ANNAI VAILAKANNI ARTS AND SCIENCE COLLEGE,
THANJAVUR – 7.

DEPARTMENT OF ZOOLOGY

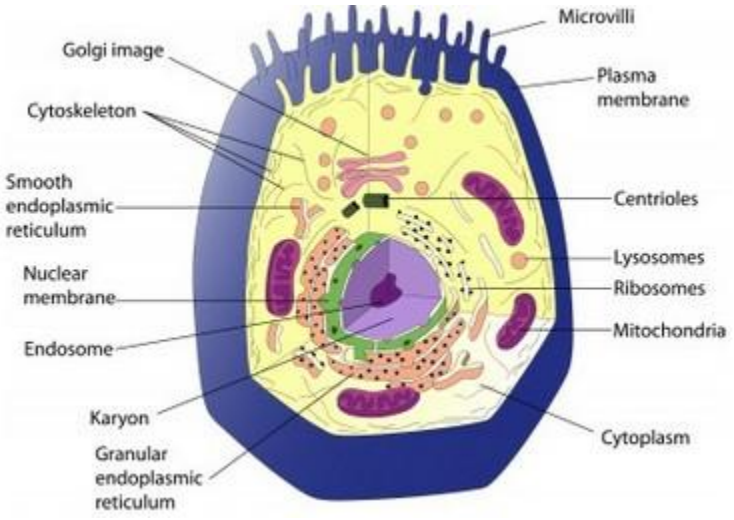
CELL AND MOLECULAR BIOLOGY

SEMESTER –IV-16SCCZO4

Dr.P.SANGEETHA
Head, Department of Zoology

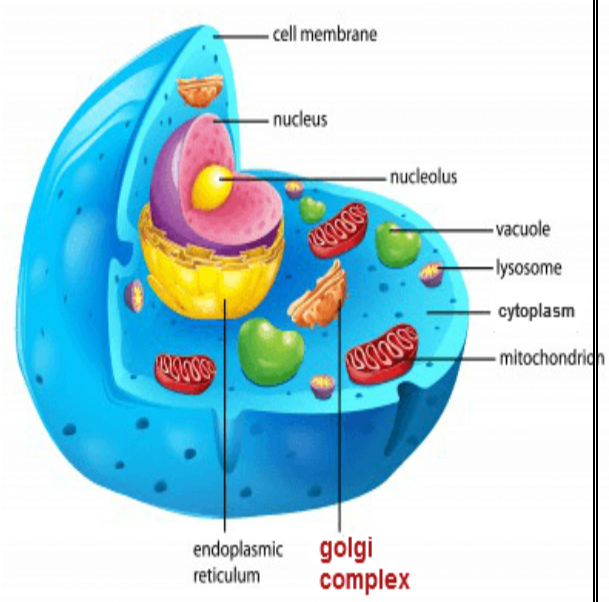
Ultra structure of Animal cell

Animal cells are eukaryotic cells, the nucleus and other organelles of the cell are bound by membrane.



Cell membrane

1. It is a semi-permeable barrier, allowing only a few molecules to move across it.
2. An electron microscopic study of cell membrane shows the lipid bi-layer model of the plasma membrane, it also known as the fluid mosaic model.
3. The cell membrane is made up of phospholipids which has polar (hydrophilic) heads and non-polar (hydrophobic) tails.



Cytoplasm

1. The fluid matrix that fills the cell is the cytoplasm.
2. The cellular organelles are suspended in this matrix of the cytoplasm.
3. This matrix maintains the pressure of the cell, ensures the cell doesn't shrink or burst.

Nucleus

1. Nucleus is the house for most of the cells genetic material- the DNA and RNA.
2. The nucleus is surrounded by a porous membrane known as the nuclear membrane.
3. The RNA moves in/out of the nucleus through these pores.
4. Proteins needed by the nucleus enter through the nuclear pores.
5. The RNA helps in protein synthesis through transcription process.

Dr.P.SANGEETHA, Head, Department of Zoology

6. The nucleus controls the activity of the cell and is known as the control center.
7. The nucleolus is the dark spot in the nucleus, and it is the location for ribosome formation.

Ribosomes

1. Ribosomes are the site for protein synthesis where the translation of the RNA takes place.
2. As protein synthesis is very important to the cell, ribosomes are found in large number in all cells.
3. Ribosomes are found freely suspended in the cytoplasm and also are attached to the endoplasmic reticulum.

Endoplasmic reticulum

1. ER is the transport system of the cell. It transports molecules that need certain changes and also molecules to their destination.
2. ER is of two types, rough and smooth.
3. ER bound to the ribosomes appears rough and is the rough endoplasmic reticulum; while the smooth ER does not have the ribosomes.

Lysosomes

1. It is the digestive system of the cell.
2. They have digestive enzymes helps in breakdown the waste molecules and also help in detoxification of the cell.
3. If the lysosomes were not membrane bound the cell could not have used the destructive enzymes.

Centrosomes

1. It is located near the nucleus of the cell and is known as the 'microtubule organizing center' of the cell.
2. Microtubules are made in the centrosome.
3. During mitosis the centrosome aids in dividing of the cell and moving of the chromosome to the opposite sides of the cell.

Vacuoles

1. They are bound by single membrane and small organelles.
2. In many organisms vacuoles are storage organelles.
3. Vesicles are smaller vacuoles which function for transport in/out of the cell.

Golgi bodies

1. Golgi bodies are the packaging center of the cell.
2. The Golgi bodies modify the molecules from the rough ER by dividing them into smaller units with membrane known as vesicles.
3. They are flattened stacks of membrane-bound sacs.

Mitochondria

1. Mitochondria are the main energy source of the cell.
2. They are called the power house of the cell because energy (ATP) is created here.
3. Mitochondria consist of inner and outer membrane.

4. It is spherical or rod shaped organelle.
5. It is an organelle which is independent as it has its own hereditary material.

Peroxisomes

1. **P**eroxisomes are single membrane bound organelle that contain oxidative enzymes that are digestive in function.
2. They help in digesting long chains of fatty acids and amino acids and help in synthesis of cholesterol.

Cytoskeleton

1. It is the network of microtubules and microfilament fibres.
2. They give structural support and maintain the shape of the cell.
3. Cilia and Flagella
4. Cilia and flagella are structurally identical structures.
5. They are different based on the function they perform and their length.
6. Cilia are short and are in large number per cell while flagella are longer and are fewer in number.
7. They are organelles of movement.
8. The flagellar motion is undulating and wave-like whereas the ciliary movement is power stroke and recovery stroke.

Functions of the Animal Cell

1. **Cell Nucleus** - Cell nucleus is referred to as the control center of the cell. The genetic material of the organism is present in the cell. The replication of DNA and synthesis of RNA occurs in the nucleus of the cell. It also regulates the activities of the other cellular organelles.

2. **Mitochondria** - The mitochondria is referred to as the power house of the cell. Its main function if to produce energy for cell by the process of cellular respiration. The energy produced is ATP.

3. **Endoplasmic Reticulum** - It is a network for transportation of certain substances in and out of the nucleus.

4. **Golgi apparatus** - It is involved with processing and packaging of the molecules that are synthesized by the cells. The crude proteins that are passed on by the ER to the apparatus are developed by the Golgi apparatus into primary, secondary, and tertiary proteins.

5. **Ribosomes** - The function of ribosomes is protein synthesis.

6. **Lysosomes** - They are referred to as the suicide bags of the cell. They have digestive enzymes and are involved in clearing the unwanted waste materials from

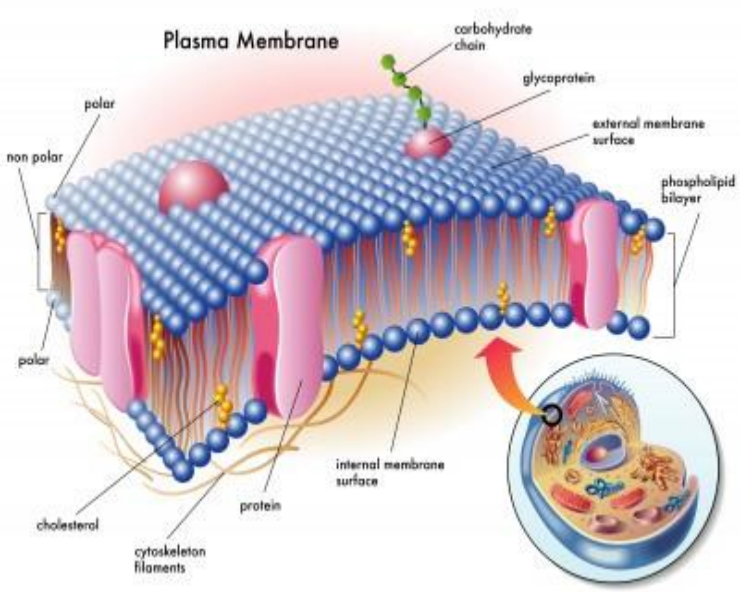
the cell. They also engulf damaged materials like the damaged cells, and invading microorganisms and digest food particles.

7. **Vacuole** - They are large storage organelles. They store excess food or water.

8. The animal cells perform variety of activities by the aid of the cellular organelles. These cells function as a unit and the cells together form tissues. A group goes tissues with similar function form an organ and a group of organ of specific function to perform becomes an organ system. Thus, the microscopic cells from the basic unit for the activities and coordination and help survival of the organism.

Plasma Membrane

The biological membrane, which is present in both eukaryotic and prokaryotic cell. It is also called as cell membrane as it is works as a barrier between the inner and outer surface of a cell. In animal cells, the plasma membrane is present in the outer most layer of the cell and in plant cell it is present just beneath the cell wall.



Plasma Membrane Definition

Plasma membrane can be defined as a biological membrane or an outer membrane of a cell, which is composed of two layers of phospholipids and embedded with proteins. It is a thin semi permeable membrane layer, which surrounds the cytoplasm and other constituents of the cell.

Structure of Plasma Membrane

Plasma Membrane Structure

1. It is the boundary, which separates the living cell from their non-living surroundings.
2. It is the phospholipids bilayer.
3. Plasma membrane is an amphipathic, which contains both hydrophilic heads and hydrophobic tails.

4. It is a fluid mosaic of lipids, proteins and carbohydrate.
5. It is lipid bilayer, which contains -two layers of phospholipids, phosphate head is polar (water loving), fatty acid tails non-polar (water fearing) and the proteins embedded in membrane.

Components of Plasma Membrane

The main components of plasma membrane include

1. Proteins like glycoprotein, which are used for cell recognition and act as receptors and antigens.
2. Proteins like glycolipids are attached to phospholipids along with the sugar chains.
3. Lipids with short chain of carbohydrates are attached on the extracellular side of the membrane.
4. Phospholipid Bilayer - which are made up of phosphates and lipids? They create a partially permeable membrane, which allows only certain substances to diffuse through the membrane.
5. Cholesterol – it maintains the fluidity of cell surface membrane.

