can generate enough ATP to run all the cell functions.



An overview of protein synthesis.

Within the nucleus of the cell (*light blue*), genes (DNA, *dark blue*) are transcribed into RNA. This RNA is then subject to post-transcriptional modification and control, resulting in a mature mRNA (*red*) that is then transported out of the nucleus and into the cytoplasm (*peach*), where it undergoes translation into a protein. mRNA is translated by ribosomes (*purple*) that match the three-base codons of the mRNA to the three-base anti-codons of the appropriate tRNA. Newly synthesized proteins (*black*) are often further modified, such as by binding to an effector molecule (*orange*), to become fully active.

Creation

Cell division involves a single cell (called a *mother cell*) dividing into two daughter cells. This leads to growth in multicellular organisms (the growth of tissue) and to procreation (vegetative reproduction) in unicellular organisms.

Prokaryotic cells divide by binary fission. Eukaryotic cells usually undergo a process of nuclear division, called mitosis, followed by division of the cell, called cytokinesis. A diploid cell may also undergo meiosis to produce haploid cells, usually four. Haploid cells serve as gametes in multicellular organisms, fusing to form new diploid cells.

DNA replication, or the process of duplicating a cell's genome, is required every time a cell divides. Replication, like all cellular activities, requires specialized proteins for carrying out the job.

Protein synthesis

Cells are capable of synthesizing new proteins, which are essential for the modulation and maintenance of cellular activities. This process involves the formation of new protein molecules from amino acid building blocks based on information encoded in DNA/RNA. Protein synthesis generally consists of two major steps: transcription and translation.

Transcription is the process where genetic information in DNA is used to produce a complementary RNA strand. This RNA strand is then processed to give messenger RNA (mRNA), which is free to migrate through the cell. mRNA molecules bind to protein-RNA complexes called ribosomes located in the cytosol, where they are translated into polypeptide sequences. The ribosome mediates the formation of a polypeptide sequence based on the mRNA sequence. The mRNA sequence directly relates to the polypeptide sequence by binding to transfer RNA (tRNA) adapter molecules in binding pockets within the ribosome. The new polypeptide then folds into a functional three-dimensional protein molecule.

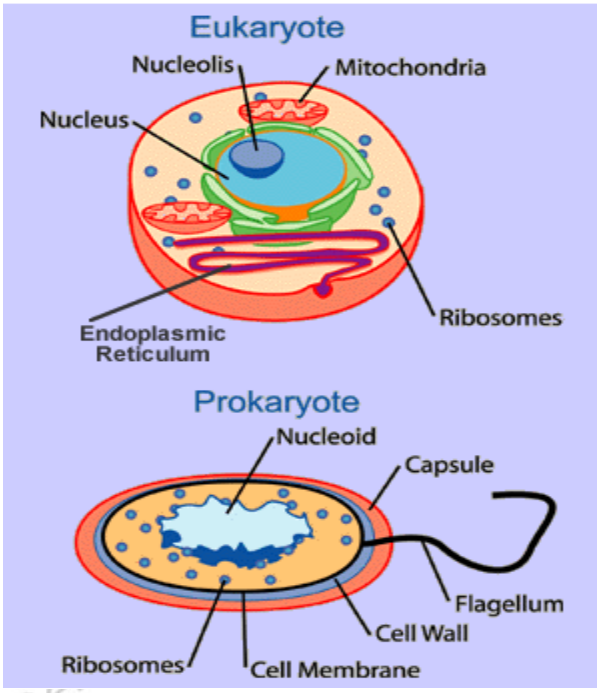
Movement or motility

Cells can move during many processes: such as wound healing, the immune response and cancer metastasis. For wound healing to occur, white blood cells and cells that ingest bacteria move to the wound site to kill the microorganisms that cause infection.

At the same time fibroblasts (connective tissue cells) move there to remodel damaged structures. In the case of tumor development, cells from a primary tumor move away and spread to other parts of the body. Cell motility involves many receptors, crosslinking, bundling, binding, adhesion, motor and other proteins.[8] The process is divided into three steps – protrusion of the leading edge of the cell, adhesion of the leading edge and de-adhesion at the cell body and rear, and cytoskeletal contraction to pull the cell forward. Each step is driven by physical forces generated by unique segments of the cytoskeleton.[9][10]

Q-3 Write down the difference between prokaryotic and eukaryotic cell

Ans.



Prokaryotic	Eukaryotic
Small cells (< 5um)	large cells (> 10um)
always unicellular	often multi cellular
no nucleus instead has a 'naked loop' called a nucleoid	always has nucleus with linear DNA (chromosomes) and histones
no membrane bound organelles	membrane bound organelles
ribosomes are small (70s) s = **svedberg** unit of measure of the size of organelles.	ribosomes are large (80s)
no mitochondria	mitochondria present
cell division by binary fission	cell division by mitosis or meiosis
reproduction mainly asexual however there are some non meiotic forms of gene exchange such as **conjugation**.	reproduction asexual or sexual
many metabolic pathways, fermentation, nitrogen fixation and photosynthesis.	common form of respiration involving organic molecules like sugar.

Cell Membrane

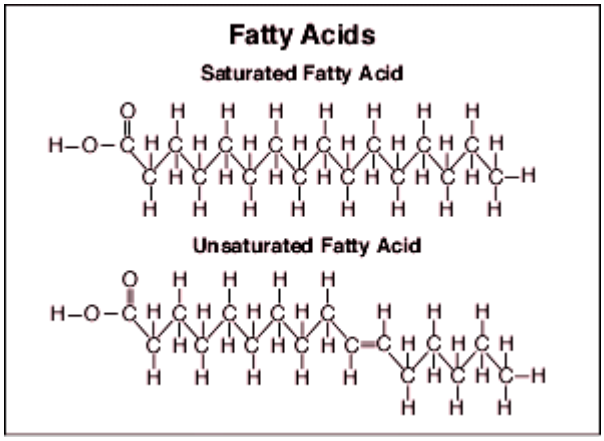
Q.1 Write down about structure and function of the cell membrane.

Ans. The cell membrane made-up of **lipids**, **proteins**, and **carbohydrates**.

Lipids

Lipid molecules are insoluble in water. Lipids are hydrophobic because the molecules consist of long, 18-22 carbon, hydrocarbon backbones with only a small amount of oxygen containing groups. Lipids are responsible for many functions in organisms. They are one of the major components of waxes, pigments, steroid hormones, and cell membranes. **Fats**, **steriods**, and **phospholipids** are very important in the functioning of cell membranes.

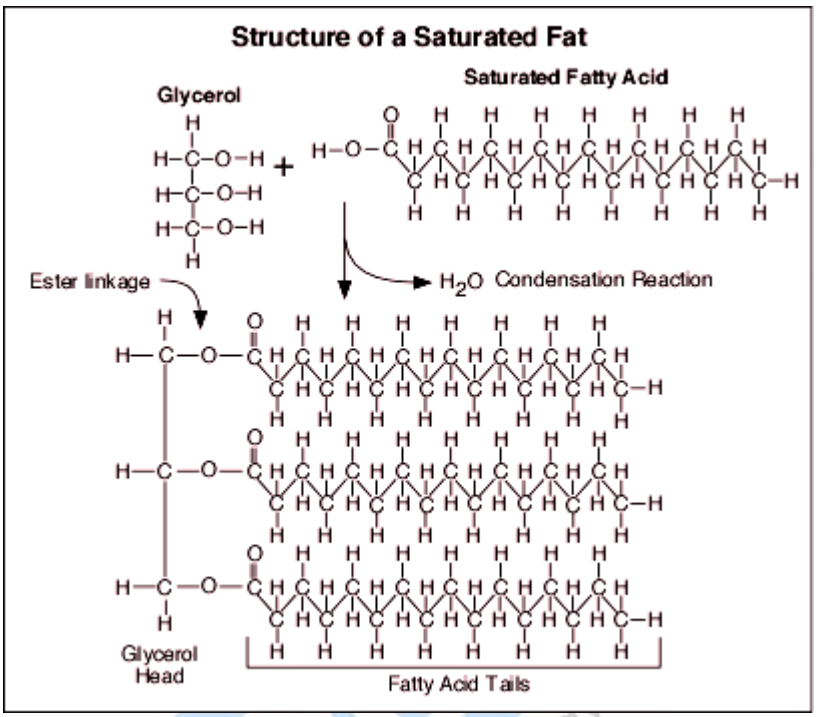
Fats (triacylglycerols)



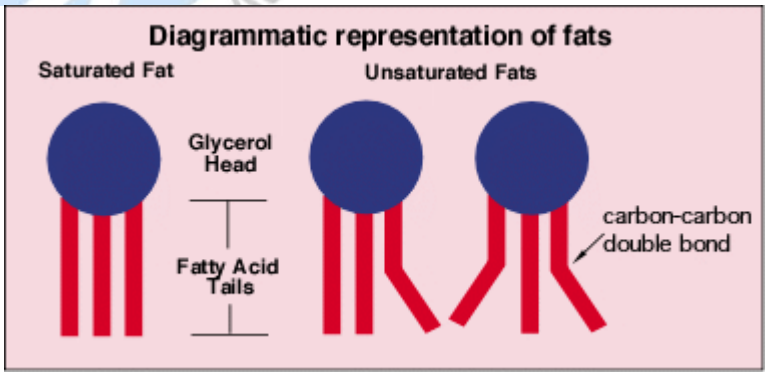
Two different classes of molecules are responsible for synthesis of fats:

Fatty acids attached to the alcohol **glycerol**. The fatty acids are long, unbranched hydrocardons that terminate with an acidic carboxyl group. The fatty acid can be of two types: **saturated** and **unsaturated**. **Saturated** fatty acids have no carbon-carbon double bonds (they are "saturated" with hydrogen) while the **unsaturated** fatty acids have one to four double bonds between adjacent carbon atoms. These double bonds introduce "kinks" in the carbon chain which has important consequences on the fluid nature of lipid membranes.To construct a **fat,** or **triacylglycerol**, three fatty acid molecules are attached to the glycerol through an

ester bond between the carboxyl group of the fatty acid and the three alcohol groups of a glycerol molecule.



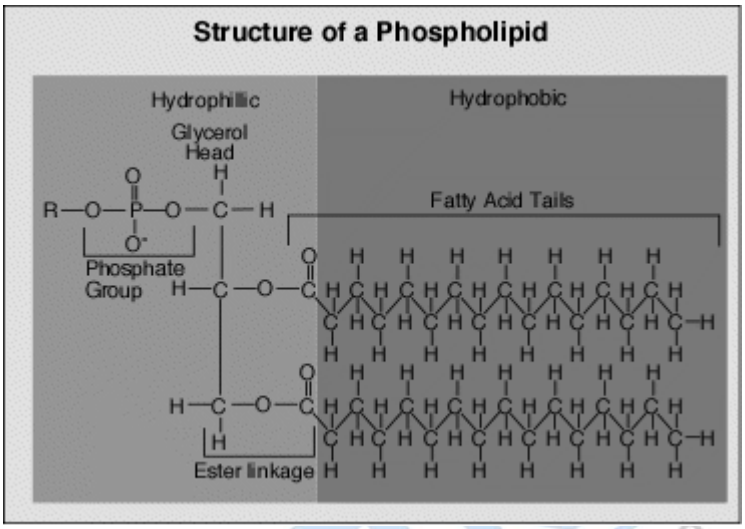
An **unsaturated** fat has at least one unsaturated fatty acid whereas a **saturated** fat has none. Becuase the double bond of the unsaturated fatty acid introduces kinks in the hydrocarbon backbone the fat will not pack into a regular structure and thus remain fluid at low temperatures. A saturated fat though will pack well and be a solid a low temperatures.



Fats play important role in energy storage and as insulating molecules. Per gram, fats contain twice as much energy as carbohydrates. Layers of fat also surround

the vital organs of animals to provide cushion them, insulation is also provide by layers of under the skin of animals.

Phospholipids



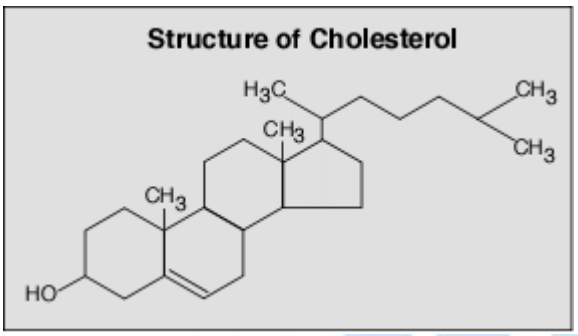
Phospholipids contain only two fatty acid tails attached to a glycerol head. This occurs by a condensation reaction similar to the one discussed above. The third alcohol group of the glycerol is attached to a phoshpate molecule. The phoshate group is then attached to other small moluecules such as choline. The phosphate group along with the glycerol group make the head of the phospholipid hydrophillic, whereas the fatty acid tail is hydrophobic. Thus phospholipids are **amphipatic**: water loving and water hating. When phospholipids are in an aqueous solution they will self assemble into **micelles** or **bilayers**, structures that exclude water molecules from the hydrophobic tails while keeping the hydrophillic head in contact with the aqueous solution.

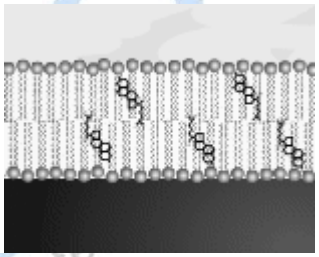
Phospholipids serve a major function in the cells of all organisms: they form the **phospholipid membranes** that surrounds the cell and intracellular structures such as the mitochondria. The cell membrane is a fluid, semi-permeable bilayer that seperates the cell's contents of from the environment, see animation below. The membrane is fluid at physiological temperatures and allows cells to change shape due to physical constraints or changing cellular volumes. The phospholipid membrane allows free difusion of some small molecules such as oxygen, carbon dioxide, and small hydrocarbons, but not water, charged ions, or other larger molecules such as glucose. This semi-permeable nature of the membrane allows

the cell to maintain the composition of the cytosol independent of the external environm

Steroids

The **steroids** are from lipid family and based on a molecule with four fused carbon rings. This plays an important role in many hormones of animals and cholesterol. **Cholesterol** is an important component of the cell membrane in animals and functions to maintain membrane fluidity becuase it prevents packing of the fatty acid tails.