THE FLUID MOSAIC MODEL

The fluid mosaic model was first proposed by S. J. Singer and G. L. Nicolson in 1972 to describe the structure of cell membranes (Singer and Nicolson 1972). In this now-accepted theory about cell structure, Phospholipid molecules, each with one hydrophobic, and one hydrophilic end, make up most of the membrane. The hydrophilic heads form the inner and outer surfaces the membrane and the hydrophobic tails, which are repelled by the water within and outside the cell, are sandwiched in between . This is known as the lipid bilayer.

This arrangement is fluid not solid, because the various functional macromolecules embedded in the Phospholipid matrix can move about the surface of the cell. Because of this fluidity such membranes are often called plasma membranes The model is called mosaic because it proposes that the membrane is made up of many different parts, including proteins, carbohydrates, and lipids . This composite structure allows the membrane to perform multiple functions. For example, certain embedded proteins may act as channels allowing particular molecules to pass through the membrane. Others may serve as labels allowing recognition of the cell. Still others may act as sensors that detect various features of the ambient environment of the cell

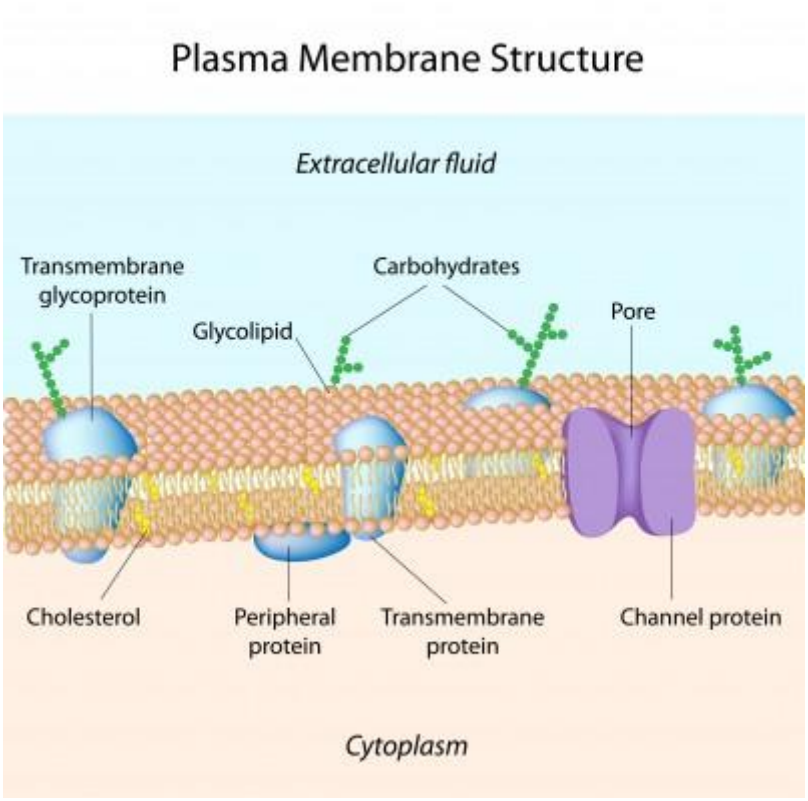
Proteins in Plasma Membrane

In plasma membrane, a protein helps in providing the support and shape to the cell. There are three types of proteins in plasma membrane, which includes

1. Cell membrane receptor proteins- It helps in communication of a cell with their external environment with the help of hormones, neurotransmitters and other signaling molecules.
2. Transport proteins - It helps in transporting molecules across cell membranes through facilitated diffusion. For example globular proteins.
3. Glycoprotein - It helps in cell to cell communications and molecule transport across the membrane.

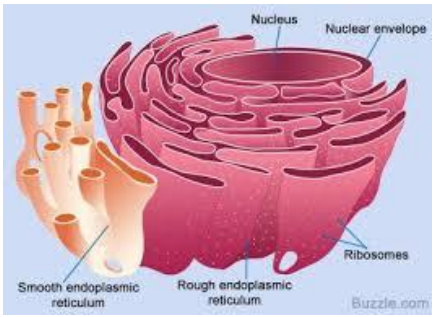
Function of Plasma Membrane

1. It separates the contents of the cell from its outside environment and it regulates what enters and exits the cell.
2. Plasma membrane plays a vital role in protecting the integrity of the interior of the cell by allowing only selected substances into the cell and keeping other substances out.
3. It also serves as a base of attachment for the cytoskeleton in some organisms and the cell wall in others. Thus the cell membrane supports the cell and helps in maintaining the shape of the cell.
4. The cell membrane is primarily composed of proteins and lipids. While lipids help to give membranes their flexibility and proteins monitor and maintain the cell's chemical climate and assist in the transfer of molecules across the membrane.
5. The lipid bilayer is semi-permeable, which allows only selected molecules to diffuse across the membrane.



Characteristics of Plasma Membrane

Below you could see characteristics of plasma membrane



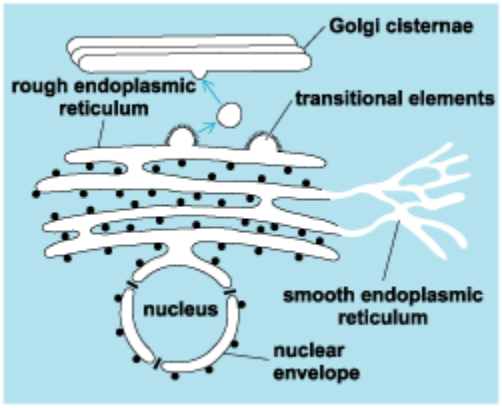
1. The plasma membrane (cell membrane) is made of two layers of phospholipids.
2. The plasma membrane has many proteins embedded in it.
3. The plasma membrane regulates the entry and exit of the cell. Many molecules cross the cell membrane by diffusion and osmosis.
4. The fundamental structure of the membrane is Phospholipid bilayer and it forms a stable barrier between two aqueous compartments.
5. The proteins present in the plasma membrane, act as pumps, channels, receptors, enzymes or structural components.

Endoplasmic reticulum

Endoplasmic Reticulum (Er)

Endoplasmic Reticulum is a complex, finely divided vacuolar system extending from the nucleus throughout the cytoplasm to the margins of the cells. Except in mature mammalian RBC, they are found in all kinds of cells. They are prominently and highly seen in cells synthesizing proteins such as secretary cells of glands.

Morphology and chemistry



They mainly occur in three forms.

1. Cisternae or lamellae form a long, flattened, unbranched units often arranged in parallel stacks and are found in secretary cells.
2. Vesicles are rounded in shape and are abundantly found in cells involved in protein synthesis.
3. Tubules are more diverse in shape and they normally occur in non secretary cells.

Types

1. Rough ER The rough ER has two transmembrane glycoproteins called riboporphyrin I and II for binding ribosomes which are not found in smooth ER. The granules on the rough type are the **ribosomes** attached as polysomes on their outer surface

2. Smooth ER is basically composed of lipoproteins and has **enzymes** mainly for the synthesis of triglycerides, phospholipids and cholesterol on its membranes. Smooth ER is highly modified as sarcoplasmic reticulum in the skeletal and cardiac muscles and as myeloid bodies in the pigmented epithelial cells of the retina.

Functions

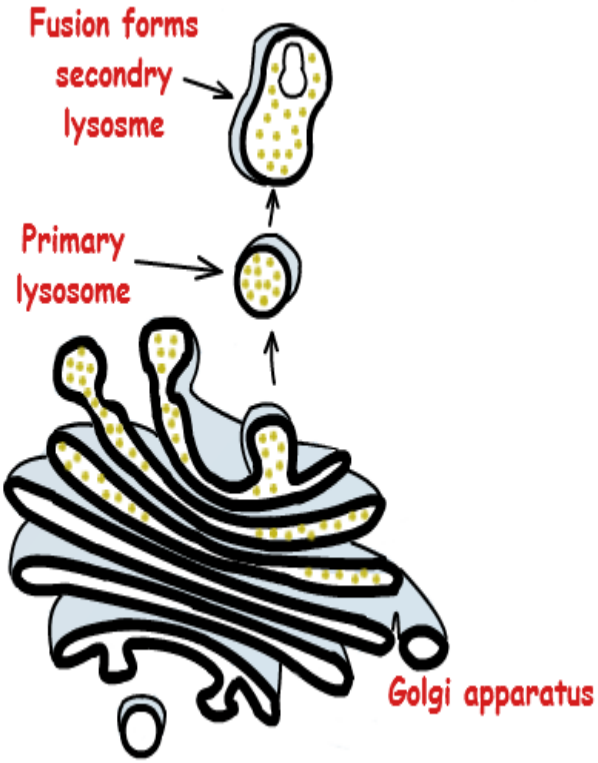
1. **Mechanical support** The ER divides the fluid contents of the cell into compartments thereby providing mechanical support for the colloidal structure of the cytoplasm.
2. **Intracellular exchange** They are involved in intracellular exchange between the matrix and the lumen of the ER by either diffusion or active transport.
3. **Protein synthesis** The polyribosomes bound to the surface of ER actively participate in the protein synthesis.
4. **Secretion of proteins by secretary cells** The proteins synthesized on the RER are either discharged into the ER or are further transferred to the Golgi where they form secretary granules and are then released to the exterior.
5. **Lipid synthesis** Phospholipid biosynthesis is largely confined to ER and is rapidly transferred to the cellular membranes.
6. **Cellular metabolism** The reticulum membrane provides an increased surface area for metabolic activities within the cytoplasm such as synthesis of cholesterol, triglycerides and other lipids.
7. **Intracellular Impulse conduction** In specialized state as sarcoplasmic reticulum in striated muscles, they transmit the impulse or excitation intracellularly from the surface to the myofibrils deep in the muscle cell.
8. **Formation of Nuclear membrane** During the cell division some of the elements of ER contribute in the formation of the new nuclear membrane after karyogamy.

9. **Origin of cell organelles** It is the site for the origin of primary **lysosomes**.
10. **Detoxification** SER is also involved in the detoxification of many endogenous and exogenous compounds.

Golgi body

Golgi apparatus was discovered in the year 1898 by an Italian biologist Camillo Golgi.

It was one of the first cellular organelles to be discovered and observed in detail due to its large



Golgi apparatus

1. The Golgi bodies are elongated, flattened structures called Cisternae and they are stacked parallel to one another.
2. They are bound by a single membrane and are found close to the nucleus.
3. The vesicle formed from the ER fuses with the membrane of the Golgi apparatus.
4. The cavity of the Golgi body is has vessel proteins that are modified for export.

The main function of the Golgi apparatus is sorting, packaging, processing and modification of proteins. It also forms lysosomes and Peroxisomes.

Specialty of Golgi bodies

With the aids of special staining techniques the Golgi bodies were seen as densely stained region of the cytoplasm under the optical microscope. Under the electron microscope the Golgi apparatus is seen to be composed of stacks of flattened structures which contain numerous vesicles containing secretary granules. The newly synthesized proteins, found in the channels of the rough endoplasmic reticulum are moved to the Golgi body where the carbohydrates are added to them and these molecules are enveloped in a part of the Golgi membrane and then the enveloped molecules leave the cell. The Golgi apparatus hence acts as the assembly factory of the cell where the raw materials are directed to the Golgi apparatus before being passed out from the cell.

Six facts about Golgi apparatus

1. The Golgi body receives substances from the endoplasmic reticulum.
2. It is made of a stack of membrane-bound sacs (see picture).
3. It produces vesicles which carry secretions to the surface of the cell.
4. Some modification can take place before substances are secreted.
5. An example of an animal cell with many Golgi bodies is an epithelial cell that secretes mucus.
6. The cell wall of plant cells is exported to the outside of the membrane by Golgi bodies.

Functions

1. **Cell secretion** The secretary materials are concentrated and packed into vesicles and vacuoles which often contain mixture of complexes of components. The secretion may be either continuous, i.e. the secretary product is discharged without storage or may be discontinuous i.e. first stored in secretary or zymogene granules and are then released out.
2. **Formation of Lysosomes** They are involved in the formation of primary **lysosomes**. Since most lysosomal enzymes are glycoproteins, Golgi is been implicited in their glycosidation.
3. **Glycosidation of Lipids and Proteins** It is involved in producing glycolipids and glycoproteins by glycosidation of lipids and proteins.
4. **Sulfation of Carbohydrates** Carbohydrates and proteoglycans are sulfated in the Golgi complex.
5. **Functioning of contractile vacuole** It assists in functioning of contractile vacuoles in certain protozoans.
6. **Formation of acrosome during** Spermiogenesis During the maturation of the **sperm** the Golgi plays a role in the formation of acrosome. In the early stages the Golgi appears as spherical body comprising Cisternae arranged in parallel stacks and numerous small vesicles. As development proceeds the Golgi becomes regular in shape and large vacuoles are formed by dilations of Cisternae sacs. In centre of these large granules a dense granule the proacrosomal granule is present. this continues to grow by a process called accretion and approaches the anterior pole of the nuclear membrane constituting the acrosomal granule. It spreads and finally collapses with the nuclear membrane forming the cap material. It becomes acrosome which lies at the apex of the nucleus and apparently comprises some enzymes involved in the process of fertilization.

Ribosomes

Introduction

Dr.P.SANGEETHA, Head, Department of Zoology

Ribosomes are small particles, present in large numbers in all the living cells. They are sites of protein synthesis. The ribosome word is derived - *'ribo'* from ribonucleic acid and '*somes*' from the Greek word '*soma*' which means '*body'*. The ribosomes link amino acids together in the order that is specified by the messenger RNA molecules.

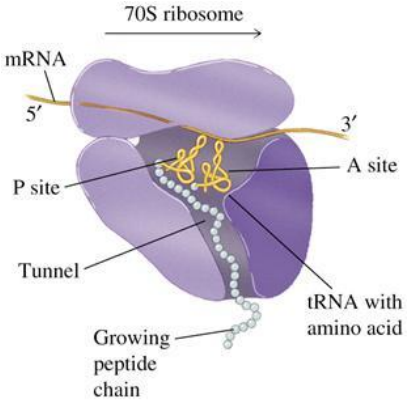
Characteristics of Ribosomes

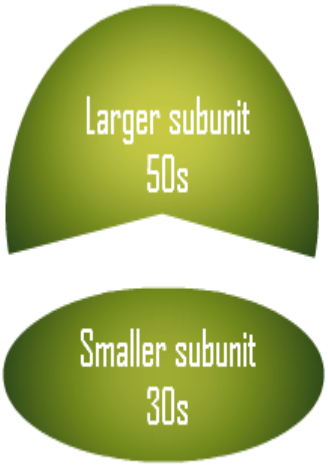
1. The ribosomes are made up of two subunits - a small and a large subunit. The small subunit reads the mRNA while the large subunit joins the amino acids to form a chain of polypeptides.
2. Ribosmal subunits are made of one or more rRNA (ribosomal RNA) molecules and various proteins.
3. The subunits of the ribosome are synthesized by the nucleolus.
4. The subunits of ribosomes join together when the ribosomes attaches to the messenger RNA during the process of protein synthesis.
5. Ribosomes along with a transfer RNA molecule (tRNA), helps to translate the protein-coding genes in mRNA to proteins.

Ribosome Structure

1. Ribosomes in a cell are located in two regions of the cytoplasm.
2. They are found scattered in the cytoplasm and some are attached to the endoplasmic reticulum.
3. When the ribosomes are bound to the ER there is known as the rough endoplasmic reticulum.
4. The bound and the free ribosomes are similar in structure and are involved in protein synthesis.
5. Ribosomes are tiny particles about 200 Ã….
6. Ribosomes are composed of both RNA and proteins.
7. About 37 - 62% of RNA is made up of RNA and the rest is proteins.
8. Ribosome is made up of two subunits. The subunits of ribosomes are named according to their ability of sedimentation on a special gel which the Sevdberg Unit.
9. Prokaryotes have 70S ribosomes each subunit consisting of small subunit is of 30S and the large subunit is of 50S.
10. Eukaryotes have 80S ribosomes each consisting of small (40S) and large (60S) subunit.
11. The ribosomes found in the chloroplasts of mitochondria of eukaryotes consists of large and small subunits bound together with proteins into one 70S particle.
12. The ribosomes share a core structure which is similar to all ribosomes despite differences in its size.

13. The RNA is organized in various tertiary structures. The RNA in the larger ribosomes are into several continuous insertions as they form loops out of the core structure without disrupting or changing it.
14. The catalytic activity of the ribosome is carried out by the RNA; the proteins reside on the surface and stabilize the structure.
15. The differences between the ribosomes of bacterial and eukaryotic are used to create antibiotics that can destroy bacterial infection without harming human cells.





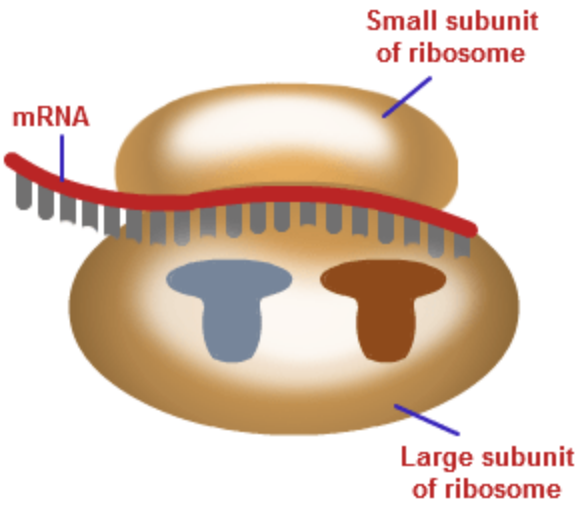
Structure of ribosomal subunit

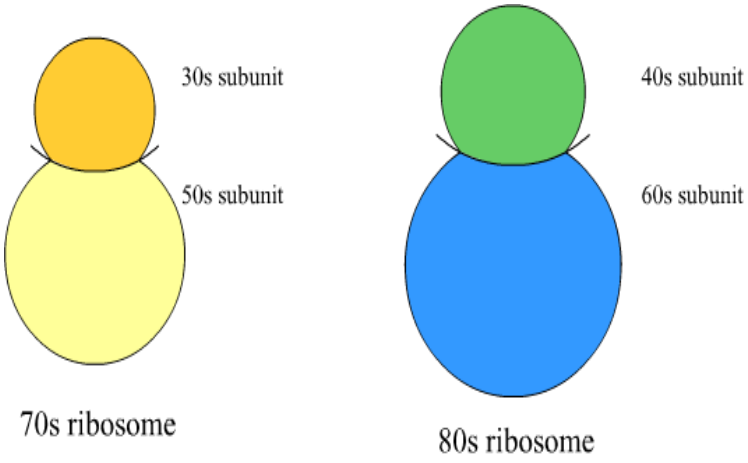
Ribosome Function

The main functions of ribosomes are

1. They assemble amino acids to form specific proteins, proteins are essential to carry out cellular activities.
2. The process of production of proteins, the deoxyribonucleic acid produces mRNA by the process of DNA transcription.
3. The genetic message from the mRNA is translated into proteins during DNA translation.
4. The sequences of protein assembly during protein synthesis are specified in the mRNA.
5. The mRNA is synthesized in the nucleus and is transported to the cytoplasm for further process of protein synthesis.

6. In the cytoplasm, the two subunits of ribosomes are bound around the polymers of mRNA; proteins are then synthesized with the help of transfer RNA.
7. The proteins that are synthesized by the ribosomes present in the cytoplasm are used in the cytoplasm itself. The proteins produced by the bound ribosomes are transported outside the cell.





LYSOSOMES

Definition

They are defined as a spherical cytoplasmic organelle limited by a single layered membrane which is rich in acid hydrolases and devoid of oxidative **enzymes**. Except in mammalian RBC, lysosomes are practically present in all animal cells.

Morphology and chemistry They are polymorphic as they exist in different shapes spherical, irregular or rod like. Unlike other organelles they are covered by single membrane. They contain variety of hydrolytic enzymes and are able to digest most of the biological substance. These enzymes function efficiently in slightly acidic medium and so

called acid hydolases. As long as the lysosomal membrane is intact the enzymes present inside are inactive.