The Fluid Quality of Membranes :

To keep the membrane fluid at physiological temperatures the cell alters the composition of the phospholipids. The right ratio of saturated to unsaturated fatty acids keeps the membrane fluid at any temperature conducive to life. For example winter wheat responds to decreasing temperatures by increasing the amount of unsaturated fatty acids in cell membranes. In animal cells cholesterol helps to prevent the packing of fatty acid tails and thus lowers the requiremnt of unsaturated fatty acids. This helps maintain the fluid nature of the cell membrane without it becomming too liquid at body temperature. The fluidity of the membrane is demonstrated in the following animation. The lipids in the membrane are in random bulk flow moving about 22 μm (micrometers) per second. Phospholipids freely move in the same layer of the membrane and rarely flip to the other layer. Flipping rarely occurs because flipping requires the hyrophillic head to enter the hydrophobic region of the bilayer.

The Mosaic Quality of Membranes

Proteins :

Because the cell membrane is only semi-permable the cell needs a way to communicate with other cells and exchange nutrients with the extracellular space. These roles are primarily filled by **proteins.** Proteins are a seperate class of molecules unrelated to the lipids and are composed of amino acids. Membrane proteins are classified into two major categories, integral proteins and peripheral proteins. Integral proteins are transmembrane proteins, with hydrophobic regions that completely span the hydrophobic interior of the membrane. The parts of the protein exposed to the interior and exterior of the cell are hydrophillic. Integral proteins can serve as pores that selectively allow ions or nutrients into the cell. They also transmit signals into and out of the cell. Unlike intergral proteins that span the membrane, peripheral proteins reside on only one side of the membrane and are often attached to integral proteins.Some peripheral proteins serve as anchor points for the cytoskeleton or extracellular fibers. Proteins are much larger than lipids and move more slowly, but some do move in seemingly directed manner while others drift.

Carbohydrates :

The extracellular surface of the cell membrane is decorated with **carbohydrate** groups attached to lipids, **glycolipids**, or proteins, **glycoproteins**. These short carbohydrates, or **oligosaccharides**, are usually chains of 15 or fewer sugar molecules. Oligosaccharides give a cell identity (i.e., distinguishing self from non-self) and are the distinguishing factor in human blood types and transplant rejection.

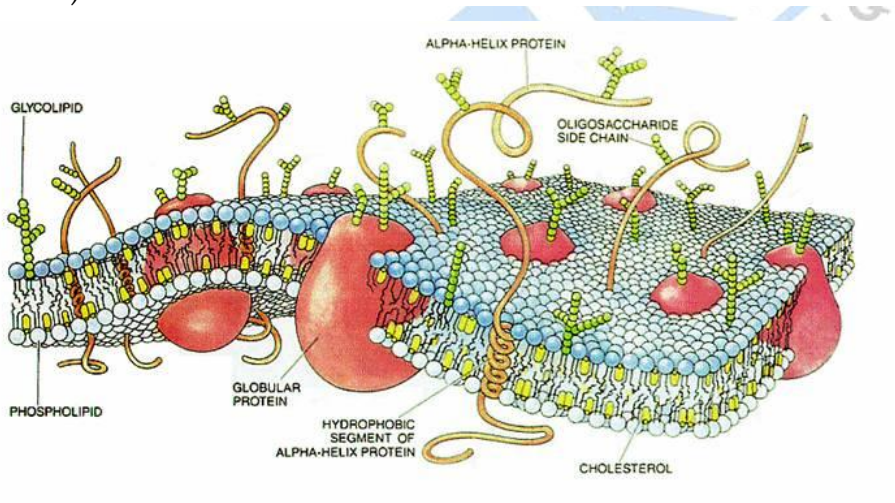
Membranes are asymmetric :

As discussed above and can be seen in the picture, we can conclude that the cell membrane is asymmetric. The extracellular face of the membrane is in contact with the extracellular matrix. The extracellular side of the membrane contains oligosaccharides that distinguish the cell as self. It also possesses the end of integral proteins that interact with signals from other cells and sense the extracellular environment. The inner membrane is in contact the contents of the cell. This side of the membrane anchors to the cytoskeleton and contains the end of integral proteins that relay signals received on the external side.

Summary: Membranes as Mosaics of Structure and Function :

The biological membrane is a group of many different proteins embedded in the fluid matrix of the lipid bilayer. The lipid bilayer is the main fabric of the membrane, and its structure creates a semi-permeable membrane. The hydrophobic core impedes the difusion of hydrophilic structures, such as ions and polar molecules but allows hydrophobic molecules, which can dissolve in the membrane, cross it with ease. Proteins determine most of the membrane's specific functions. The plasma membrane and the membranes of the various organelles each have unique collections of proteins.

The cell membrane functions as a semi-permeable barrier, allowing a very few molecules across it while fencing the majority of organically produced chemicals inside the cell. Electron microscopic examinations of cell membranes have led to the development of the lipid bilayer model (also referred to as the fluid-mosaic model).



Cell Membrane Transport

Q.2 Write a short note on passive transport.

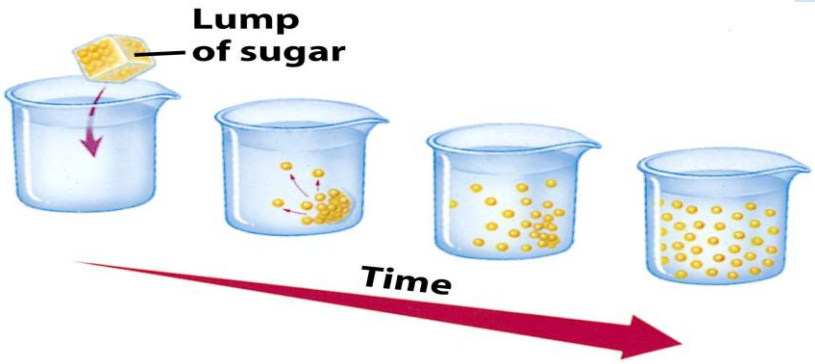
Ans. **Passive transport** is one of the cellular process in which molecules and other substances move across the membranes.

In the processes of passive there is no involvement of any chemical energy so it is different from active transport in this manner. Passive transport relies on the innate permeability of the cell membrane and its component proteins and lipids.

There are four main types of passive transport:

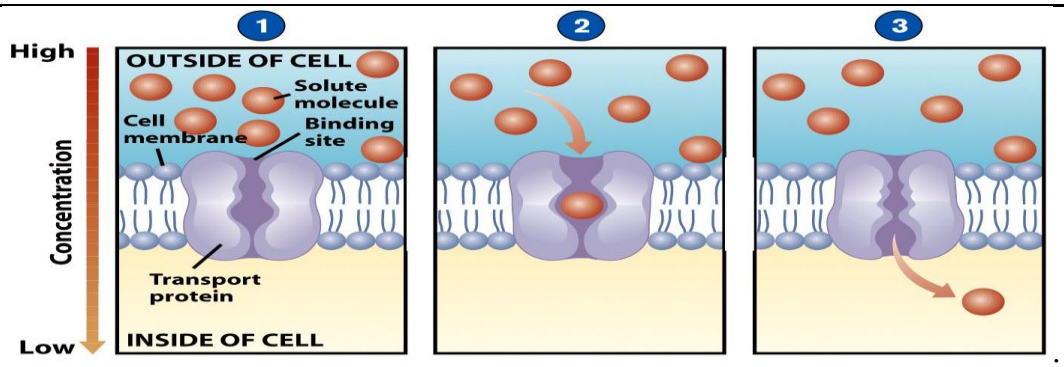
Diffusion :-

Diffusion describes the spread of particles through random motion from regions of higher concentration to regions of lower concentration. The time dependence of the statistical distribution in space is given by the diffusion equation. The concept of diffusion is tied to that of mass transfer driven by a concentration gradient. Diffusion is invoked in the social sciences to describe the spread of ideas.



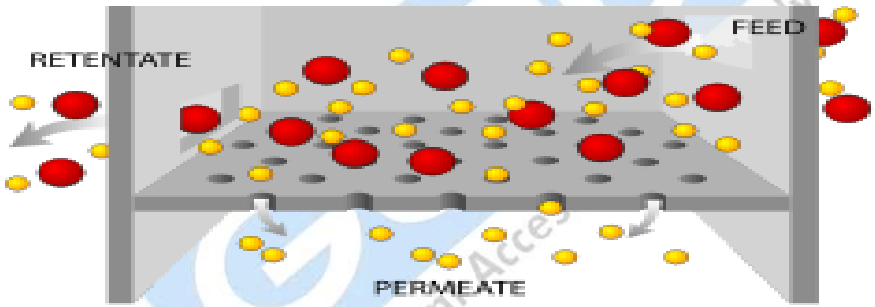
Facilitative Diffusion:-

Facilitated diffusion, also called carrier-mediated diffusion, is the movement of molecules across the cell membrane via special transport proteins that are embedded within the cellular membrane. Many large molecules, such as glucose, are insoluble in lipids and too large to fit through the membrane pores. Therefore, it will bind with its specific carrier proteins, and the complex will then be bonded to a receptor site and moved through the cellular membrane. Bear in mind, however, that facilitated diffusion is a passive process, and the solutes still move down the concentration gradient



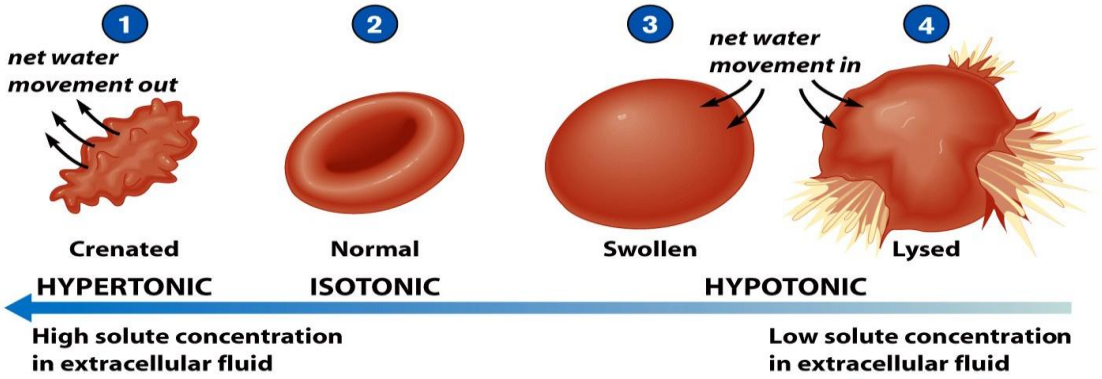
Filtration :-

Molecules across the cell membrane due to hydrostatic pressure generated by the cardiovascular system. Depending on the size of the membrane pores, only solutes of a certain size may pass through it. For example, the membrane pores of the Bowman's capsule in the kidneys are very small, and only albumins, the smallest of the proteins, have any chance of being filtered through. On the other hand, the membrane pores of liver cells are extremely large, to allow a variety of solutes to pass through and be metabolized.



Osmosis:-

Osmosis is the diffusion of water molecules across a selectively permeable membrane. The net movement of water molecules through a partially permeable membrane from a solution of high water potential to an area of low water potential. A cell with a less negative water potential will draw in water but this depends on other factors as well such as solute potential (pressure in the cell e.g. solute molecules) and pressure potential (external pressure e.g. cell wall). Because the cell wall is a wall around the wall of a cell of a cell like a cell membrane.



Q.3 What do you understand by active transport? Explain it.

Ans. **Active transport** is an energy mediated process of moving molecules and other substances across membranes.

Active transport differs from **passive transport** in that it utilizes chemical energy in the form of adenosine triphosphate, or ATP, to move molecules against the concentration gradient from an area of lower concentration to an area of higher concentration.

There are two types of active transport:

Primary active transport :
Primary active transport directly utilizes chemical energy to move molecules through a membrane.

The **Active transport** is the mediated process of moving molecules and other substances across membranes.

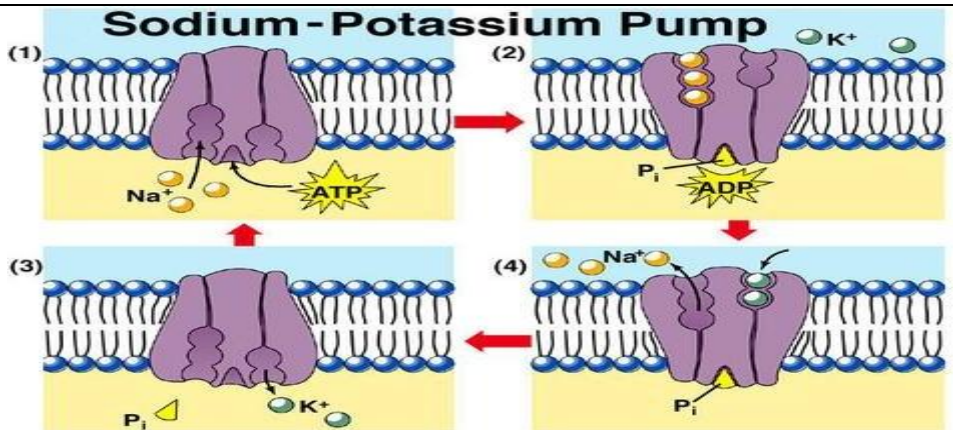
There are two types of active transport:

Secondary active transport :

In secondary active transport, molecules are moved through a membrane as the direct result of the diffusion of another substance.

The **sodium-calcium exchanger,** or **antiporter**, uses the normal diffusion of sodium ions into the cell to power the transport of calcium out of the cell (and across a higher concentration gradient).

In another example, the glucose symporter uses the normal diffusion of sodium ions into the cell to piggyback the transport of glucose into the cell as well.

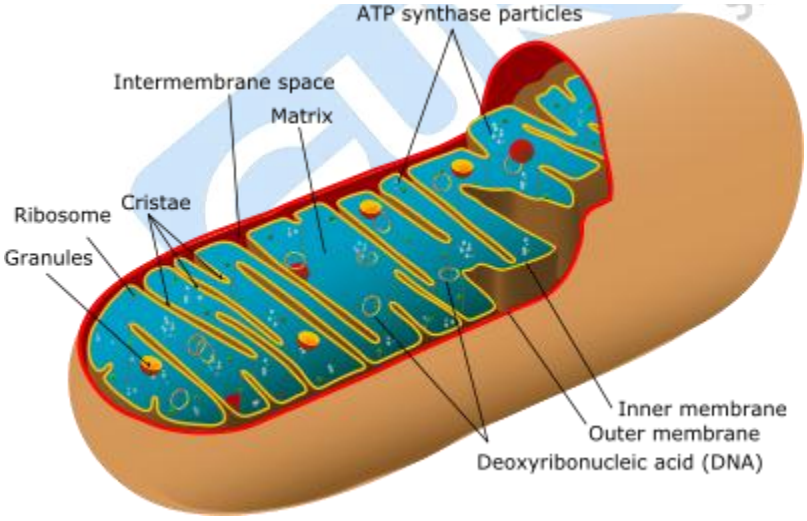


Cytoplasmic Organelles

Q.4 Describe structure and functions of mitochondria?

Ans.

Structure



A mitochondrion contains outer and inner membranes composed of phospholipid bilayers and proteins.The two membranes, however, have different properties.

Because of this double-membraned organization, there are five distinct compartments within the mitochondrion. They are:

1. the outer mitochondrial membrane,
2. the intermembrane space (the space between the outer and inner membranes),
3. the inner mitochondrial membrane,
4. the cristae space (formed by infoldings of the inner membrane), and
5. the matrix (space within the inner membrane).

Function

Mitochondria are organelles appearing in all eukaryotic cells which produce ATP as useful energy for the cell by oxidative phosphorylation. The proteins for the adenosine 5'-triphosphate (ATP)-generating electron transport of the respiration chain are located in the inner mitochondrial membrane. Mitochondria contain many enzymes of the citric acid cycle and for fatty acid β-oxidation. Many of them are coded for by nuclear DNA.

Energy production

The main function of the mitochondrion is the production of energy, in the form of adenosine triphosphate (ATP). The cell uses this energy to perform the specific work necessary for cell survival and function.

The raw materials used to generate ATP are the foods that we eat, or tissues within the body that are broken down in a process called *catabolism*. The breaking down of food into simpler molecules such as carbohydrates, fats, and protein is called *metabolism*. These molecules are then transferred into the mitochondria, where further processing occurs. The reactions within the mitochondria produce specific molecules that can have their electrical charges separated within the inner mitochondrial membrane. These charged molecules are processed within the five electron transport chain complexes to finally combine with oxygen to make ATP. The process of the charged substances combining with oxygen is called *oxidation*, while the chemical reaction making ATP is called *phosphorylation*. The overall process is called *oxidative phosphorylation*. The product produced by this process is ATP.

Programmed cell death :

Cell death can occur either by injury due to toxic exposure, by mechanical damage, or by an orderly process called *programmed cell death* or *apoptosis*. Programmed cell death occurs during development as the organism is pruning away unwanted, excess cells. It also occurs during infections with viruses, cancer therapy, or in the immune response to illness. The process of programmed cell death is another function of mitochondria.

Normally, ATP production is coupled to oxygen consumption. During abnormal states such as fever, cancer, or stroke, or when dysfunction occurs within the mitochondria, more oxygen is consumed or required than is actually used to make ATP. The mitochondria become partially "uncoupled" and produce highly reactive oxygen species called free radicals. When the production of free radicals overwhelms the mitochondria's ability to "detoxify" them, the excess free radicals damage mitochondrial function by changing the mitochondrial DNA, proteins, and membranes. As this process continues, it can induce the cell to undergo apoptosis. Abnormal cell death due to mitochondrial dysfunction can interfere with organ function.

Cell-specific functions :

Other functions of mitochondria are related to the cell type in which they are found. Mitochondria are involved in building, breaking down, and recycling products needed for proper cell functioning. For example, some of the building blocks of DNA and RNA occur within the mitochondria. Mitochondria are also involved in making parts of blood and hormones such as estrogen and testosterone. They are required for cholesterol metabolism, neurotransmitter metabolism, and detoxification of ammonia in the urea cycle. Thus, if mitochondria do not function properly, not only energy production but also cell-specific products needed for normal cell functioning will be affected.

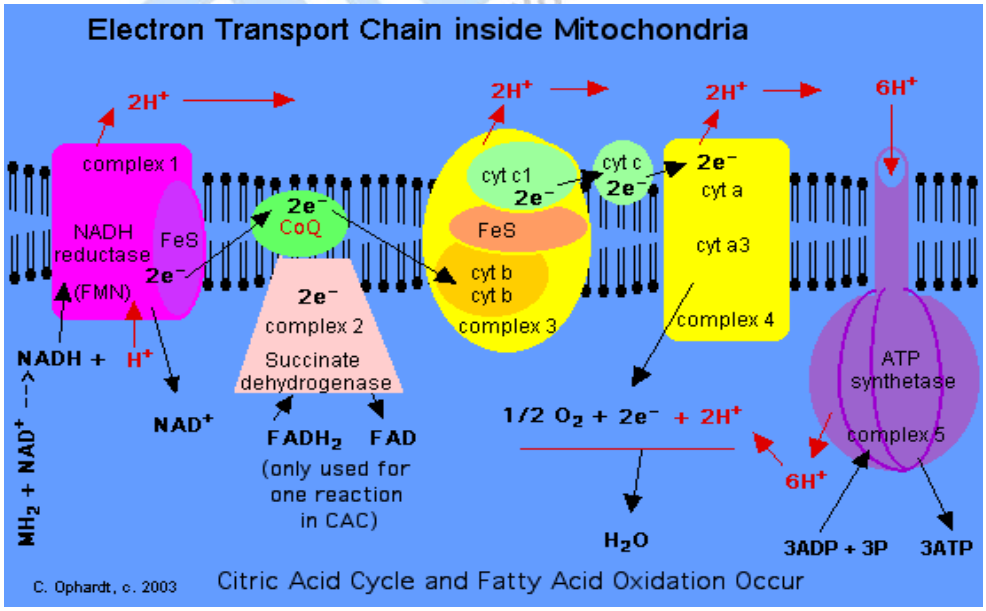
Q-3 What is electron transport system?

Ans **Eelectron transport chain (ETC)** couples electron transfer between an electron donor (such as NADH) and an electron acceptor (such as O_2) with the transfer of H^+ ions (protons) across a membrane. The resulting electrochemical proton gradient is used to generate chemical energy in the form of adenosine triphosphate (*ATP*). Electron transport chains are the cellular mechanisms used for extracting energy from sunlight in photosynthesis and also from redox reactions, such as the oxidation of sugars (respiration).

In chloroplasts, light drives the conversion of water to oxygen and $NADP^+$ to NADPH with transfer of H^+ ions across chloroplast membranes. In mitochondria, it is the conversion of oxygen to water, NADH to NAD^+ and succinate to fumarate that generates a proton. Electron transport chains are major sites of premature electron leakage to oxygen, generating superoxide and potentially resulting in increased oxidative stress.

Electron transport chains in mitochondria

Most eukaryotic cells have mitochondria, which produce ATP from products of the citric acid cycle, fatty acid oxidation, and amino acid oxidation. At the mitochondrial inner membrane, electrons from NADH and succinate pass through the electron transport chain to oxygen, which is reduced to water. The electron transport chain comprises an enzymatic series of electron donors and acceptors. Each electron donor passes electrons to a more electronegative acceptor, which in turn donates these electrons to another acceptor, a process that continues down the series until electrons are passed to oxygen, the most electronegative and terminal electron acceptor in the chain. Passage of electrons between donor and acceptor releases energy, which is used to generate a proton gradient across the mitochondrial membrane by actively "pumping" protons into the intermembrane space, producing a thermodynamic state that has the potential to do work. The entire process is called oxidative phosphorylation, since ADP is phosphorylated to ATP using the energy of hydrogen oxidation in many steps



Four membrane-bound complexes have been identified in mitochondria. Each is an extremely complex transmembrane structure that is embedded in the inner membrane. Three of them are proton pumps. The structures are electrically connected by lipid-soluble electron carriers and water-soluble electron carriers. The overall electron transport chain:

NADH → ***Complex I*** → **Q** → ***Complex III*** → **cytochrome** ***c*** → ***Complex IV*** → $\mathbf{O_2}$

↑

Complex II

↑

FADH

Complex I

In *Complex I* (NADH dehydrogenase, also called NADH:ubiquinone oxidoreductase; EC 1.6.5.3) two electrons are removed from NADH and transferred to a lipid-soluble carrier, *ubiquinone* (Q). The reduced product, *ubiquinol* (QH_2) freely diffuses within the membrane, and Complex I translocates four protons (H^+) across the membrane, thus producing a proton gradient. Complex I is one of the main sites at which premature electron leakage to oxygen occurs, thus being one of the main sites of production of harmful superoxide.[3]

The pathway of electrons occurs as follows:

NADH is oxidized to NAD^+, by reducing Flavin mononucleotide to $FMNH_2$ in one two-electron step. $FMNH_2$ is then oxidized in two one-electron steps, through a semiquinone intermediate. Each electron thus transfers from the $FMNH_2$ to an Fe-S cluster, from the Fe-S cluster to ubiquinone (Q). Transfer of the first electron results in the free-radical (semiquinone) form of Q, and transfer of the second electron reduces the semiquinone form to the ubiquinol form, QH_2. During this process, four protons are translocated from the mitochondrial matrix to the intermembrane space. [3]

Complex II

In *Complex II* (succinate dehydrogenase; EC 1.3.5.1) additional electrons are delivered into the quinone pool (Q) originating from succinate and transferred (via FAD) to Q. Complex II consists of four protein subunits: SDHA, SDHB,

SDHC, and SDHD. Other electron donors (e.g., fatty acids and glycerol 3-phosphate) also direct electrons into Q (via FAD).

Complex III

In *Complex III* (cytochrome bc_1 complex; EC 1.10.2.2), the Q-cycle contributes to the proton gradient by an asymmetric absorption/release of protons. Two electrons are removed from QH_2 at the Q_O site and sequentially transferred to two molecules of cytochrome *c*, a water-soluble electron carrier located within the intermembrane space. The two other electrons sequentially pass across the protein to the Q_i site where the quinone part of ubiquinone is reduced to quinol. A proton gradient is formed by two quinol (4H+4e-) oxidations at the Q_o site to form one quinol (2H+2e-) at the Q_i site. (in total six protons are translocated: two protons reduce quinone to quinol and four protons are released from two ubiquinol molecules).

When electron transfer is reduced (by a high membrane potential or respiratory inhibitors such as antimycin A), Complex III may leak electrons to molecular oxygen, resulting in superoxide formation.

Complex IV

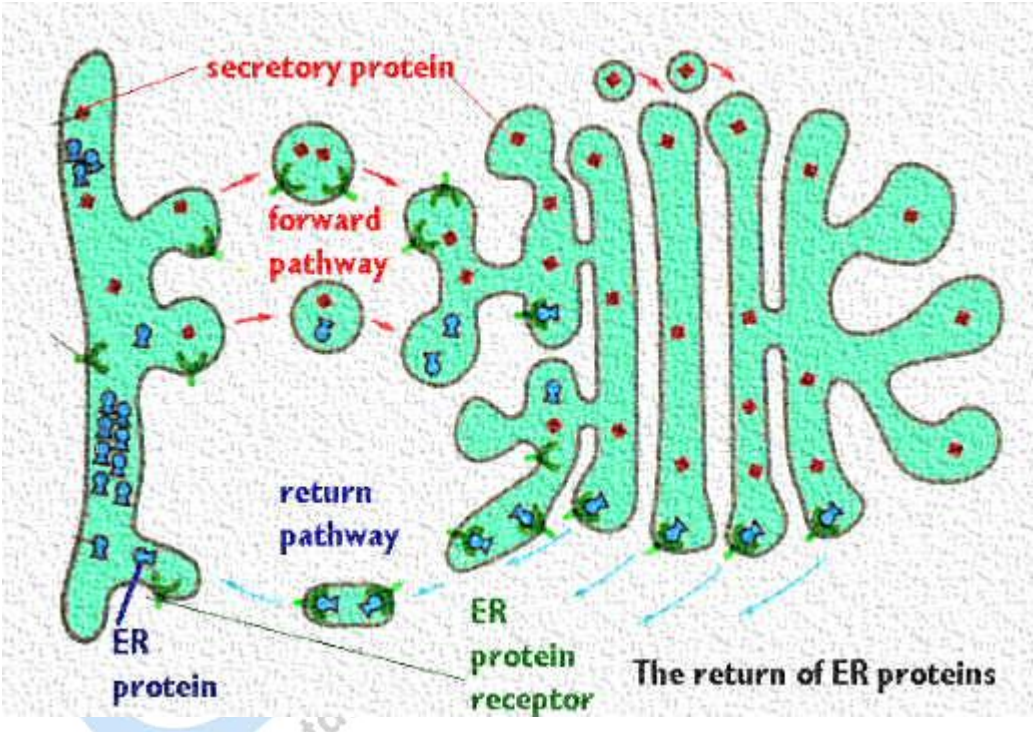
In *Complex IV* (cytochrome *c* oxidase; EC 1.9.3.1), sometimes called cytochrome A3, four electrons are removed from four molecules of cytochrome *c* and transferred to molecular oxygen (O_2), producing two molecules of water. At the same time, four protons are translocated across the membrane, contributing to the proton gradient. The activity of cytochrome c oxidase is inhibited by cyanide

Q.4 Write a short note on Endoplasmic Reticulum.

Ans. Endoplasmic reticulum (ER) is a membranous labyrinth so extensive that it accounts for more than half the total membrane in many eukaryotic cells. The word endoplasmic means "within" the cytoplasm, and the word reticulum is derived from a word meaning "network." The ER consists of a network of membranous tubules and sacs called cisternae. The ER membrane separates its internal compartment, the cisternal space, from the cystosol. Because the ER membrane is continuous with the nuclear envelope, the space between the two membranes of the envelope is continuous with the cisternal space of the ER.

There are two specific regions of ER that are different in structure and function. The two forms are rough ER and smooth ER. The rough ER appears rough because of ribosomes. The ribosomes are attached to ER making appear bumpy.