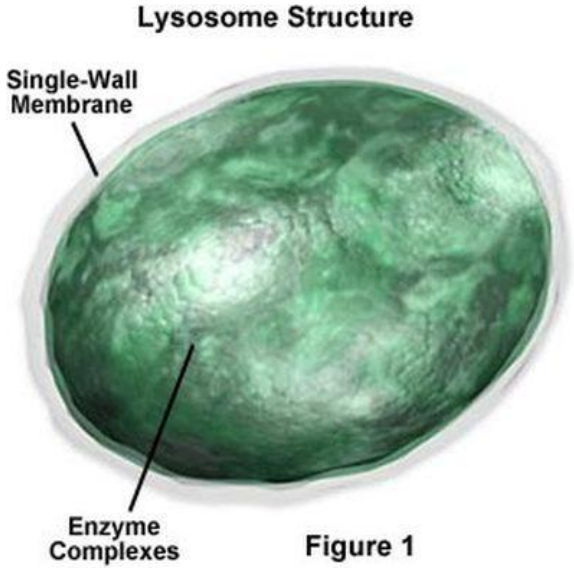
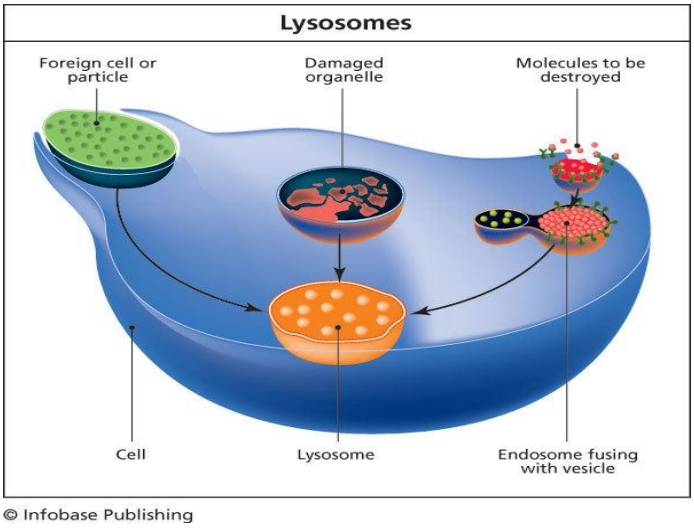


Figure 1



There are four types of lysosomes

1. **Primary lysosomes** They are also called as storage granules and are filled with enzymes acid hydrolases in an inactive state.
2. **Digestive vacuoles** They are also called as heterophagosomes and are formed by the fusion of primary lysosomes with the phagosome which is to be digested or already digested material.
3. **Residual bodies** After the digested end products pass through the lysosomal membrane and enter the cytoplasm, the remaining undigested material with secondary lysosome is called residual body.
4. **Autophage vacuole** When lysosomes contain parts of cell as **mitochondria**, **endoplasmic reticulum** etc. in a process of digestion they are called cytolysosomes or autophages. By this process the cell can degrade its own constituents.

Functions

1. **Heterophagy** Foreign particles undergo digestion within the cell by a process of endocytosis. The endosomes containing foreign particles fuse with lysosomes and thereby are acted upon by their enzymes. The digested material diffuses into the cytoplasm, while the undigested matter is excreted by reverse endocytosis.
2. **Autophagy** Under some conditions the cell organelles like **ribosomes**, endoplasmic reticulum, mitochondria to provide energy or material for the cell are surrounded by lysosome and digested by their enzymes. This lysosome is called autophage lysosome or cytolysosomes and the phenomenon is called Autophagy.
3. **Extracellular digestion** The enzymes from lysosome are released outside the cell by a process of exocytosis where they digest and destroy the surrounding particles.
4. **Crinophagy** The mechanism by which the secretary granules produced in excess of physiological needs are removed is referred as crinophagy. This is seen in exocrine and endocrine glands.
5. **Cellular digestion or Autolysis** The damaged cells are digested by hydrolases released from the rupture of its own lysosomes thereby clearing these cells. The process is called as autolysis and the lysosomes are called as suicidal bags.
6. **Role in Development and Metamorphosis** Lysosomes are important in developmental processes as they trigger cell division and also the tissues that undergo regression after a period of activity are a result of lysosomal activity.
7. **Storage diseases** The absence of lysosomal enzymes due to defective inheritance of its genes result in accumulation of certain substances within the cell. These congenital diseases are called storage diseases.

MITOCHONDRIA

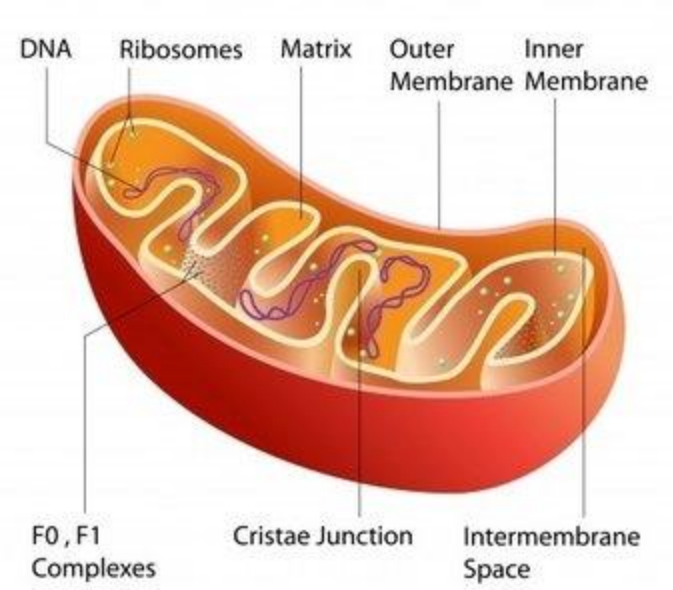
HISTORY

In 1890, mitochondria were first described by Richard Altmann and he called them as bioplasts. Benda in the year 1897 coined the term mitochondrion. In the 1920s, a biochemist Warburg found that oxidative reactions takes place in most tissues in small parts of the cell.

The term 'mitochondrion' is derived from a Greek word 'mitos' which means 'thread' and 'chondrion' which means 'granule'.

Structure of Mitochondria

Mtochondria are rod shaped structure found in both animal and plant cells. It is a double membrane bound organelle. It has the outer membrane and the inner membrane. The membranes are made up of phospholipids and proteins.



The mitochondria range from 0.5 to 1.0 micrometer in diameter.
The components of mitochondria are as follows

Outer membrane

1. It is smooth and is composed of equal amounts of phospholipids and proteins.
2. It has a large number of special proteins known as the porins.
3. The porins are integral membrane proteins and they allow the movement of molecules that are of 5000 Daltons or less in weight to pass through it.
4. The outer membrane is freely permeable to nutrient molecules, ions, energy molecules like the ATP and ADP molecules.

Inner membrane

1. The inner membrane of mitochondria is more complex in structure.
2. It is folded into a number of folds many times and is known as the cristae.
3. This folding help to increase the surface areas inside the organelle.
4. The cristae and the proteins of the inner membrane aids in the production of ATP molecules.
5. Various chemical reactions takes place in the inner membrane of the mitochondria.
6. Unlike the outer membrane, the inner membrane is strictly permeable, it is permeable only to oxygen and ATP and it also helps in regulating transfer of metabolites across the membrane.

Intermembrane space

1. It is the space between the outer and inner membrane of the mitochondria, it has the same composition as that of the cell's cytoplasm.
2. There is a difference in the protein content in the intermembrane space.
3. Small particles adhere to the outside of outer membrane and inside of the inner membrane.

Dr.P.SANGEETHA, Head, Department of Zoology

4. The inner membrane particles are called F1 particles or repeating units or oxysomes or inner membrane subunits or elementary particles.

Matrix

The matrix of the mitochondria is a complex mixture of proteins and enzymes. These enzymes are important for the synthesis of ATP molecules, mitochondrial ribosomes, tRNAs and mitochondrial DNA.

The shape, size and number of mitochondria are variable in a cell and depend on physiological conditions and functions. They may be filamentous, granular, club shaped, vesicular or rod shaped.

The mitochondria have a complete set of enzymes of aerobic respiration, phospholipids metabolism enzymes, fatty acid oxidative enzymes. It contains both **DNA** and **RNA**, which are dissimilar to the nucleic acids found in nucleus within the same cell. They have the ability to replicate and that is why they are called semiautonomous organelles. It can code and synthesize some proteins.

Functions

Functions of mitochondria depends on the cell type in which they are present.

1. The most important function of the mitochondria is to produce energy. The simpler molecules of nutrition are sent to the mitochondria to be processed and to produce charged molecules. These charged molecules combine with oxygen and produce ATP molecules. This process is known as oxidative phosphorylation.
2. Mitochondria help the cells to maintain proper concentration of calcium ions within the compartments of the cell.
3. The mitochondria also help in building certain parts of blood and hormones like testosterone and estrogen.
4. The liver cells mitochondria have enzymes that detoxify ammonia.
5. The mitochondria also play important role in the process of apoptosis or programmed cell death. Abnormal death of cells due to the dysfunction of mitochondria can affect the function of organ
6. Mitochondria is a membrane bound cellular structure and is found in most of the eukaryotic cells.
7. The mitochondria also involved in other cellular activities like signaling, cellular differentiation, cell senescence and also control of cell cycle and cell growth.
8. Mitochondria also affect human health, like mitochondrial disorder and cardiac dysfunction and they also play important role in the aging process.

Importance of Mitochondria

As power plant of the cell The main mitochondrial function is to generate high energy ATP. In cellular respiration while the first stage of glycolysis takes place in cytoplasm, the remaining three stages Kreb's cycle, respiratory chain or electron transport system and oxidation phosphorylating system occur inside the mitochondria. The whole process is based on these three coordinated steps which occur in mitochondria. This process requires oxygen, ADP, phosphate and acetyl coA from the external cytoplasm, while certain enzymes, coenzymes and numerous cofactors and metals involved is found in mitochondria. The outer and inner membranes of mitochondria show variable permeability for allowing passage of various metabolites and end products involved in the whole process.

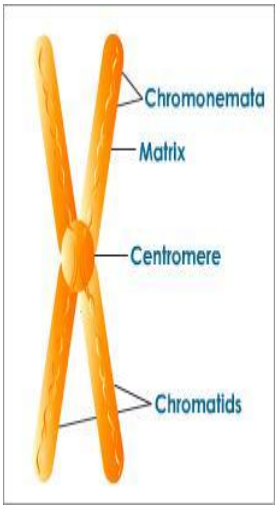
CHROMOSOMES

Definition

A chromosome is a molecule of DNA that is super coiled around proteins so it can fit into the nucleus of a cell.

Introduction

1. The term chromosome is derived from a Greek word 'chrome' which means 'color' and 'soma' which means 'body'.
2. The chromosomes are named so because they are cellular structures or cellular bodies and they are strongly stained by some dyes used in research.
3. Chromosomes play an important role that ensures DNA is copied and distributed accurately in the process of cell division.
4. In most of the organisms chromosomes are arranged in pairs in the nucleus of the cell. We have 23 pairs of chromosomes.
5. The DNA molecule of a single chromosome ranges between 14 and 73 mm in length
6. Chromosomes are organized structure of DNA and proteins found in cells.
7. Chromosomes are passed on from parents to offspring.



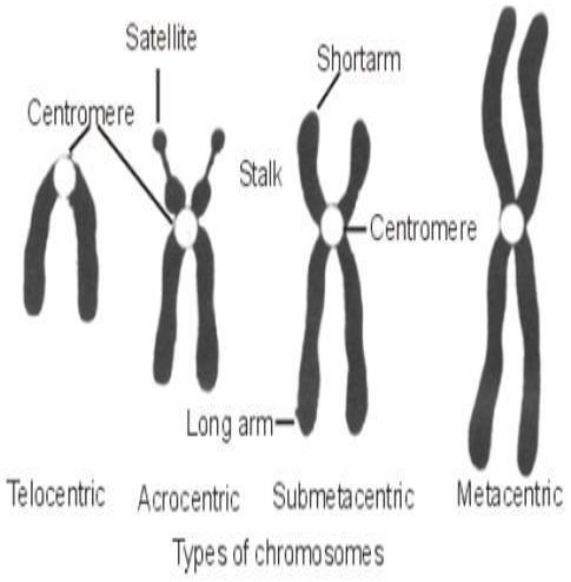
Chromosome Morphology

According to the position of centromere and their shape chromosomes may be classified as

1. **Acrocentric chromosomes** with nearly terminal centromere they are rod like having very small and a very long arm.
2. **Submetacentric chromosomes** centromere divides

chromosome into unequal arms resembling L shape.

3. **Metacentric chromosomes** centromere divides chromosome into equal arms as in V shape.
4. **Telocentric chromosomes** centromere is located at the end of the chromosome.



Types of chromosomes

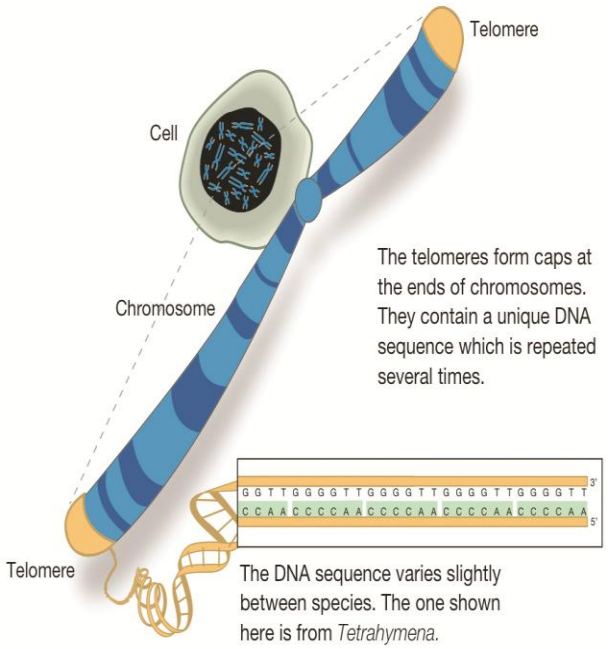
Chromosome Nomenclature

By convention each chromosome arm is divided into regions and each region is subdivided into bands, numbering always from the centromere outwards. At a given point on a chromosome is designated by the chromosome number, the arm (p or q), the region, and the band.

Chromosome Structure

1. They are thread-like structures located inside the nucleus of animal and plant cells.
2. In eukaryotic cells, chromosomes are composed of single molecule of DNA with many copies of five types of histones.
3. Histones are proteins molecules and are rich in lysine and arginine residues, they are positively charged. Hence they bind tightly to the negatively-charged phosphates in the DNA sequence.
4. A small number of non-histone proteins are also present, these are mostly transcription factors. Transcription factors regulate which parts of DNA to be transcribed into RNA.
5. During most of the cell's life cycle, chromosomes are elongated and cannot be observed under the microscope.

6. During the S phase of the mitotic cell cycle the chromosomes are duplicated.



7. At the beginning of mitosis the chromosomes are duplicated and they begin to condense into short structures which can be stained and observed easily under the light microscope.
8. These duplicated condensed chromosomes are known as dyads.
9. The duplicated chromosomes are held together at the region of centromeres.
10. The centromeres in humans are made of about 1-10 million base pairs of DNA.
11. The DNA of the centromere are mostly repetitive short sequences of DNA, the sequences are repeated over and over in tandem arrays.
12. The attached, duplicated chromosomes are commonly called sister chromatids.
13. Kinetochores are the attachment point for spindle fibers which helps to pull apart the sister chromatids as the mitosis process proceeds to anaphase stage. The kinetochores are a complex of about 80 different proteins.
14. The shorter arm of the two arms of the chromosome extending from the centromere is called the p arm and the longer arm is known the q arm.

Types

Autosomes
All of the chromosomes in the body except for sex chromosomes.

Sex Chromosomes

Sex chromosomes differ in form of size, behavior from the ordinary chromosome. The sex chromosomes determine the sex of an individual during reproduction. These sex chromosomes differ between the male and the females. Females have two copies of X chromosome, males have one X chromosome and one Y chromosome. In the process of sexual reproduction in humans, two different gametes fuse to form a zygote.

Homologous Chromosomes

1. The homologous chromosomes are pairs of chromosomes that are approximately of the same length, position of centromere, and pattern of staining, genes for the same characteristic are at a corresponding loci.
2. In an organism one of the homologous chromosome is inherited from the mother and the other from the father.
3. These chromosomes are usually not identical, but they carry the same type of genes
4. Homologous chromosomes are also known as homologs or homologues.
5. Homologous chromosomes are not identical but they are similar.
6. .During the process of mitosis the daughter chromosomes carry the same sequence of nucleotide, assuming there are no errors during the replication process.
7. The genome in diploid organisms is composed of homologous chromosomes

8. One of homologous pair is the maternal chromosome and the other is the paternal chromosome. During the process of meiosis the homologous chromosomes cross over.

Giant Chromosomes

There are chromosomes which are extremely large compared to normal chromosomes. Such chromosomes, called giant chromosomes occur in some animal cells. Two types of giant chromosomes are known

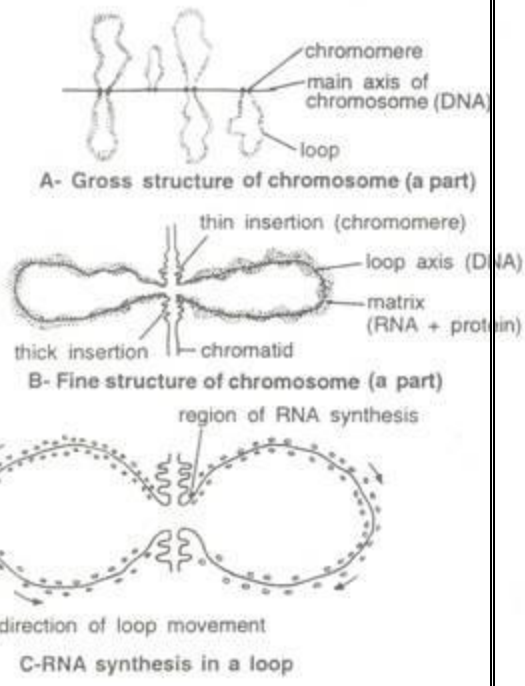


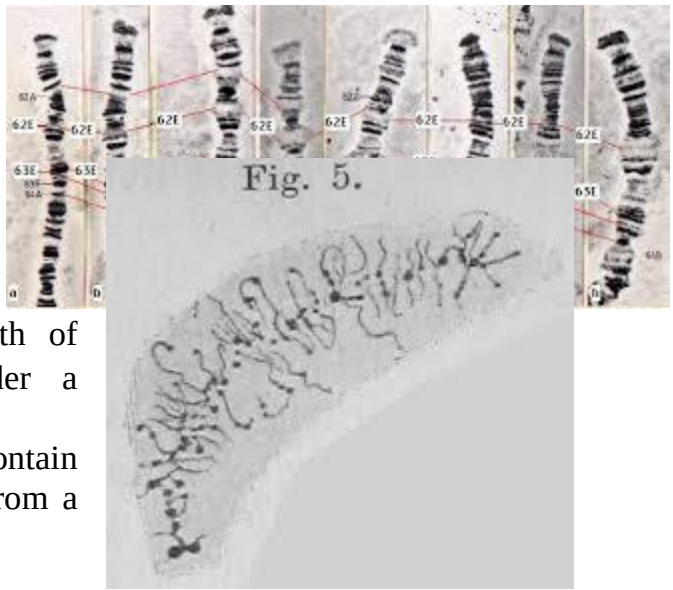
Fig. 11. Lampbrush chromosome.

Lamp Brush Chromosomes

These chromosomes occur in the oocytes (germ cells in the ovary) of amphibians and in some insects.
They are extremely large synapse homologous chromosomes which can be seen in the diplotene stage of prophase-I in meiosis.

1. They measure about 1500 to 2000 μm in length.
2. A lampbrush chromosome consists of an axis from which paired loops extend in opposite directions, giving the appearance of a lamp brush.
3. The axis consists of chromomeres (nucleosomes) and interchromomere regions.
4. The loops consist of transcriptionally active DNA which can synthesize large amount of mRNA, necessary for the synthesis of yolk.

Polytene Chromosomes



1. These are giant chromosomes found in the salivary gland cells of the fruit fly Drosophila.
2. They are many times larger than the normal chromosomes reaching a length of 2000 μm and are visible even under a compound microscope.
3. The Polytene chromosomes appear to contain five long and one short arm radiating from a central point called chromocentre.

Dr.P.SANGEETHA, Head, Department of Zoology

4. It is formed by the fusion of centromeres of all the eight chromosomes found in the cell.
5. Of the 6 arms, the short arm represents the fused IV chromosome and the longest represents the fused sex chromosomes.
6. These arms contain numerous chromonemata resulting from repeated replication of DNA, without separation into daughter chromosomes.
7. The arms show characteristic dark bands and light bands.
8. The dark bands are euchromatic regions.
9. Some of the dark bands temporarily swell up and form enlargements called chromosomal puffs or Balbiani rings.
10. These regions contain actively transcribing DNA involved in the synthesis of RNA types

Function of Chromosomes

Functions of Chromosomes are as follows

1. **Genetic Code Storage** Chromosome contains the genetic material that is required by the organism to develop and grow. DNA molecules are made of chain of units called genes. Genes are those sections of the DNA which code for specific proteins required by the cell for its proper functioning.

2. **Sex Determination** Humans have 23 pairs of chromosomes out of which one pair is the sex chromosome. Females have two X chromosomes and males have one X and one Y chromosome. The sex of the child is determined by the chromosome passed down by the male. If X chromosome is passed out of XY chromosome, the child will be a female and if a Y chromosome is passed, a male child develops.

3. **Control of Cell Division** Chromosomes check successful division of cells during the process of mitosis. The chromosomes of the parent cells insure that the correct information is passed on to the daughter cells required by the cell to grow and develop correctly.

4. **Formation of Proteins and Storage** Proteins are essential for the activity of a cell. The chromosomes direct the sequences of proteins formed in our body and also maintain the order of DNA. The proteins are also stored in the coiled structure of the chromosomes. These proteins bound to the DNA help in proper packaging of the DNA.

THE CELL CYCLE

Definition

The cyclical sequence of events involving growth and division of cell is called cell cycle. It encompasses the entire sequence of events that occur in a cell from the time it is formed from its parent cell till the time of its own division into daughter cells.