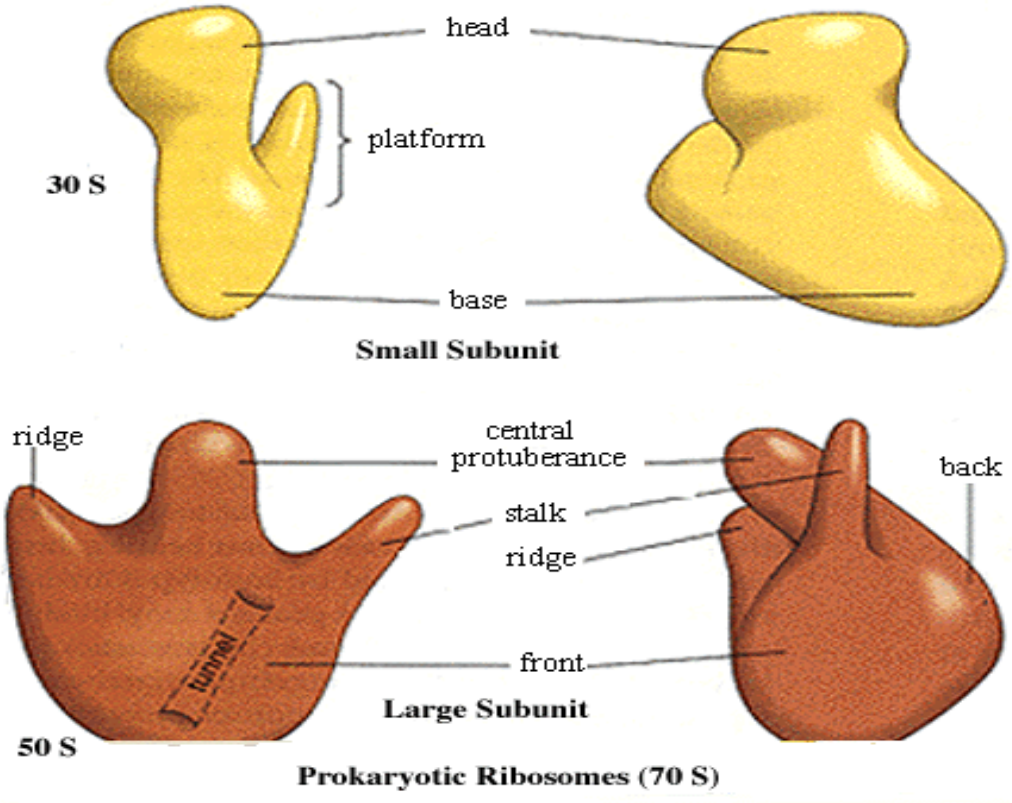
Smooth ER has its name simply beacuse its cytoplasmic surface does not contain ribosomes. Rough ER specializes in protein synthesis. The endoplasmic reticulum is a transport system. Protein molecules move from the rough ER into the smooth ER, which then sensds them enclosed within the vesicles usually to the Golgi complex. The smooth ER of various cell types functions in diverse metabolic processes, including the synthesis of lipids, carbohydrate metabolism, and the detoxification of drugs and other poisons. Enzymes in the smooth ER are important to the synthesis of fats, phospolipids, steroids, and other lipids. The enzymes detoxify drugs and other poisons, especially in the liver cells. This makes it easier to flush the toxic out of the body.



Q.5 What are Ribosomes?

Ans. Ribosomes are the protein-synthesizing complex of the cell and are present in all organisms from bacteria to man to green plants. Ribosomes have two subunits; the smaller subunit, 30 S for the bacterial and 40 S for the eukaryotic ribosome, containing a single ribosomal RNA and 21–33 proteins (depending on the organism), 15 of which share homology between 30 S and 40 S ribosomal subunits.1 The small ribosomal subunit is responsible for initial interactions with mRNA, and the correct positioning of the ribosome for translation start. mRNA decoding and tRNA fidelity verification is carried out by the small subunit.2 The

larger subunit of ribosomes, 50 S for the bacterial and 60 S for the eukaryotic ribosome, is composed of two orthree rRNAs and from 33 to 47 proteins, with 17 of these proteins conserved between 50 S and 60 S ribosomal subunits.1 The large subunit houses the peptidyl transferase reaction center and the nascent polypeptide exit tunnel.



Section B

Nucleus

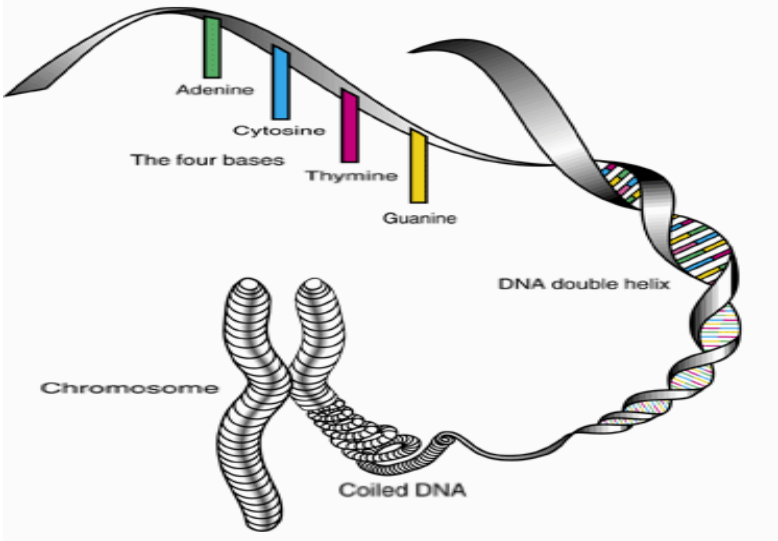
Q.1 What do you know about chromosome?

Ans. A **chromosome** is an organized structure of DNA and protein found in cells. It is a single piece of coiled DNA containing many genes, regulatory elements and other nucleotide sequences. Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions.

Chromosomes vary widely between different organisms. The DNA molecule may be circular or linear, and can be composed of 100,000 to 10,000,000,000[1] nucleotides in a long chain. Typically, eukaryotic cells (cells with nuclei) have large linear chromosomes and prokaryotic cells (cells without defined nuclei) have smaller circular chromosomes, although there are many exceptions to this rule. Also, cells may contain more than one type of chromosome; for example, mitochondria in most eukaryotes and chloroplasts in plants have their own small chromosomes.

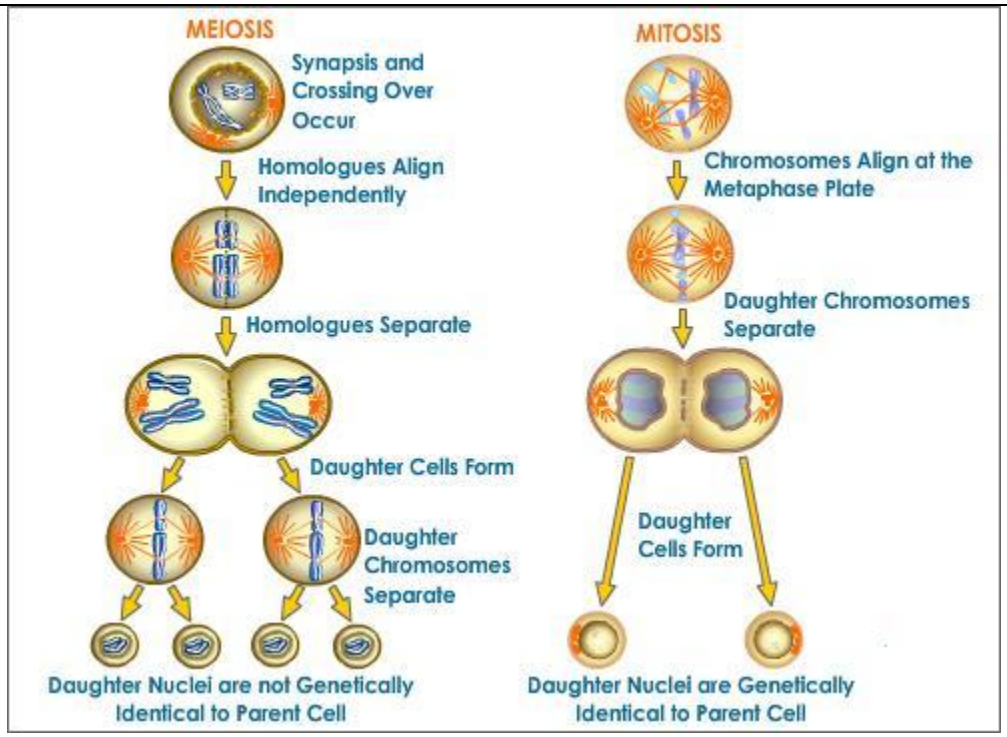
In eukaryotes, nuclear chromosomes are packaged by proteins into a condensed structure called chromatin. This allows the very long DNA molecules to fit into the cell nucleus. The structure of chromosomes and chromatin varies through the cell cycle. Chromosomes are the essential unit for cellular division and must be replicated, divided, and passed successfully to their daughter cells so as to ensure the genetic diversity and survival of their progeny. Chromosomes may exist as either duplicated or unduplicated. Unduplicated chromosomes are single linear strands, whereas duplicated chromosomes contain two identical copies (called chromatids) joined by a centromere.

Compaction of the duplicated chromosomes during mitosis and meiosis results in the classic four-arm structure (pictured to the right). Chromosomal recombination plays a vital role in genetic diversity. If these structures are manipulated incorrectly, through processes known as chromosomal instability and translocation, the cell may undergo mitotic catastrophe and die, or it may unexpectedly evade apoptosis leading to the progression of cancer.



Q.2 Describe cell division.

Ans. Cell division is the process by which a *parent cell* divides into two or more *daughter cells*.Cell division is usually a small segment of a larger cell cycle. This type of cell division in eukaryotes is known as mitosis, and leaves the daughter cell capable of dividing again. The corresponding sort of cell division in prokaryotes is known as binary fission. In another type of cell division present only in eukaryotes, called meiosis, a cell is permanently transformed into a gamete and may not divide again until fertilization. Right before the parent cell splits, it undergoes DNA replication.

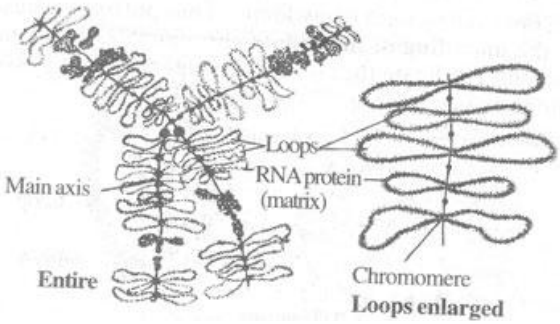


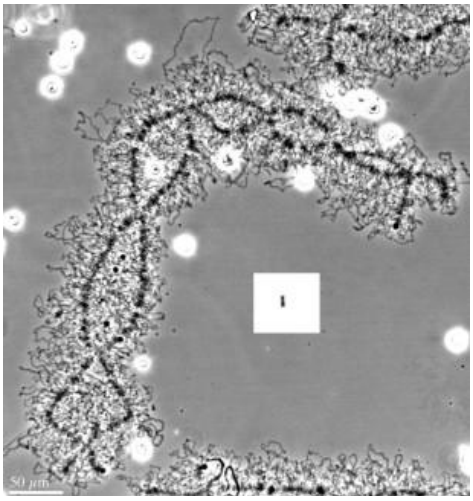
Q.3 Write a short note on lampbrush chromosome.

Ans. A Lampbrush chromosome (first seen by Flemming in 1882) is the largest chromosome known and is found in the amphibian oocytes (immature eggs). Lampbrush chromosomes occur during the diplotene stage of meiosis I. They are meiotic bivalents, each consisting of 2 sister chromatids. Lampbrush chromosomes are clearly visible even in the light microscope, where they are seen to be organized into a series of large chromatin loops emanating from a linear chromosomal axis.

A given loop always contains the same DNA sequence, and it remains extended in the same manner as the oocyte grows. These chromosomes are producing large amounts of RNA for the oocyte, and most of the genes present in the DNA loops are being actively expressed. The majority of the DNA, however, is not in loops but remains highly condensed in the chromomeres on the axis, where genes are generally not expressed. It is thought that the interphase chromosomes of all eucaryotes are similarly arranged in loops. Although these loops are normally too small and fragile to be easily observed in a light microscope, other methods can be used to infer their presence. For example, it has become possible to assess the frequency with which two loci along an interphase chromosome are paired with each other, thus revealing candidates for the sites on chromatin that form the closely apposed bases of loop structures. These experiments and others suggest

that the DNA in human chromosomes is organized into loops of different lengths. A typical loop might contain between 50,000 and 200,000 nucleotide pairs of DNA, although loops of a million nucleotide pairs have also been suggested. Giant chromosomes in the lampbrush form are useful model for studying chromosome organization and gene expression during meiotic prophase, since they allow the individual transcription units to be visualized.





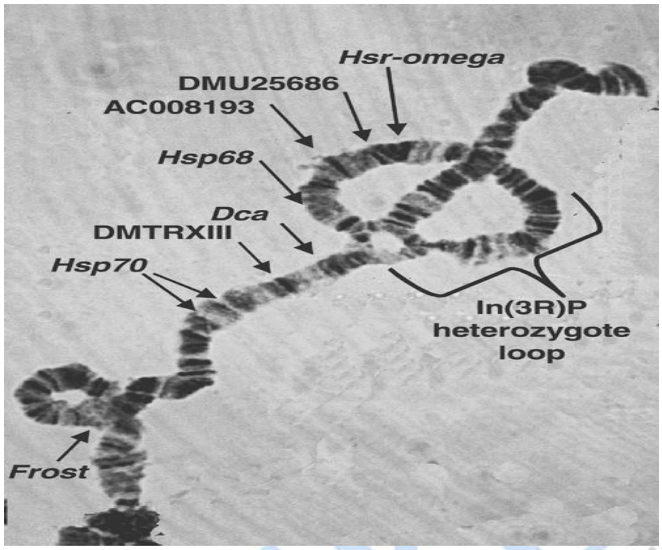
Q.4 Write a note on polytene chromosome.

Ans. Polytene chromosomes are giant chromosomes common to many dipteran (two-winged) flies. They begin as normal chromosomes, but through repeated rounds of DNA replication without any cell division (called endoreplication), they become large, banded chromosomes (see figure). For unknown reasons, the centromeric regions of the chromosomes do not endoreplicate very well. As a result, the centromeres of all the chromosomes bundle together in a mass called the chromocenter.

Polytene chromosomes are usually found in the larvae, where it is believed these many-replicated chromosomes allow for much faster larval growth than if the cells remained diploid. Simply because each cell now has many copies of each gene, it can transcribe at a much higher rate than with only two copies in diploid cells.

The polytene chromosomes at the right are from the salivary glands of the fruit fly *Drosophila melanogaster*. the bands on each chromosome are like a road map, unique to each chromosome and well defined enough to allow high resolution

mapping of each chromosome. The *Drosophila* Genome Project uses polytene chromosomes as a framework for the map.



Nucleic Acid

Q-1 What is DNA? Explain with suitable diagram.