Cell cycle has three main stages namely

1. Interphase
2. Karyokinesis
3. Cytokinesis

Interphase

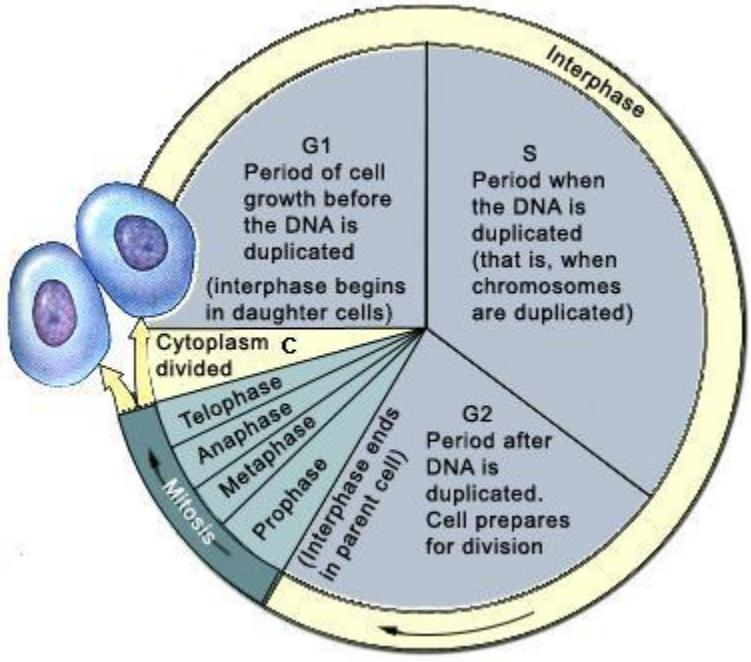
This is a period of intense synthesis and growth in the cell. The cell produces many materials required for its own growth and activities. The genetic material DNA replicates during Interphase.

Karyokinesis

It is the process of nuclear division, which involves separation of chromatids and their redistribution as chromosomes into daughter cells.

Cytokinesis

It is the process of division of the cytoplasm to result in the formation of daughter cells.



The Cell Cycle

Phase	Events within cell

Phase	Events within cell
G_1	Intensive cellular synthesis, mitochondria, chloroplasts (in plants), ER, lysosomes, Golgi complex, vacuoles and vesicles produced. Nucleus produces rRNA, mRNA and tRNA and ribosomes are synthesized. Cell produces structural and functional proteins. Cell metabolic rate high and controlled by enzymes. Cell growth occurs. Substances produced to inhibit or stimulate onset of next phase.
S	DNA replication occurs. Protein molecules called histones are synthesized and cover each DNA strand, Each chromosome has become two chromatids.
G_2	Intensive cellular synthesis. Mitochondria and chloroplasts divide. Energy stores increase. Mitotic spindle begins to form.
Mitosis	Nuclear division occurs in four phases
C	Equal distribution of organelles and cytoplasm into each daughter cells

The length of the cycle depends on the nature of cell and various external factors like temperature food and oxygen availability. Bacterial cells may divide every 20 minutes, epithelial cells living the small intestine divide once in 8 to 10 hours; onion root tip cells take about 20 hours to divide. Some specialized cells like the nerve cells never divide.

Regulation of the cell cycle

How cell division (and thus tissue growth) is controlled is very complex. The following terms are some of the features that are important in regulation, and places where errors can lead to cancer. Cancer is a disease where regulation of the cell cycle goes awry and normal cell growth and behavior is lost.

Cdk (cyclin dependent kinase, adds phosphate to a protein), along with cyclins, are major control switches for the cell cycle, causing the cell to move from G1 to S or G2 to M.

MPF (Maturation Promoting Factor) includes the CdK and cyclins that triggers progression through the cell cycle.

p53 is a protein that functions to block the cell cycle if the DNA is damaged. If the damage is severe this protein can cause apoptosis (cell death).

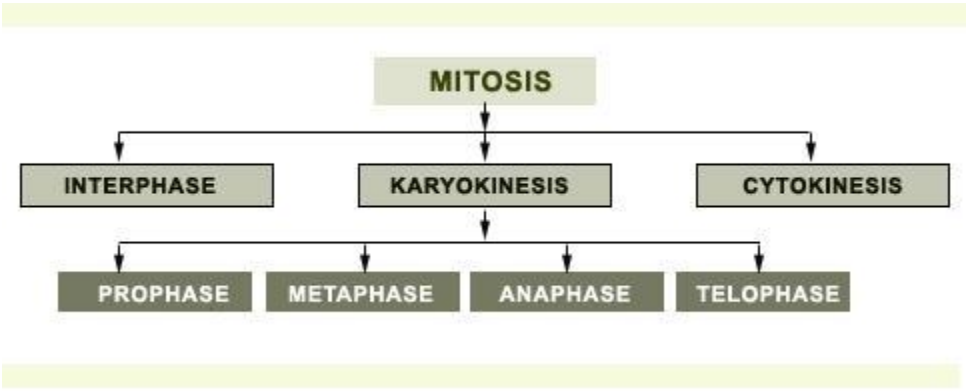
1. p53 levels are increased in damaged cells. This allows time to repair DNA by blocking the cell cycle.
2. A p53 mutation is the most frequent mutation leading to cancer. An extreme case of this is Li Fraumeni syndrome, where a genetic a defect in p53 leads to a high frequency of cancer in affected individuals.
3. **p27** is a protein that binds to cyclin and cdk blocking entry into S phase. Recent

research (*Nature Medicine* 3, 152 (1997)) suggests that breast cancer prognosis is determined by p27 levels. Reduced levels of p27 predict a poor outcome for breast cancer patients.

MITOSIS

Definition

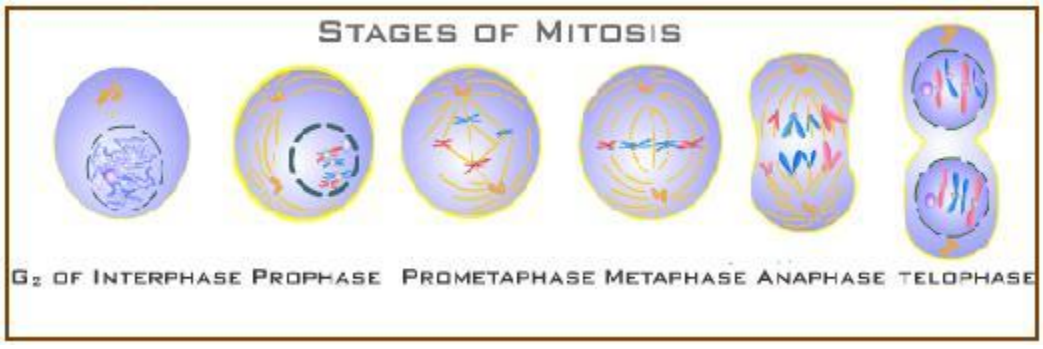
Mitosis s a type of cell division in which the daughter cells are exactly the same as parent cells, it provides cell division responsible for growth of the body, and in other words it occurs in the non-sexual parts or the vegetative or somatic cells of the body.



Mitosis is divided into the following stages

Mitosis is a fast and highly complex process. The events of mitosis is divided into the following stages prophase, prometaphase, metaphase, anaphase and telophase.

Below figure shows the stages of mitosis



Interphase

1. Mitosis starts with Interphase. In Interphase the cell prepares itself for division.
2. The Interphase is divided into three phases G_1, S and G_2.
3. During these phases the cells grow by producing proteins and cytoplasmic organelles.

4. In the S phase the chromosomes replicate. In G_1 phase the cell grows, in S phase the chromosomes duplicate and in G phase the cell grows more and prepares for mitosis and finally divides in the Mitotic cycle.
5. The cell cycle is regulated by proteins.
6. The phases of the Interphase follow strict order and have checkpoints.
7. There is another phase in the Interphase G_0 where the cell has the option to enter this stage.
8. Interphase takes about 90% of the cell's life span.

Prophase

1. In the nucleus the genetic material is loosely bundled in coil called chromatin.
2. At the onset of prophase the chromatin fibres become tightly coiled and condense into discrete chromosomes.
3. Inside the nucleus, the nucleolus also disappears from view.
4. The centrioles begin to move to opposite ends of the cell and the spindle fibres extend from the centromere.
5. Some fibres cross the cell to form the mitotic spindle fibres.

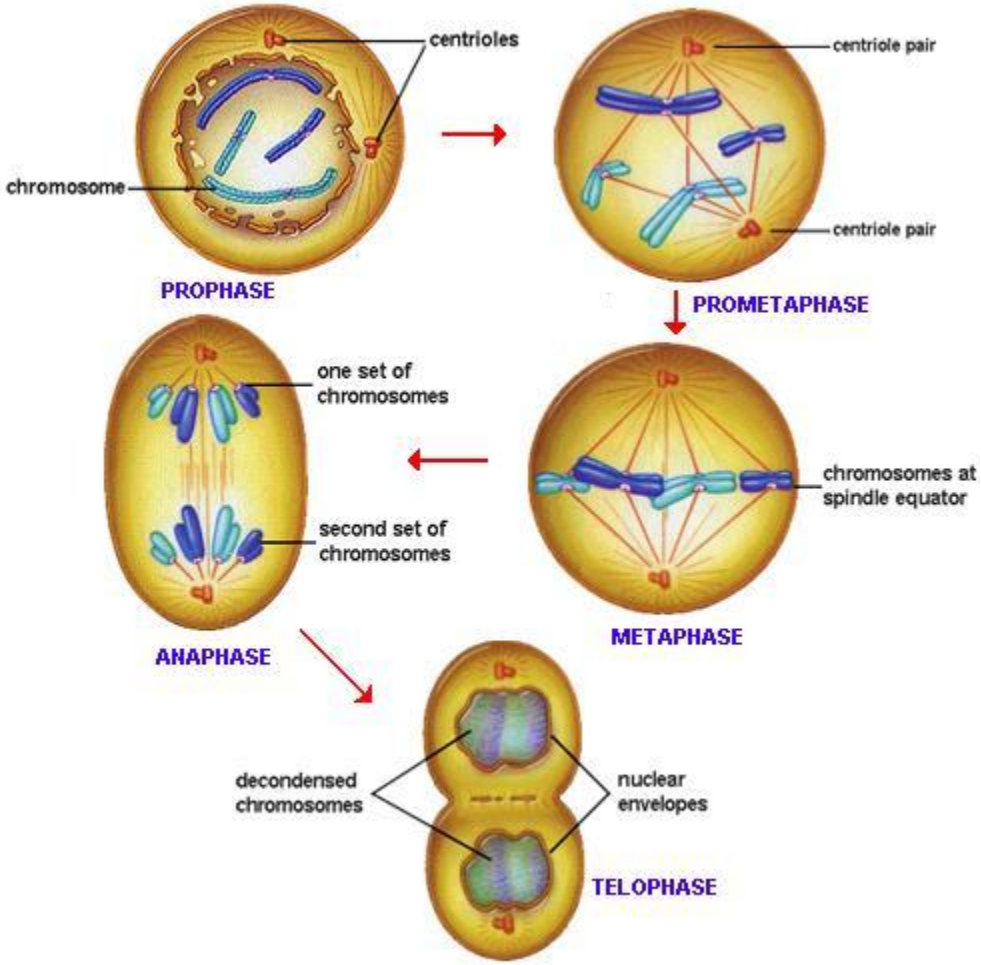
Prometaphase

1. Prometaphase is sometimes considered as the end of prophase and early metaphase.
2. During the early stage of prometaphase the nuclear membrane disintegrates and the microtubules enter the nuclear space.
3. This is known as "open mitosis" and it occurs in most multicellular organisms.
4. Organisms like fungi, some portists like algae or trichomonads undergo "closed mitosis" where the spindle formation happens inside the nucleus.
5. The nuclear membrane stays intact and the microtubules are not able to penetrate the intact nuclear membrane.
6. During the late prometaphase, at the centromere of each chromosome forms two kinetochores.
7. Kinetochore is a complex protein structure; it is the point where the microtubules attach themselves to the chromosome.