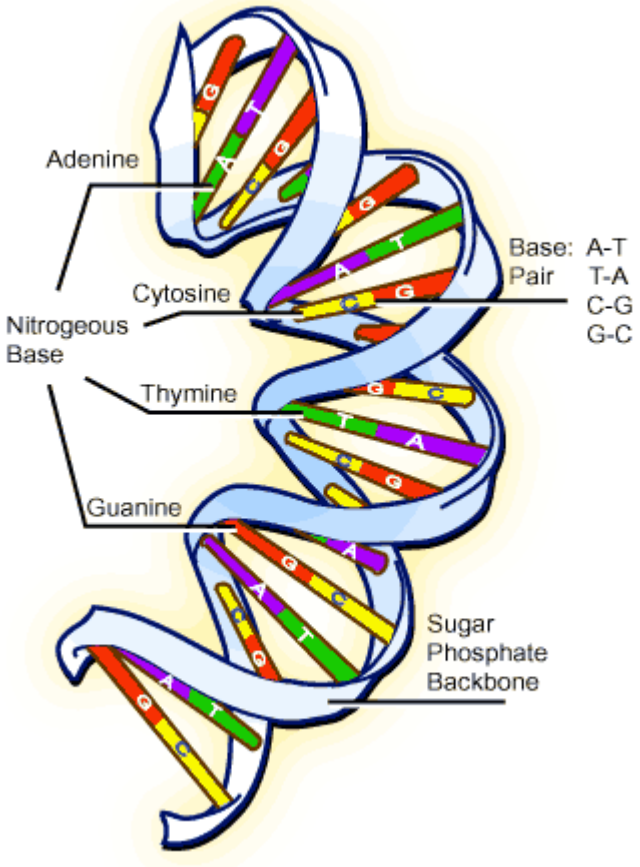
Ans. **Deoxyribonucleic acid** is a nucleic acid containing the genetic instructions used in the development and functioning of all known living organisms (with the exception of RNA viruses). The DNA segments carrying this genetic information are called genes. Likewise, other DNA sequences have structural purposes, or are involved in regulating the use of this genetic information. Along with RNA and proteins, DNA is one of the three major macromolecules that are essential for all known forms of life.

DNA consists of two long polymers of simple units called nucleotides, with backbones made of sugars and phosphate groups joined by ester bonds. These two strands run in opposite directions to each other and are therefore anti-parallel. Attached to each sugar is one of four types of molecules called nucleobases (informally, *bases*). It is the sequence of these four nucleobases along the backbone that encodes information. This information is read using the genetic code, which specifies the sequence of the amino acids within proteins. The code is read by copying stretches of DNA into the related nucleic acid RNA in a process called transcription.

Within cells DNA is organized into long structures called chromosomes. During cell division these chromosomes are duplicated in the process of DNA replication, providing each cell its own complete set of chromosomes. Eukaryotic organisms (animals, plants, fungi, and protists) store most of their DNA inside the cell nucleus and some of their DNA in organelles, such as mitochondria or chloroplasts.[1] In contrast, prokaryotes (bacteria and archaea) store their DNA only in the cytoplasm. Within the chromosomes, chromatin proteins such as histones compact and organize DNA. These compact structures guide the interactions between DNA and other proteins, helping control which parts of the DNA are transcribed.

Grooves

Twin helical strands form the DNA backbone. Another double helix may be found by tracing the spaces, or grooves, between the strands. These voids are adjacent to the base pairs and may provide a binding site. As the strands are not directly opposite each other, the grooves are unequally sized. One groove, the major groove, is 22 Å wide and the other, the minor groove, is 12 Å wide.[14] The narrowness of the minor groove means that the edges of the bases are more accessible in the major groove. As a result, proteins like transcription factors that can bind to specific sequences in double-stranded DNA usually make contacts to the sides of the bases exposed in the major groove.[15] This situation varies in unusual conformations of DNA within the cell , but the major and minor grooves are always named to reflect the differences in size that would be seen if the DNA is twisted back into the ordinary B form.



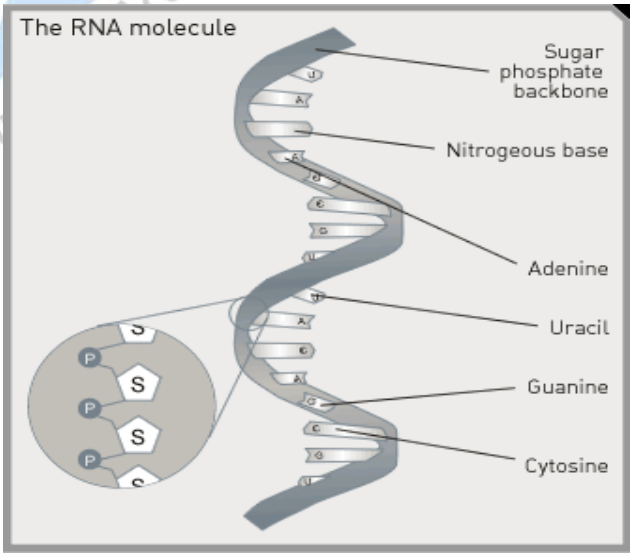
Q.2 What do you understand by RNA?

Ans. **Ribonucleic acid** is one of the three major macromolecules (along with DNA and proteins) essential for all known forms of life. Like DNA, RNA is made up of a long chain of components called nucleotides. Each nucleotide consists of a nucleobase, a ribose sugar, and a phosphate group. The sequence of nucleotides allows RNA to encode genetic information. All cellular organisms use messenger RNA (mRNA) to carry the genetic information that directs the synthesis of proteins. In addition, many viruses use RNA instead of DNA as their genetic material.

Some RNA molecules play an active role in cells by catalyzing biological reactions, controlling gene expression, or sensing and communicating responses to cellular signals. One of these active processes is protein synthesis, a universal function whereby mRNA molecules direct the assembly of proteins on ribosomes. This process uses transfer RNA (tRNA) molecules to deliver amino acids to the ribosome, where ribosomal RNA (rRNA) links amino acids together to form proteins.

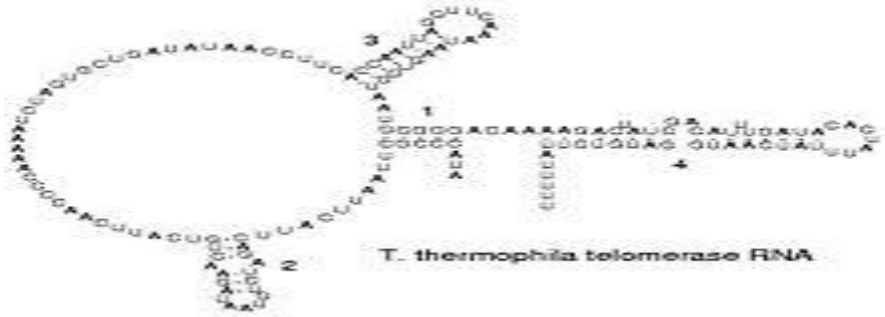
The chemical structure of RNA is very similar to that of DNA, with two differences: (a) RNA contains the sugar *ribose*, while DNA contains the slightly different sugar *deoxyribose* (a type of ribose that lacks one oxygen atom), and (b) RNA has the nucleobase uracil while DNA contains thymine. Unlike DNA, most RNA molecules are single-stranded and can adopt very complex three-dimensional structures.

Structure



Each nucleotide in RNA contains a ribose sugar, with carbons numbered 1' through 5'. A base is attached to the 1' position, in general, adenine (A), cytosine (C), guanine (G), or uracil (U). Adenine and guanine are purines, cytosine, and uracil are pyrimidines. A phosphate group is attached to the 3' position of one ribose and the 5' position of the next. The phosphate groups have a negative charge each at physiological pH, making RNA a charged molecule (polyanion). The bases may form hydrogen bonds between cytosine and guanine, between adenine and uracil and between guanine and uracil.[4] However, other interactions are possible, such as a group of adenine bases binding to each other in a bulge, or the GNRA tetraloop that has a guanine–adenine base-pair.

An important structural feature of RNA that distinguishes it from DNA is the presence of a hydroxyl group at the 2' position of the ribose sugar. The presence of this functional group causes the helix to adopt the A-form geometry rather than the B-form most commonly observed in DNA. This results in a very deep and narrow major groove and a shallow and wide minor groove.[7] A second consequence of the presence of the 2'-hydroxyl group is that in conformationally flexible regions of an RNA molecule (that is, not involved in formation of a double helix), it can chemically attack the adjacent phosphodiester bond to cleave the backbone.



Secondary structure of a telomerase RNA.

RNA is transcribed with only four bases (adenine, cytosine, guanine and uracil), but these bases and attached sugars can be modified in numerous ways as the RNAs mature. Pseudouridine (Ψ), in which the linkage between uracil and ribose is changed from a C–N bond to a C–C bond, and ribothymidine (T) are found in various places (the most notable ones being in the TΨC loop of tRNA).[10] Another notable modified base is hypoxanthine, a deaminated adenine base whose nucleoside is called inosine (I). Inosine plays a key role in the wobble hypothesis of the genetic code.[11]

There are nearly 100 other naturally occurring modified nucleosides, of which pseudouridine and nucleosides with 2'-O-methylribose are the most common. The specific roles of many of these modifications in RNA are not fully understood. However, it is notable that, in ribosomal RNA, many of the post-transcriptional modifications occur in highly functional regions, such as the peptidyl transferase center and the subunit interface, implying that they are important for normal function.

The functional form of single-stranded RNA molecules, just like proteins, frequently requires a specific tertiary structure. The scaffold for this structure is provided by secondary structural elements that are hydrogen bonds within the molecule. This leads to several recognizable "domains" of secondary structure like hairpin loops, bulges, and internal loops. Since RNA is charged, metal ions such as Mg^{2+} are needed to stabilise many secondary and tertiary structures.

Synthesis

Synthesis of RNA is usually catalyzed by an enzyme—RNA polymerase—using DNA as a template, a process known as transcription. Initiation of transcription begins with the binding of the enzyme to a promoter sequence in the DNA (usually found "upstream" of a gene). The DNA double helix is unwound by the helicase activity of the enzyme. The enzyme then progresses along the template strand in the 3′ to 5′ direction, synthesizing a complementary RNA molecule with elongation occurring in the 5′ to 3′ direction. The DNA sequence also dictates where termination of RNA synthesis will occur.

RNAs are often modified by enzymes after transcription. For example, a poly(A) tail and a 5' cap are added to eukaryotic pre-mRNA and introns are removed by the spliceosome.

There are also a number of RNA-dependent RNA polymerases that use RNA as their template for synthesis of a new strand of RNA. For instance, a number of RNA viruses (such as poliovirus) use this type of enzyme to replicate their genetic material. Also, RNA-dependent RNA polymerase is part of the RNA interference pathway in many organisms.

Types of RNA

Messenger RNA (mRNA) is the RNA that carries information from DNA to the ribosome, the sites of protein synthesis (translation) in the cell. The coding

sequence of the mRNA determines the amino acid sequence in the protein that is produced. Many RNAs do not code for protein however (about 97% of the transcriptional output is non-protein-coding in eukaryotes

These so-called non-coding RNAs ("ncRNA") can be encoded by their own genes (RNA genes), but can also derive from mRNA introns. The most prominent examples of non-coding RNAs are transfer RNA (tRNA) and ribosomal RNA (rRNA), both of which are involved in the process of translation.[1] There are also non-coding RNAs involved in gene regulation, RNA processing and other roles. Certain RNAs are able to catalyse chemical reactions such as cutting and ligating other RNA molecules, and the catalysis of peptide bond formation in the ribosome; these are known as ribozymes.

In translation

Messenger RNA (mRNA) carries information about a protein sequence to the ribosomes, the protein synthesis factories in the cell. It is coded so that every three nucleotides (a codon) correspond to one amino acid. In eukaryotic cells, once precursor mRNA (pre-mRNA) has been transcribed from DNA, it is processed to mature mRNA. This removes its introns—non-coding sections of the pre-mRNA. The mRNA is then exported from the nucleus to the cytoplasm, where it is bound to ribosomes and translated into its corresponding protein form with the help of tRNA. In prokaryotic cells, which do not have nucleus and cytoplasm compartments, mRNA can bind to ribosomes while it is being transcribed from DNA. After a certain amount of time the message degrades into its component nucleotides with the assistance of ribonucleases.[20]

Transfer RNA (tRNA) is a small RNA chain of about 80 nucleotides that transfers a specific amino acid to a growing polypeptide chain at the ribosomal site of protein synthesis during translation. It has sites for amino acid attachment and an anticodon region for codon recognition that binds to a specific sequence on the messenger RNA chain through hydrogen bonding.[25]

Ribosomal RNA (rRNA) is the catalytic component of the ribosomes. Eukaryotic ribosomes contain four different rRNA molecules: 18S, 5.8S, 28S and 5S rRNA. Three of the rRNA molecules are synthesized in the nucleolus, and one is synthesized elsewhere. In the cytoplasm, ribosomal RNA and protein combine to form a nucleoprotein called a ribosome. The ribosome binds mRNA and carries out protein synthesis. Several ribosomes may be attached to a single mRNA at any time.[20] Nearly all the RNA found in a typical eukaryotic cell is rRNA.

Transfer-messenger RNA (tmRNA) is found in many bacteria and plastids. It tags proteins encoded by mRNAs that lack stop codons for degradation and prevents the ribosome from stalling.[27]

Reverse transcribing viruses replicate their genomes by reverse transcribing DNA copies from their RNA; these DNA copies are then transcribed to new RNA. Retrotransposons also spread by copying DNA and RNA from one another,[50] and telomerase contains an RNA that is used as template for building the ends of eukaryotic chromosomes.[51]

Double-stranded RNA

Double-stranded RNA (dsRNA) is RNA with two complementary strands, similar to the DNA found in all cells. dsRNA forms the genetic material of some viruses (double-stranded RNA viruses). Double-stranded RNA such as viral RNA or siRNA can trigger RNA interference in eukaryotes, as well as interferon response in vertebrates.

Q.3 What do you understand by genetic code?

Ans. The sequence of nucleotides in DNA or RNA that determines the specific amino acid sequence in the synthesis of proteins. It is the biochemical basis of heredity and nearly universal in all organisms. The genetic code is the set of rules by which information encoded in genetic material (DNA or RNA sequences) is translated into proteins (amino acid sequences) by living cells. A more precise term for the concept might be "genetic cipher". The code defines a mapping between tri-nucleotide sequences, called codons, and amino acids. A triplet codon in a nucleic acid sequence usually specifies a single amino acid (though in some cases the same codon triplet in different locations can code unambiguously for two different amino acids, the correct choice at each location being determined by context). Because the vast majority of genes are encoded with exactly the same code (see the RNA codon table), this particular code is often referred to as the canonical or standard genetic code, or simply the genetic code, though in fact there are many variant codes. Thus the canonical genetic code is not universal. For example, in humans, protein synthesis in mitochondria relies on a genetic code that varies from the canonical code.

It is important to know that not all genetic information is stored using the genetic code. All organisms' DNA contain regulatory sequences, intergenic segments, and chromosomal structural areas that can contribute greatly to phenotype but operate using distinct sets of rules that may or may not be as straightforward as the codon-to-amino acid paradigm that usually underlies the genetic code (see epigenetics).

Transfer of information via the genetic code :

The genome of an organism is inscribed in DNA, or in some viruses RNA. The portion of the genome that codes for a protein or an RNA is referred to as a gene. Those genes that code for proteins are composed of tri-nucleotide units called codons, each coding for a single amino acid. Each nucleotide sub-unit consists of a phosphate, deoxyribose sugar and one of the 4 nitrogenous nucleotide bases. The purine bases adenine (A) and guanine (G) are larger and consist of two aromatic rings. The pyrimidine bases cytosine (C) and thymine (T) are smaller and consist of only one aromatic ring. In the double-helix configuration, two strands of DNA are joined to each other by hydrogen bonds in an arrangement known as base pairing. These bonds almost always form between an adenine base on one strand and a thymine on the other strand and between a cytosine base on one strand and a guanine base on the other. This means that the number of A and T residues will be the same in a given double helix, as will the number of G and C residues. In RNA, thymine (T) is replaced by uracil (U), and the deoxyribose is substituted by ribose.

Each protein-coding gene is transcribed into a template molecule of the related polymer RNA, known as messenger RNA or mRNA. This, in turn, is translated on the ribosome into an amino acid chain or polypeptide. The process of translation requires transfer RNAs specific for individual amino acids with the amino acids covalently attached to them, guanosine triphosphate as an energy source, and a number of translation factors. tRNAs have anticodons complementary to the codons in mRNA and can be "charged" covalently with amino acids at their 3' terminal CCA ends. Individual tRNAs are charged with specific amino acids by enzymes known as aminoacyl tRNA synthetases, which have high specificity for both their cognate amino acids and tRNAs. The high specificity of these enzymes is a major reason why the fidelity of protein translation is maintained.

There are $4^3 = 64$ different codon combinations possible with a triplet codon of three nucleotides; all 64 codons are assigned for either amino acids or stop signals during translation. If, for example, an RNA sequence, UUUAAACCC is considered and the reading-frame starts with the first U (by convention, 5' to 3'), there are three codons, namely, UUU, AAA and CCC, each of which specifies one amino acid. This RNA sequence will be translated into an amino acid sequence, three amino acids long. A comparison may be made with computer science, where the codon is similar to a word, which is the standard "chunk" for handling data (like one amino acid of a protein), and a nucleotide is similar to a bit, in that it is the smallest unit.

The standard genetic code is shown in the following tables. Table 1 shows what amino acid each of the 64 codons specifies. Table 2 shows what codons specify each of the 20 standard amino acids involved in translation. These are called forward and reverse codon tables, respectively. For example, the codon AAU represents the amino acid asparagine, and UGU and UGC represent cysteine (standard three-letter designations, Asn and Cys, respectively).

	U	C	A	G
U	UUU Phe UUC UUA Leu UUG	UCU UCC UCA Ser UCG	UAU Tyr UAC UAA *Stop* UAG	UGU Cys UGC UGA *Stop* UGG Trp
C	CUU CUC CUA Leu CUG	CCU CCC CCA Pro CCG	CAU His CAC CAA Gln CAG	CGU CGC CGA Arg CGG
A	AUU AUC Ile AUA AUG Met	ACU ACC ACA Thr ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG
G	GUU GUC GUA Val GUG	GCU GCC GCA Ala GCG	GAU Asp GAC GAA Glu GAG	GGU GGC GGA Gly GGG

Q.4 Describe protein synthsis.

Ans. **Protein biosynthesis** is the process in which cells build or manufacture proteins. The term is sometimes used to refer only to protein translation but more often it refers to a multi-step process, beginning with amino acid synthesis and transcription of nuclear DNA into messenger RNA, which is then used as input for translation.

The cistron DNA is transcribed into a variety of RNA intermediates. The last version is used as a template in synthesis of a polypeptide chain. Proteins can often be synthesized directly from genes by translating mRNA. When a protein must be available on short notice or in large quantities, a protein precursor is produced. A proprotein is an inactive protein containing one or more inhibitory peptides that can be activated when the inhibitory sequence is removed by proteolysis during posttranslational modification. A preprotein is a form that contains a signal sequence (an N-terminal signal peptide) that specifies its insertion into or through membranes, i.e., targets them for secretion. The signal peptide is cleaved off in the endoplasmic reticulum.[1] Preproproteins have both sequences (inhibitory and signal) still present.

For synthesis of protein, a succession of tRNA molecules charged with appropriate amino acids have to be brought together with an mRNA molecule and matched up by base-pairing through their anti-codons with each of its successive codons. The amino acids then have to be linked together to extend the growing protein chain, and the tRNAs, relieved of their burdens, have to be released. This whole complex of processes is carried out by a giant multimolecular machine, the ribosome, formed of two main chains of RNA, called ribosomal RNA (rRNA), and more than 50 different proteins. This molecular juggernaut latches onto the end of an mRNA molecule and then trundles along it, capturing loaded tRNA molecules and stitching together the amino acids they carry to form a new protein chain.

Transcription:

Simply stated **transcription is the synthesis of RNA from a DNA template**. Also important is the concept that transcription, whether prokaryotic or eukaryotic, has three main events.

1. **Initiation** - binding of RNA polymerase to double-stranded DNA; this step involves a transition to single-strandedness in the region of binding; RNA polymerase binds at a sequence of DNA called the promoter. **Initiation is the most important step in gene expression!!!**
2. **Elongation** - the covalent addition of nucleotides to the 3' end of the growing polynucleotide chain; this involves the development of a short stretch of DNA that is transiently single-stranded
3. **Termination** - the recognition of the transcription termination sequence and the release of RNA polymerase

Although transcription is performed by RNA Polymerase, the enzyme needs other proteins to produce the transcript. These factors are either associated directly with RNA Polymerase or add in building the actual transcription apparatus. The general term for these associated proteins is **transcription factor**.

Transcription factor - any protein other than RNA Polymerase that is required for transcription

Functions of Transcription Factors

- bind to RNA Polymerase
- bind another transcription factor
- bind to cis-acting DNA sequences

RNA Polymerase and the group of protein that directly interact with it are called the **basal transcription apparatus**. This is the apparatus that is directly responsible for transcription.

Basal transcription apparatus - RNA polymerase + general factors; both needed to initiate transcription

Other factors, those that interact directly or through a coactivator with the proteins of the basal transcription apparatus, are also important for transcription. These generally have a positive effect on transcription, but occasionally they can repress gene expression through transcripion. These factors are called **upstream factors**.

Upstream factors - ubiquitous factors that increase the efficiency of transcription initiation; set of factors unique to each promoter

Functions of Upstream Factors

- influence the initiation of transcription by contacting members of the basal apparatus
- promotes assembly of the apparatus
- may bind coactivators that interact with the basal apparatus
- typically bind to TFIID, TFIIB or TFIIA
- TFIID provides various TAFs that can be interacted with; if TAFs are unique to a specific promoter, then the interaction can control promoter specific transcription
- most interactions are positive in nature and induce transcription
- repressors may prevent the building of the basal apparatus

Finally, some factors are turned in a temporal or spatial manner, or directly in response to the environment. These factors provide the final link in controlling gene expression. These are termed **inducible factors**.

Inducible factors - act in the same manner as an upstream factor but their synthesis is regulated in a temporal or spatial manner

Given all of the discussion regarding the basal transcription apparatus, and upstream and inducible factors, we can know arrive at a definition of a promoter. The definition is reflects the interaction of the all of the important proteins and the DNA to which the bind.

Promoter - all the DNA sequences containing binding sites for RNA polymerase and the transcription factors necessary for normal transcription

Translation:

1. Initiation

- The small subunit of the ribosome binds to a site "upstream" (on the 5' side) of the start of the message.
- It proceeds downstream (5' -> 3') until it encounters the start codon AUG. (The region between the mRNA cap and the AUG is known as the 5'-untranslated region [5'-UTR].)
- Here it is joined by the large subunit and a special initiator tRNA.
- The initiator tRNA binds to the P site (shown in pink) on the ribosome.
- In eukaryotes, initiator tRNA carries methionine (Met). (Bacteria use a modified methionine designated fMet.)

2. Elongation

- An aminoacyl-tRNA (a tRNA covalently bound to its amino acid) able to base pair with the next codon on the mRNA arrives at the A site (green) associated with:
    - an elongation factor (called EF-Tu in bacteria; EF-1 in eukaryotes)
    - GTP (the source of the needed energy)
- The preceding amino acid (Met at the start of translation) is covalently linked to the incoming amino acid with a peptide bond (shown in red).
- The initiator tRNA is released from the P site.

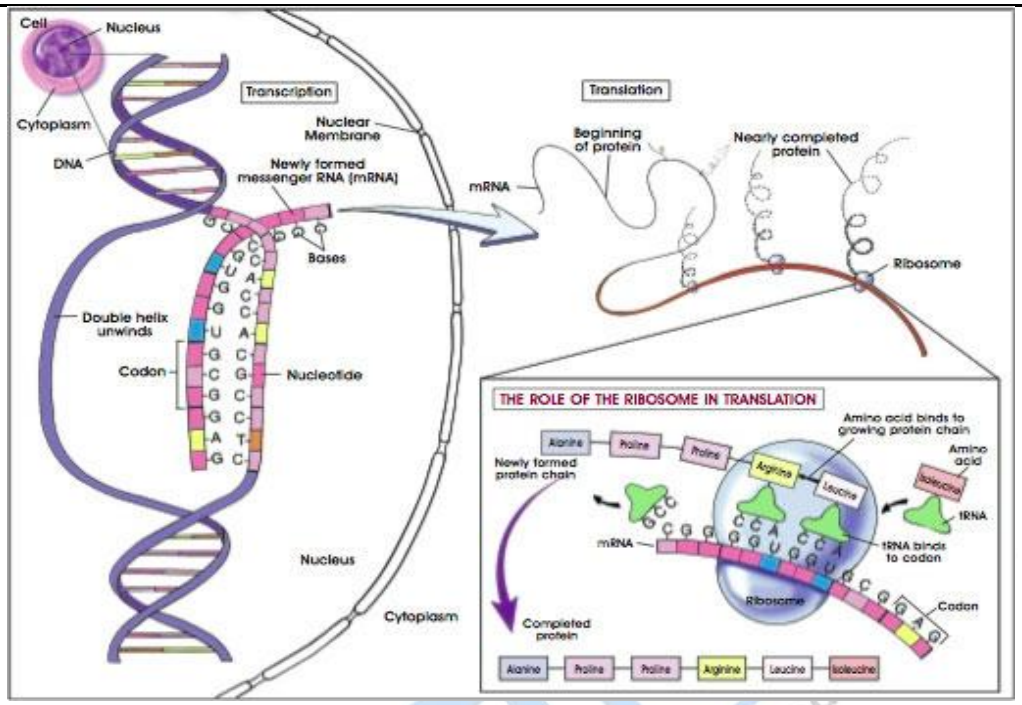
- The ribosome moves one codon downstream.
- This shifts the more recently-arrived tRNA, with its attached peptide, to the P site and opens the A site for the arrival of a new aminoacyl-tRNA.
- This last step is promoted by another protein elongation factor (called EF-G in bacteria; EF-2 in eukaryotes) and the energy of another molecule of GTP.

Note: the initiator tRNA is the only member of the tRNA family that can bind directly to the P site. The P site is so-named because, with the exception of initiator tRNA, it binds only to a peptidyl-tRNA molecule; that is, a tRNA with the growing peptide attached.

The A site is so-named because it binds only to the incoming aminoacyl-tRNA; that is the tRNA bringing the next amino acid. So, for example, the tRNA that brings Met into the interior of the polypeptide can bind only to the A site.

3. Termination

- The end of translation occurs when the ribosome reaches one or more STOP codons (UAA, UAG, UGA). (The nucleotides from this point to the poly(A) tail make up the 3'-untranslated region [3'-UTR] of the mRNA.)
- There are no tRNA molecules with anticodons for STOP codons. However, protein release factors recognize these codons when they arrive at the A site.
- Binding of these proteins —along with a molecule of GTP — releases the polypeptide from the ribosome. The ribosome splits into its subunits, which can later be reassembled for another round of protein synthesis.



Q.3 What is wobble hypothesis?

Ans Wobble Effect

The Wobble effect hypothesis discovered by Frances Crick, states that rules of base pairing are relaxed at the third position, so that a base can pair with more than one complementary base. The Wobble Effect, or sloppy pairing is where the 5' end of an anticodon can shift or "wobble" to allow pairing with more than one nitrogen base on the codon. This happens to minimize the total number of tRNA molecules necessary for translation. Because there are a huge number of three base combinations, if wobble did not exist, there would have to be an equal number of tRNA for every combination. With wobble, though, one tRNA molecule can bindwith multiple codons, as long as the first two bases in the tRNA are correct. Notable Wobbles 5'end of anticodon Pairs with 3' end of codon G > U or C C > G A > U U > A or G I > U,C, or A

Section C

Mendelism

Q.1 Describe Mendel's Laws.

Ans. The principles of heredity were written by the Augustinian monk Gregor Mendel in 1865. Mendel discovered that by crossing white flower and purple flower plants, the result was not a blend. Rather than being a mix of the two, the offspring was purple flowered. He then conceived the idea of heredity units, which he called "factors", one which is a recessive characteristic and the other dominant. Mendel said that factors, later called genes, normally occur in pairs in ordinary body cells, yet segregate during the formation of sex cells. Each member of the pair becomes part of the separate sex cell. The dominant gene, such as the purple flower in Mendel's plants, will hide the recessive gene, the white flower. After Mendel self-fertilized the F1 generation and obtained the 3:1 ratio, he correctly theorized that genes can be paired in three different ways for each trait; AA, aa, and Aa. The capital A represents the dominant factor and lowercase a represents the recessive. (The last combination listed above, Aa, will occur roughly twice as often as each of the other two, as it can be made in two different ways, Aa or aA.)