Metaphase

1. The term metaphase is derived from Greek word 'meta' which means 'after'.
2. In the prometaphase after the microtubules are attached to the prometaphase the chromosomes start pulling the chromosomes towards the ends of the cell.
3. The centromeres of the chromosomes assemble along the metaphase plate also known as the equatorial plane.
4. It is an imaginary line that is in between the centrosome poles and is called the spindle equator.

5. This helps to ensure that when the chromosomes are separated the new nucleus will receive one copy of each chromosome.



Anaphase

1. After the metaphase stage the chromosomes proceed to the anaphase stage.
2. The term anaphase is derived from the Greek word "ava" which means "up", or "against", or "back", or "re".
3. First the proteins that bind the sister chromatids are cleaved making the sister chromatids as separate daughter chromosomes and are pulled apart towards the respective centrosomes to which they are attached.
4. The microtubules at the poles pull the set of chromosome that are attached to it the opposite ends of the cell. At the end of anaphase the microtubules all degrade.

Telophase

1. Telophase is derived from the Greek word "telos" meaning "end".
2. It is a reversal of prophase and prometaphase events. In the telophase stage the polar microtubules continue to lengthen elongating the cell.

3. The daughter chromosomes attach at opposite site ends of the cell.
4. New membranes are formed around the daughter nuclei.
5. The chromosomes spread and are no longer visible under the light microscope.
6. The spindle fibers also disperse; cytokinesis may also begin during this stage.

Cytokinesis

1. Cytokinesis is a separate process that begins at the same time as the telophase.
2. Cytokinesis is not a phase of mitosis; it is a separate process necessary for completing cell division.
3. In animal cells a pinch like cleavage furrow containing a contractile ring develops at the position of the metaphase plate separating the nuclei.
4. In the animal and plant cells the division of cell is driven by vesicles derived from the Golgi apparatus.
5. In plant cells, the rigid wall requires a cell plate be synthesized between the two daughter cells.

Significance of Mitosis

The formation of new cells is necessary for the following reasons

1. multicellular plants and animals start life as *single cells, the zygotes or fertilized egg* cells; the process of Mitosis gives rise to many cells which *differentiate to form tissues, organs and organ-systems* of the organism.
2. *mitosis* results in an *increase in size and growth* of an organism,
3. cell reproduction is used to form new cells to *renew certain tissues* and to *replace worn out cells*
4. mitosis is also used as a form of *asexual reproduction in some organisms* like in unicellular *Amoeba* and multicellular *Hydra* as well as vegetative reproduction in plants.

MEIOSIS

Definition

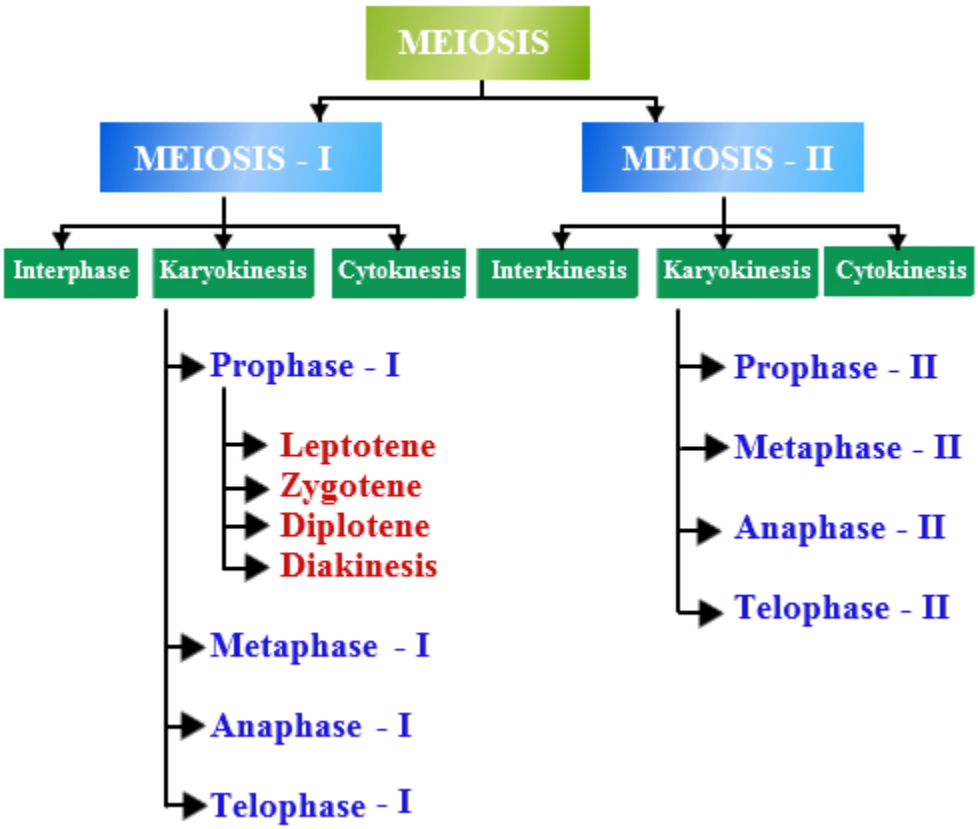
Meiosis, which is also referred to as "reduction division", is the form of cell division in which a cell divides into four "daughter cells" each of which has half of the number of chromosomes of the original cell. Meiosis occurs prior to the formation of sperm (in males) and ova (in females).

Meiosis is a reduction division of a diploid nucleus to form haploid nuclei.

Importance

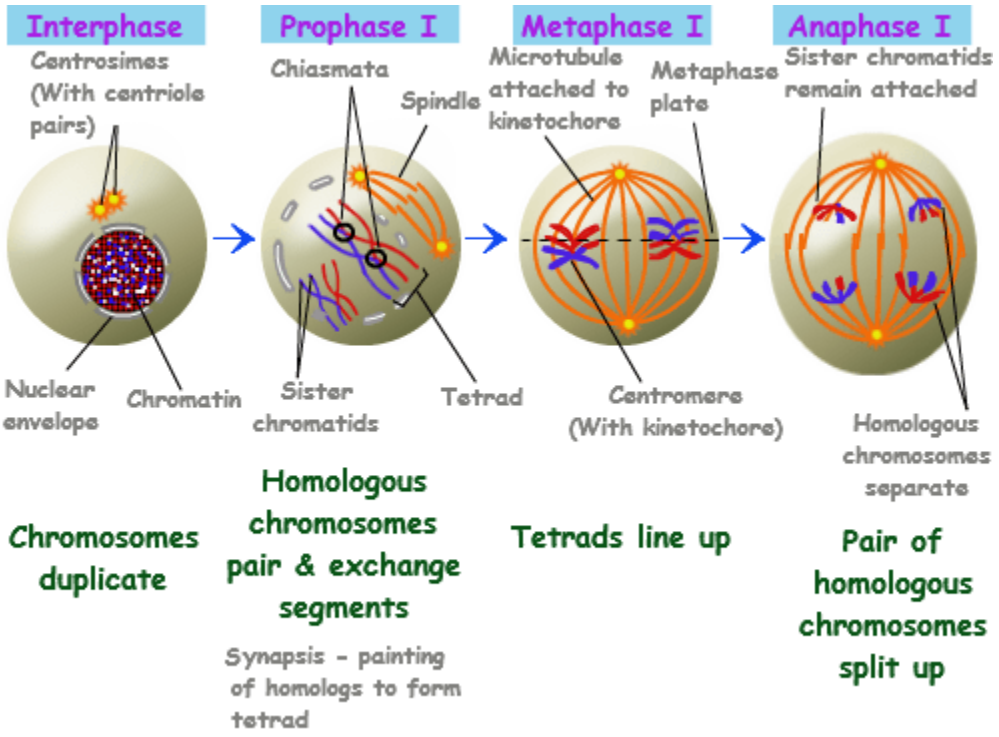
1. Meiosis Is a Special Type of Cell Division That Occurs in Sexually Reproducing Organisms
2. Meiosis reduces the chromosome number by half, enabling sexual recombination to occur.
3. Meiosis of diploid cells produces haploid daughter cells, which may function as gametes.
4. Gametes undergo fertilization, restoring the diploid number of chromosomes in the zygote
5. Meiosis and fertilization introduce genetic variation in three ways
    a) Crossing over between homologous chromosomes at prophase I.
    b) Independent assortment of homologous pairs at metaphase I
    c) Each homologous pair can orient in either of two ways at the plane of cell division.
    d) The total number of possible outcomes = 2n (n = number of haploid chromosomes).
6. Random chance fertilization between any one female gamete with any other male gamete.

Meiosis Chart



Stages of Meiosis

Meiosis is a one way process, unlike mitosis is a cell cycle. The preparatory phase to meiosis is identical in pattern and name to the Interphase of the mitotic cell cycle.



Interphase

Meiosis Interphase is divided into three phases

1. *G_1 phase* or Growth 1 phase is a very active period. In this period the cell synthesizes vast range of proteins which includes the enzymes and structural proteins necessary for growth of the cell. In the G_1 phase the chromosome are made of single molecule of DNA, at this point, in humans, the number of chromosomes per cell is 46 which is 2N and identical to the somatic cells.
2. *S phase* or the Synthesis phase - There is replication of genetic material in this phase. Chromosomes duplicate, each of the 46 chromosomes become a complex of two sisters, identical chromatids.
3. *G_2 phase* or Growth phase is not present in meiosis.

The Interphase stage is followed by meiosis I and meiosis II.

Meiosis is divided into meiosis I and meiosis II stages. It is further divided into Karyokinesis I and Cytokinesis I and Karyokinesis II and Cytokinesis II respectively.

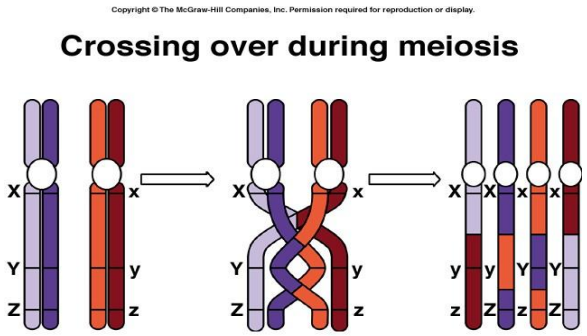
Meiosis I

1. The pairs of homologous chromosomes, made up of two sister chromatids are split into two cells.
2. The resulting daughter cells contain one entire haploid set of chromosomes.