Mendel stated that each individual has two factors for each trait, one from each parent. The two factors may or may not contain the same information. If the two factors are identical, the individual is called homozygous for the trait. If the two factors have different information, the individual is called heterozygous. The alternative forms of a factor are called alleles. The genotype of an individual is made up of the many alleles it possesses. An individual's physical appearance, or phenotype, is determined by its alleles as well as by its environment. An individual possesses two alleles for each trait; one allele is given by the female parent and the other by the male parent. They are passed on when an individual matures and produces gametes: egg and sperm. When gametes form, the paired alleles separate randomly so that each gamete receives a copy of one of the two alleles. The presence of an allele doesn't promise that the trait will be expressed in

the individual that possesses it. In heterozygous individuals the only allele that is expressed is the dominant. The recessive allele is present but its expression is hidden.

Mendel summarized his findings in two laws; the **Law of Segregation** and the **Law of Independent Assortment**.

Law of Segregation (The "First Law") :

The Law of Segregation states that when any individual produces gametes, the copies of a gene separate, so that each gamete receives only one copy. A gamete will receive one allele or the other. The direct proof of this was later found when the process of meiosis came to be known. In meiosis the paternal and maternal chromosomes get separated and the alleles with the characters are segregated into two different gametes.

Law of Independent Assortment (The "Second Law") :

The Law of Independent Assortment, also known as "Inheritance Law", states that alleles of different genes assort independently of one another during gamete formation. While Mendel's experiments with mixing one trait always resulted in a 3:1 ratio (Fig. 1) between dominant and recessive phenotypes, his experiments with mixing two traits (dihybrid cross) showed 9:3:3:1 ratios (Fig. 2). But the 9:3:3:1 table shows that each of the two genes are independently inherited with a 3:1 ratio. Mendel concluded that different traits are inherited independently of each other, so that there is no relation, for example, between a cat's color and tail length. This is actually only true for genes that are not linked to each other.

Independent assortment occurs during meiosis I in eukaryotic organisms, specifically metaphase I of *meiosis*, to produce a gamete with a mixture of the organism's maternal and paternal chromosomes. Along with chromosomal crossover, this process aids in increasing genetic diversity by producing novel genetic combinations.

Of the 46 chromosomes in a normal diploid human cell, half are maternally-derived (from the mother's egg) and half are paternally-derived (from the father's sperm). This occurs as sexual reproduction involves the fusion of two haploid

gametes (the egg and sperm) to produce a new organism having the full complement of chromosomes. During gametogenesis - the production of new gametes by an adult - the normal complement of 46 chromosomes needs to be halved to 23 to ensure that the resulting haploid gamete can join with another gamete to produce a diploid organism. An error in the number of chromosomes, such as those caused by a diploid gamete joining with a haploid gamete, is termed aneuploidy.

In independent assortment the chromosomes that end up in a newly-formed gamete are randomly sorted from all possible combinations of maternal and paternal chromosomes. Because gametes end up with a random mix instead of a pre-defined "set" from either parent, gametes are therefore considered assorted independently. As such, the gamete can end up with any combination of paternal or maternal chromosomes. Any of the possible combinations of gametes formed from maternal and paternal chromosomes will occur with equal frequency. For human gametes, with 23 pairs of chromosomes, the number of possibilities is 223 or 8,388,608 possible combinations. The gametes will normally end up with 23 chromosomes, but the origin of any particular one will be randomly selected from paternal or maternal chromosomes. This contributes to the genetic variability of progeny.

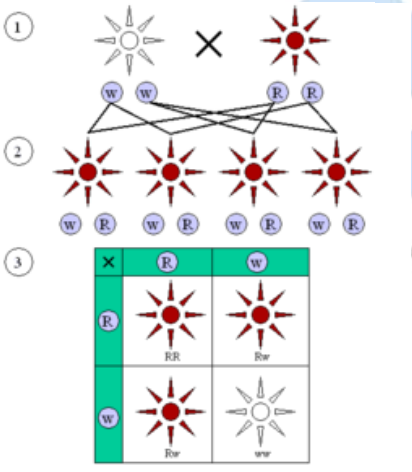


Figure 1: Dominant and recessive phenotypes.
(1) Parental generation. (2) F1 generation. (3) F2 generation. Dominant (red) and recessive

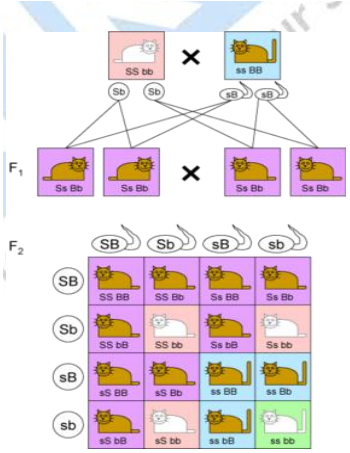


Figure 2: The genotypes of two independent traits show a 9:3:3:1 ratio in the F2 generation. In this example, coat color is indicated by **B** (brown, dominant) or **b** (white) while tail length is indicated by **S** (short, dominant) or **s** (long). When parents are homozygous for

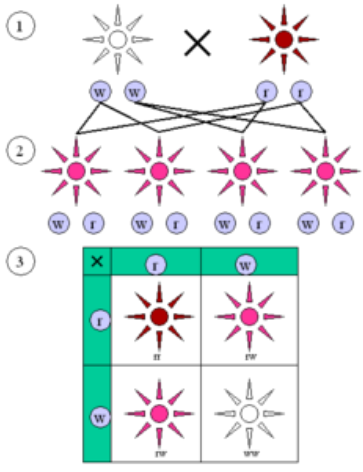


Figure 3: The color alleles of Mirabilis jalapa are not dominant or recessive. (1) Parental generation. (2) F1 generation. (3) F2 generation.

(white) phenotype look alike in the F1 (first) generation and show a 3:1 ratio in the F2 (second) generation	each trait ('*SSbb* ***and*** *ssBB*), their children in the F1 generation are heterozygous at both loci and only show the dominant phenotypes. If the children mate with each other, in the F2 generation all combination of coat color and tail length occur: 9 are brown/short (purple boxes), 3 are white/short (pink boxes), 3 are brown/long (blue boxes) and 1 is white/long (green box).
	The "red" and "white" allele together make a "pink" phenotype, resulting in a 1:2:1 ratio of red:pink:white in the F2 generation.

Chromosomal Mutations

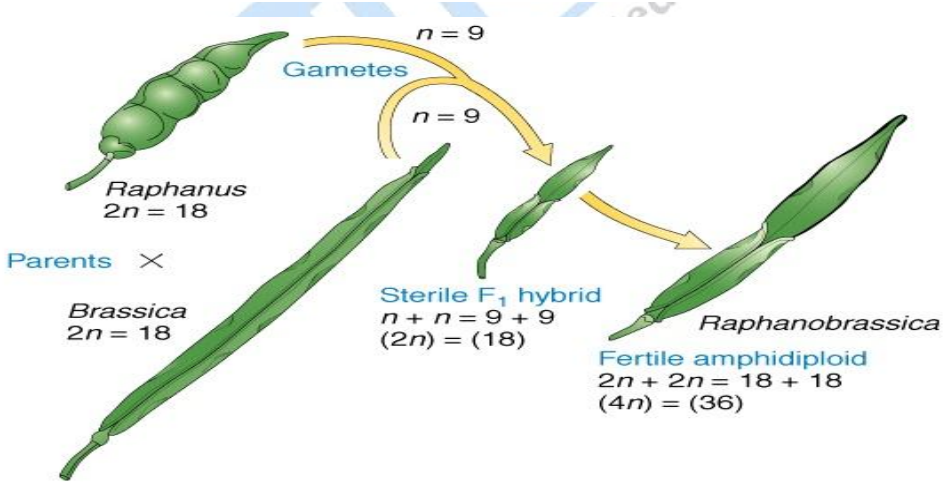
Q.2 Describe polyploidy.

Ans. Polyploidy

The occurrence of related forms possessing chromosome numbers which are multiples of a basic number (n), the haploid number. Forms having 3n chromosomes are triploids; 4n, tetraploids; 5n, pentaploids, and so on. Autopolyploids are forms derived by the multiplication of chromosomes from a single diploid organism. As a result the homologous chromosomes come from the same source. These are distinguished from allopolyploids, which are forms derived from a hybrid between two diploid organisms. As a result, the homologous chromosomes come from different sources. About one-third of the species of vascular plants have originated at least partly by polyploidy, and as many more appear to have ancestries which involve ancient occurrences of polyploidy. The condition can be induced artificially with the drug colchicine and the production of polyploid individuals has become a valuable tool for plant breeding.

In animals, most examples of polyploidy occur in groups which are parthenogenetic, or in species which reproduce asexually by fission. See Breeding (plant), Chromosome aberration, Gene, Genetics, Plant evolution, Speciation

In addition to polyploid organisms in which all of the body cells contain multiples of the basic chromosome number, most plants and animals contain particular tissues that are polyploid or polytene. Both polyploid and polytene cells contain extra copies of DNA, but they differ in the physical appearance of the chromosomes. In polytene cells the replicated copies of the DNA remain physically associated to produce giant chromosomes that are continuously visible and have a banded pattern. The term polyploid has been applied to several types of cells: multinucleate cells; cells in which the chromosomes cyclically condense but do not undergo nuclear or cellular division (this process is termed endomitosis); and cells in which the chromosomes appear to be continually in interphase, yet the replicated chromosomes are not associated in visible polytene chromosomes.



Cytoplasmic Inheritance

Q.3 Cytoplasmic inheritance.

Ans. When most people think of DNA, they think of it as stored in chromosomes that replicate inside the nucleus.[citation needed] Extranuclear inheritance is the transmission of genes that occur outside the nucleus. It is found in most

eukaryotes and is commonly known to occur in cytoplasmic organelles such as mitochondria and chloroplasts or from cellular parasites like viruses or bacteria.

Contents

Extranuclear Inheritance of Organelles :

Mitochondria are organelles which function to produce energy as a result of cellular respiration. Chloroplasts are organelles which function to produce sugars via photosynthesis in plants and algae. The genes located in mitochondria and chloroplasts are very important for proper cellular function, yet the genomes replicate independently of the DNA located in the nucleus, which is typically arranged in chromosomes that only replicate one time preceding cellular division. The extranuclear genomes of mitochondria and chloroplasts however replicate independently of cell division. They replicate in response to a cells increasing energy needs which adjust during that cells lifespan. Since they replicate independently, genomic recombination of these genomes is rarely found in offspring contrary to nuclear genomes, in which recombination is favored.

Extranuclear Inheritance of Parasites :

Extranuclear transmission of viral genomes and symbiotic bacteria is also possible. An example of viral genome transmission is perinatal transmission. This occurs from mother to fetus during the perinatal period, which begins before birth and ends about 1 month after birth. During this time viral material may be passed from mother to child in the bloodstream or breastmilk. This is of particular concern with mothers carrying HIV or Hepatitis C viruses (2,3). Examples of cytoplasmic symbiotic bacteria have also been found to be inherited in organisms such as insects and protists.

Types of Extranuclear Inheritance :

Three general types of extranuclear inheritance exist. These are vegetative segregation, uniparental inheritance and biparental inheritance.

- Vegetative segregation results from random replication and partitioning of cytoplasmic organelles. It occurs with chloroplasts and mitochondria during mitotic cell divisions and results in daughter cells that contain a random sample of the parent cell's organelles. An example of vegetative segregation is with mitochondria of asexually replicating yeast cells (8).
- Uniparental inheritance occurs in extranuclear genes when only one parent contributes organellar DNA to the offspring. A classic example of uniparental gene transmisison is the maternal inheritance of human mitochondria. The mother's mitochondria are transmitted to the offspring at fertilization via the egg. The father's mitochondrial genes are not transmitted to the offspring via the sperm. Very rare cases which require further investigation have been reported of paternal mitochondrial inheritance in humans, in which the father's mitochondrial genome is found in offspring. Chloroplast genes can also inherit uniparentally during sexual reproduction. They are historically thought to inherit maternally, but paternal inheritance in many species is increasingly being identified. The mechanisms of uniparental inheritance from species to species differ greatly and are quite complicated. For instance, chloroplasts have been found to exhibit maternal, paternal and biparental modes even within the same species.
- Biparental inheritance occurs in extranuclear genes when both parents contribute organellar DNA to the offspring. It may be less common than uniparental extranuclear inheritance, and usually occurs in a permissible species only a fraction of the time. An example of biparental mitochondrial inheritance is in the yeast, [[Saccharomyces cerevisiae]]. When two haploid cells of opposite mating type fuse they can both contribute mitochondria to the resulting diploid offspring

□□□

Glossary

- Acellular: -Without cellular organization.
- Amphipathic:- Molecules with hydrophobic and hydrophilic ends e.g. phospholipids.
- denosine triphosphate (ATP):- An organic compound rich in energy having there phosphate groups joined by high energy bonds .On hydrolysis it produces adenosine diphosphate ,-PO_4 and energy.
- Aneuploids: - The organisms having chromosomes of a set present in different numbers.
- Cell: - the structural and functional unit of all living organisms (plants and animals) which is a mass of protoplasm enclosed by plasma –membrane and contains one to many nuclei.
- Cell division:-The process of division of pre-existing (parental) cell into two new daughter cell.
- Chiasma (Pl. chiasmata):-These are the point of contact and interchange between the chromatids to two homologous chromosomes of a pair observed at diplotene stage of the meiosis. These are points where crossing over takes place.
- Codon: - A sequence of three nucleotides in one of the two strands of a DNA double helix, or in a molecule of messenger RAN, that determines which of 20 amino acids will be inserted at a particular position in a polypeptide chain.
- Crossing over: - Exchange of segments of homologous chromosomes at meiosis.
- Diplotene :-A stage in the first prophase of meiosis , in which each of the synaptic chromosomes get doubled by splitting .It comes after pachytene and is followed by diakinesis .
- Duplication:-The presence of a block of genes twice in a particular chromosome or the same chromosome complement represented twice in an organism.
- Eukaryotic cell: - A type of cell which possesses a well defined nuclear membranes.

- Genome: - The total complement of genes of an organism.
- Glycolysis:-Anaerobic process of glucose dissimilation to pyruvic acid or latic acid.
- Heterochromatin: - Darkly stained part of the chromatin in the interphase nucleus which represents the condensed chromatin and the results due to failure of its conversion into a nuclear reticulum.
- Linkage:-The tendency of alleles of different characters to be inherited together to the next generation.
- Meiosis:-Process of cell division where tow cell divisions occur in succession with duplication of chromosomes only once .Thus four cells are formed ,each with half the number of chromosomes as present in the parent cell.
- Nucleotide: - the smallest unit of nucleic acid (DNA or RAN) formed of a molecule of phosphoric acid, suger and a nitrogenous base(either a purine or a pyrimidine).
- Osmosis :-The passage of a fluid through a semi-permeable membrane due to osmotic pressure.
- Prokaryotic cell:-A type of cell in which the nuclear substances are not enclosed within a membrane.
- Purine :- Double ring, nitrogen containing base which is an important component of DNA and RNA and certain other biologically active substances. Two purines , the adenine and guanine are found in both DNA and RNA.
- Pyrimidine :- single ring nitrogen containing base that is also a component of DNA and RNA. The eytosine and thymine are the two pyrimidines found in DNA While eytosine and uracil are the two pyrimidines of RNA.
- Transcription :- The transfer of a particular nucleotide sequence from DNA to a completementary sequence in RNA by means of RNA polymerase.
- Translocation: - The exchange of parts between two nonhomologous chromosomes , following breakage, either spontanecous or reduced.

- Unit membrane:- The membrane formed of two layers of lipid molecules sandwiched between the two layers of protein molecules .It forms the outer boundary of almost all the cell organelles.

Multiple Choice Questions

1. Fluid Mosaic model of plasma membrabe was first suggested by:-
   (1) R . Brown
   (2) Danielli and Davson in 1935
   (3)Robertson in 1959
   (4) Singer and Nicolson in 1972
   Ans (4)

2. All cells come From pre- existing cells was first given by:-
   (1) M. J. Schleiden
   (2) Theodore Schwann
   (3) H.J. Dutrochet
   (4) Rudolf Virchow
   Ans(4)

3. Mitochondria were first observed by:-
   (1) Robert Brown in 1990
   (2) Attman in 1986
   (3) Benda in 1897
   (4) None of the above
   Ans(2)

4. If a bacteriophage having S^{35} infects a normal bacterium growing on normal medium the bacteriophages produced after the death of bacterium will:-
   (1) Incorporate S^{35} into their particles.
   (2) Not incorporate S^{35} into their particles.
   (3) Incorporate S^{35} into their protein coat
   (4) Incorporate S^{35} into their nucleic acid
   Ans(2)

5. Main amino acids in the plasma membrane are:-
   (1)Arginine and lysine (2) Histidine and glycine
   (3)Tryptophan and alanine (4) Methionine and Tryptophan
   Ans(1)

6. Lignin is a polymer of :-
(1) Galactouronic acid (2) Xylose (3) Glucose (4) Fructose
Ans(2)

7. Mitochondrial cristae are sites of:-
(1) Breakdown of macromolecules (2) Protein synthesis
(3) Phosphorylation of flavoprotains (4)Oxidation reduction reaction
Ans (4)

8. The cell wall of bacteria is composed of :-
(a)Chitin (2)Murein (3)Cellulose (4)Suberin
Ans(2)

9. Smallest cell organelles are
(1) Microsome (2) lysosomes (3) Dictyosomes (4) Ribosomes
Ans(4)

10. Polytene chromosomes are formed due to
(1) Mitosis (2) Meiosis (3) Endomitosis (4) Endomixis
Ans(3)

11. Which of the following represents the correct order in prophase :-
(1) Zygotene , Diplotene , Pachytene , Leptotene , Diakinesis
(2) Diakinesis , Diplotene Leptotene , Pachytene , Zygotene
(3) Leptotene , Zygotene , Pachytene, Diplotene , Diakinesis
(4) Pachytene , Leptotene , Zygotene , Diplotene, Diakinesis
Ans(3)

12. A red green colour blind male would have inherited the gave for this defect from:-
(1) His mother
(2) His father
(3) Both mother and father
(4) Either mother of father
Ans(1)

13. In a plasmolyed cell , the space between cell wall and cell membrane is filled with:-
(1) Hypertonic solution (2) Hypotonic Solution
(3) Isotonic solution (4) There is no solution in the space

Ans(1)

14. L- shaped chromosomes are also called:-
(1) Acrocentric (2) Telocentric (3) Sub –metacentric (4) None of these
Ans(3)

15. A cell plate is laid during :-
(1) cytokinesis (2) Karyokinesis (3) Interphase (4) None of these
Ans(1)

16. In cell cycle , DNA replication occurs during:-
(1) G_1 phase (2) G_2 Phase (3) Metaphase (4) Anaphase (5) S- Phase
Ans(5)

17. Spindle fibres are made up of :-
(1) Tubulin (2) Humulin (3) Intermediate filament (4) Flagellin
Ans(1)

18. F_1 Particles present in mitochondria are :-
(1) Episome (2) Sphaerosomes (3) Oxysomes (4) Microsomes
Ans(3)

19. If a dihybrid for a quantitative character is crossed to a dominant homozygous. Individual for
the same character , the phenotypic ratio of the progeny would be :-
(1) 1: 1: 1: 1 (2) 1: 2: 1 (3) 3: 1 (4) 13:3
Ans(2)

20. One of the following acts as a an initiator codon:-
(1) U U U (2) U U C (3) A U G (4) A A A
Ans(3)

21. In *Mirabilis* , when two pink flowered varieties were crossed , the progeny had 20 red flowered plants, 41 pink flowered plants and 19 white flowered plants . The inheritance of flower colour in *Mirabilis* was due to :-
(1) Complementary genes (2) Incomplete dominance of a gene
(3) Duplicate genes (4) Epistatic gene
Ans(2)

22. The human beings having x x y or x x y y chromosomes develop :-

(1) Klinefelter's syndrome (2) Turner's syndrome
(3)Down's syndrome (4) None of the abone
Ans (1)

23. One of the following is a specific stain for D N A
(1) Basic fuchsin (2) Fehling's solution
(3) Iodine solution (4) Benedict's reagent
Ans (1)

24. Lampbrush chromosomes are found in :
(1) Salivary gland cells of Drosophila (2) Oocytes of amphibians
(3)Spermatocytesof amphibians (4) Gonads of man
Ans (2)

25. DNA replication occurs through the activity of :-
(1) DNA Polymerase (2) RNA Polymerase
(3) Ribonuclease (4) Deoxyribonuclease
Ans(1)

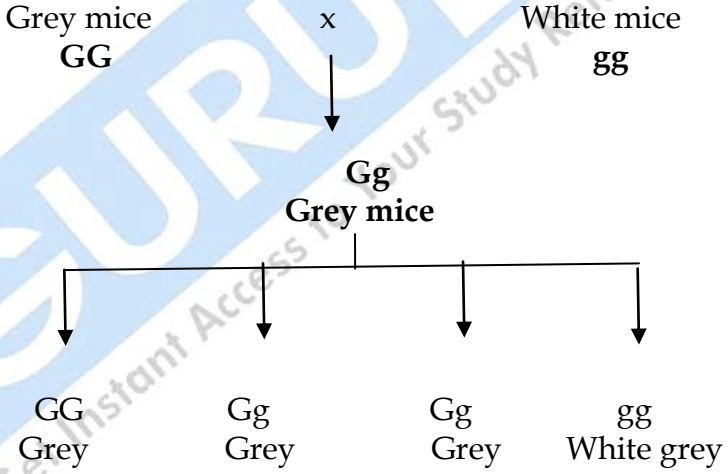
Case study

1. French biologist cue not crossed wild grey coloured mice with white (albino) mice In the first generation all were grey. From many litters he obtained in F_2 198 grey and 72 white mice.

   (a)Propose a hypothesis to explain these results?

   (b)On the basis of hypothesis ,diagram the cross and compare the observed results with those expected.

Ans : In a cross between grey and white only grey mice appear in F_1. It means grey colour is dominant over white .In F2 generation grey and white mice appear in the ratio of 198:72 or 2.75:1. This mean that the cross follows the monohybrid cross of mendel and exhibits phenomenon of segregation and complete dominance. This experiment and result of the cross can be tabulated as follows:-



In the above cross the grey and white are expected to appear in the ratio of 3:1;but in the experiment the ratio is found to be 2.75:1.

B.Sc. (Part I) Examination, 2011
(Faculty of Science)
[Also Common with Subsidiary Paper of B.Sc. (Hons.) Part I]
(Three – Year Scheme of 10+2+3 Pattern)
Zoology
Second Paper
Cell Biology and Genetics

Year – 2011

Time allowed : Three Hour **Maximum Marks : 33**

Question No. 1 part-I is compulsory. Attempt four questions from Part-II selecting at least one question from each section. All questions in Part-II carry equal 6 marks.

Part-I

1. Answer the following question in short (Maximum 25 words) 1 x 9 = 9

(i) What are the desmosomes ?

(ii) Explain the function of centriole ?

(iii) What is phagocytosis ?

(iv) What is inerphase ?

(v) What are exons ?

(vi) What is euchromatain ?

(vii) Explain the process of crossing over

(viii) What do you understand by aneuploidy

(ix) In the context of ABO blood groups, where are the antigens and antibodies present in the blood.

Part-II

Section-A

2. Describe the structure, chemical composition and functions of mitochondria .

3. Draw neat and labeled diagrams of the following : -
   (a) A typical animal cell, as seen by an electron microscope.
   (b) T. s. of flagellum.

4. Write notes on the following
   (a) Sodium pump (b) Polymorphism in lysosomes

Section-B

5. Explain the mechanism of protein synthesis

6 Draw beat and labeled diagrams of the process of meiosis. No description is required

7. Write notes on the following: -
   (a) Different between mitosis and meiosis
   (b) Okazaki fragments.

Section-C

8. What do you understand by linkage? What id its importance? Explain different types of linkages with suitable examples.

9. Discuss mendal`s laws with examples.

10. Write notes on the following:-
    (a) Supplementary genes (b) Rh factor and its significance.

B.Sc. (Part I) Examination, 2010

Zoology

Second Paper

Cell Biology and Genetics

Year – 2010

Time allowed : Three Hour **Maximum Marks : 33**

Question No. 1 part-I is compulsory. Attempt four questions from Part-II selecting at least one question from each section. All questions in Part-II carry equal 6 marks.

Part-I

1. Answer the following question in short (Maximum 25 words): 1 x 9 = 9

   (i) Give two exceptions of cell theory.

   (ii) Who has propounded the fluid mosaic model of plasma membrane?

   (iii) Which stage of cell cycle is suitable for chromosome study?

   (iv) Which are termination codons?

   (v) What type of cell division takes place during grafting and cell culture?

   (vi) Explain in brief the law of incomplete dominance.

   (vii) Give two example of translocation mutation.

   (viii) What is linkage?

   (ix) Why in cytoplasm inheritance, are the material characters inherited in offspring?

Part-II

Section-A

2. Differentiate between prokaryotic and eukaryotic cell.

3. Draw neat and labeled diagram of plasma membrance.
4. Explain biogenesis of mitochondria.

Section-B

5. Write details account on structure and function of nuclear envelope.
6. Explain the process of DNA replication in eukaryotic cell.
7. Write short notes on the following:
   (a) Call cycle
   (b) Genetic code

Section-C

8. Explain the brief the work of Mendel and write their significance.
9. Explain chromosomal mutation with suitable example.
10. Write short notes on following:
    (i) Epitasis
    (ii) ABO blood groups

B.Sc. (Part I) Examination, 2009

Zoology

Second Paper

Cell Biology and Genetics

Year – 2009

Time allowed : Three Hour **Maximum Marks : 33**

Question No. 1 part-I is compulsory. Attempt four questions from Part-II selecting at least one question from each section. All questions in Part-II carry equal 6 marks.

Part-I

1. Answer the following question in short (Maximum 25 words): 1 x 9 = 9

   (i) Who has propounded the fluid mosaic model of plasma membrance?

   (ii) What is active transport?

   (iii) Who has discovered the ribosome in animal cell?

   (iv) What is Barr body? Write its location in the cell.

   (v) In which animals are the polytene chromosomes found?

   (vi) What is central dogmaof protein synthesis?

   (vii) In which chromatids does crossing over take place ?

   (viii) Give two examples of lethal genes.

   (ix) Write factors responsible for imduced mutation.

Part-II

Section-A

2. Write short notes on the following:

   (i) Plasma membrance

(ii) Passive transport

3. Describe chemiosmotic hypothesis of Mitchell.
4. Describe in brief:
   (i) Rough endoplasmic reticulum
   (ii) Lysosomes

Section-B

5. Draw neat, labeled diagram of D.N.A.
6. Explain the experiment of Mselson and Stahl.
7. Describe the process of protein synthesis in eukaryotic cell.

Section-C

8. How many contrasting characters were taken by Mendel for his experiment to give law of independent assortment? Give genotypic ratio of F2 generation.
9. Describe in brief:
   (i) Chromosome mapping
   (ii) Linkage in Drosophila
11. Describe multiple allele inheritance with suitable examples.

B.Sc. (Part I) Examination, 2008

Zoology

Second Paper

Cell Biology and Genetics

Year – 2008

Time allowed : Three Hour **Maximum Marks : 33**

Question No. 1 part-I is compulsory. Attempt four questions from Part-II selecting at least one question from each section. All questions in Part-II carry equal 6 marks.

Part-I

1. Answer the following question in short (Maximum 25 words): 1 x 9 = 9

   (i) Give three characteristics of mitochondrial DNA.

   (ii) What is unit membrane concept?

   (iii) Differentiate active and passive transports.

   (iv) Give three features of Prokaryotes.

   (v) What is erythroblastosis feetalis?

   (vi) Give three characteristics of genetic code.

   (vii) What are high energy compounds?

   (viii) Give three features of Lampbrush chro-mosome.

   (ix) What are introns and exons?

Part-II

Section-A

2. Write short notes on the following:

   (i) Cell theory. (ii) Cytoskeleton

3. Describe the structure, functions and biogenesis of mitochondria.

4. Write short notes on the following:
   (i) Golgi body (ii) Ribosome

Section-B

5. What are chromosomes? Describe the detail structure of the eukaryotic chromosome with the help of nucleosome concept.
6. Write short notes on the following:
   (i) DNA replication on the following:
   (ii) Lampbrush chromosome.
7. Write short notes on the following:
   (i) Call cycle (ii) Transcription

Section-C

8. Explain in brief Mendel's laws of inheritance. What is test corss.
9. Write short notes on any two of the following:
   (i) Chromosomal mutations (ii) Polyploidy
   (ii) Multiple gene inheritance
10. Explain in brief cytoplasmic inheritance.

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Notes

Notes