3. The first meiotic division reduces the ploidy of original cell by a factor of two.
4. It produces two haploid cells (N chromosomes, 23 in humans).
5. Hence meiosis I is referred to as a reductional division.
6. A diploid human cell contains 46 chromosomes and is said to be 2N because it contains 23 pairs of homologous chromosomes.
7. Meiosis II is an equational division similar to mitosis, where the sister chromatids split and creating 4 haploid cells, two from each daughter cells from meiosis I.

Prophase I

1. Prophase I is the longest phase of meiosis I.
2. During this phase, there is exchange of DNA between homologous chromosomes, this process is known as homologous recombination. This process often results in chromosomal crossover.
3. The DNA created are of new combinations, and during crossover they are a significant source of genetic variation. This may result in beneficial new combinations of alleles.
4. The chromosomes that are paired and replicated are called bivalents or tetrads.
5. They have two chromosomes and four chromatids; each chromosome comes from each parent.
6. Pairing of homologous chromosomes is called synapsis. At the stage of synapsis formation, the non-sister chromatids may cross-over at points called chiasmata.



- Genetic material from the **homologous chromosomes** is randomly swapped
- This creates four unique chromatids
- Since each chromatid is unique, the overall genetic diversity of the gametes is greatly increased

Leptotene

1. Leptotene is the first stage of prophase I and is also known as leptonema, which is derived from a Greek word which means "thin threads".
2. In this stage, individual chromosomes consists of two sister chromatids.
3. The chromosomes condense into visible strands within the nucleus.
4. The two sister chromatids are tightly bound, that they are not distinguishable from one other.
5. During this phase the lateral elements of the synaptonemal complex assemble.
6. This stage is of very short duration and progressive condensation and coiling of chromosome takes place.

Zygotene

1. Zygotene is also known as zygonema, it is derived from Greek word which means 'paired threads'.
2. The chromosomes in this line up with each other into homologous chromosome pairs.
3. This stage is known as bouquet stage, due to the way the telomeres cluster at one end of the nucleus.
4. Synapsis of homologous chromosomes takes place in this stage; it is facilitated by the assembly of central element of the synaptonemal complex.
5. Pairing of chromosomes happens in a zipper like fashion and starts at the centromere (procentric) or at the chromosome ends (proterminal) or at any other portion (intermediate).
6. Two chromosomes in a pair are equal in length and in position of the centromere, making the pairing highly specific and exact.
7. These paired chromosomes are called bivalent or tetrad chromosomes.

Pachytene

1. The pachytene stage is also known as pachynema and is derived from Greek which means "thick threads". This is the stage where chromosomal crossing over occurs.
2. Non sister chromatids of homologous chromosomes exchange segments over homologous regions.
3. Sex chromosomes are not identical and they exchange information over a small region of homology.
4. Chiasma is formed where exchange happens.
5. There is exchange of information between the non-sister chromatids and this results in a recombination of information.
6. Every chromosome has a complete set of information and there are no gaps formed as the result of the process.

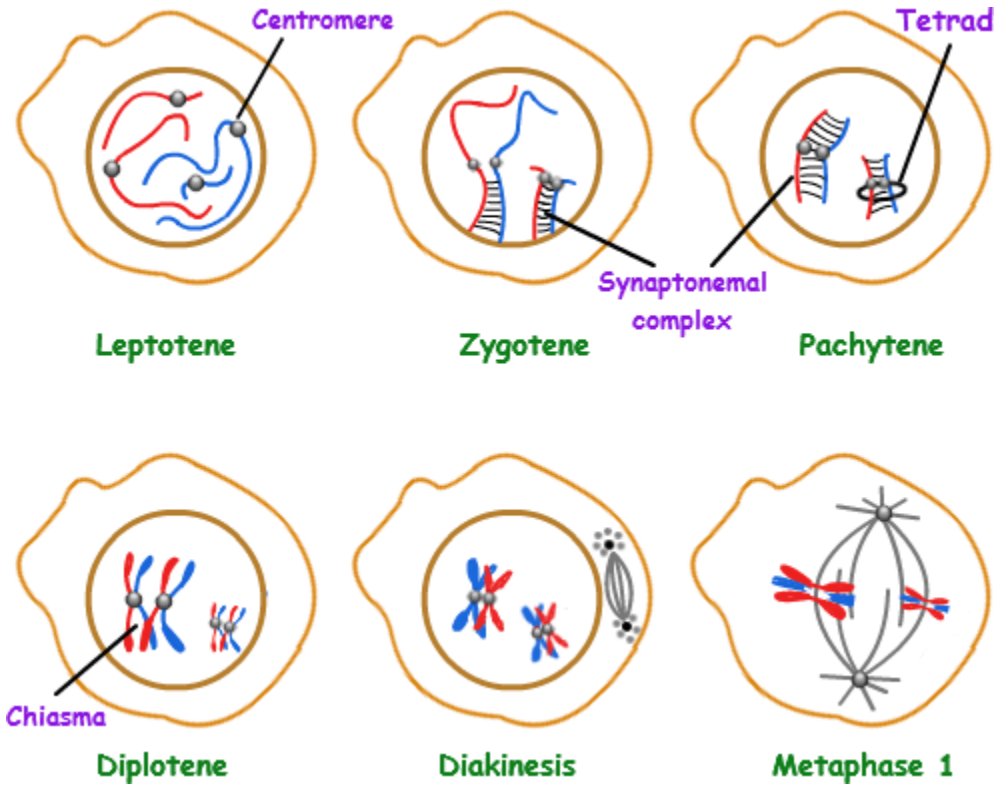
Diplotene

1. The diplotene stage is also known as diplonema, which is derived from Greek word meaning "two threads".
2. During this stage there is degradation of synaptonemal complex and the homologous chromosomes separate a little from one another.
3. The chromosomes in this stage uncoil a little, this allows transcription of DNA.
4. The bivalent homologous chromosomes remain tightly bound at the region of the chiasmata, where crossing over occurred.
5. The chiasmata regions remain on the chromosomes until they are separated in the anaphase.

In the cogenesis of humans the developing oocytes in the fetal stage stop at this stage of diplotene before birth. This state is referred to as the dictyotene stage and it remains in this suspended stage until puberty.

Diakinesis

1. During the stage of diakinesis the chromosomes condense further.
2. The word diakinesis is derived from Greek word which means "moving through".
3. This stage is the first part of meiosis where the four arms of the tetrads are visible.
4. The sites where crossing over has occurred entangle together, overlapping effectively and making the chiasmata visible clearly.
5. This stage resembles the prometaphase of mitosis, where the nucleoli disappear and the nuclear membrane disintegrates into vesicle and also there is formation of the meiotic spindle.



Metaphase I

1. The homologous pairs of chromatids move together along the metaphase plate.
2. The Kinetochore microtubules from the centrioles attach to their kinetochores respectively.
3. The homologous chromosomes align along the equatorial plane, this alignment happens due to the continuous counterbalancing forces exerted on the bivalents by the microtubules emanating from the kinetochores of the homologous chromosomes.

Anaphase I

1. During this phase the Kinetochore microtubules shorten, this severs the recombination nodules and pulls the homologous chromosomes apart.
2. As each chromosome has only one functional unit of a pair of kinetochores, the whole chromosomes are pulled towards the opposite poles which results in the formation of two haploid sets.
3. Each chromosomes contains a pair of sister chromatids.
4. Disjunction occurs during this time, this is one of the process that leads to genetic diversity as the chromosomes end up in either of the daughter cells.
5. The nonkinetochore microtubules lengthen and push the centrioles farther apart. The cell is elongated and it prepares for division at the center.

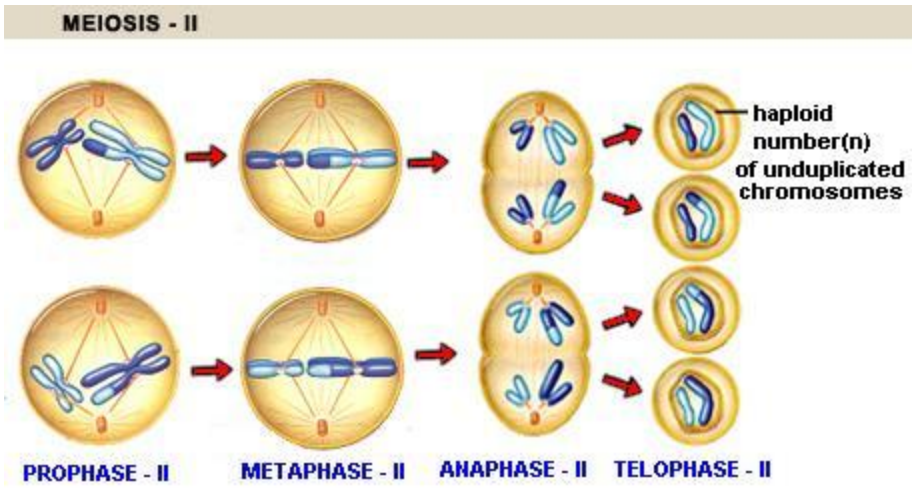
Telophase I

1. The first phase of meiotic division ends when the chromosomes arrive at the poles.
2. The daughter cells now have half the number of chromosomes, the chromosomes consists of a pair of chromatids.
3. The microtubules of the spindle network disappear and nuclear membrane surrounds each haploid set.
4. The chromosomes uncoil and return back to the chromatin stage.
5. The process of cytokinesis occurs where, the cell membrane in the animal's cells is pinched off, and in plant cells there is formation of the cell wall in between the daughter cells.
6. This completes the creation of two daughter cells. The sister chromatids remain attached during the telophase I stage.

Meiosis II

It is the second part of the meiotic process and is also known as equational division. Meiosis II is similar to mitosis. The genetically results are fundamentally different from that of mitosis. The end result of mitosis II is the production of four haploid cells from two haploid cells produced in meiosis I, each cell consisting of 23 chromosomes in humans and the chromosomes consists of two sister chromatids.
In meiosis II there are four steps

1. *Prophase II*
2. *Metaphase II*
3. *Anaphase II*
4. *Telophase II.*



Prophase II

1. During this stage there is disappearance of the nucleoli and the nuclear envelope, also there is shortening and thickening of the chromatids.
2. The centrioles move to the polar region and the spindle fibers are arranged for the second meiotic division.

Metaphase II

1. During this stage the centromeres that contain two kinetochores attach to the spindle fibers at each pole from the centrioles.
2. The equatorial plate formed here is rotated by 90 degrees, compared to meiosis I and is perpendicular to the previous metaphase plate.

Anaphase II

1. The metaphase II is followed by the anaphase II, in the anaphase II stage the centromeres are cleaved, this allows the microtubules attached to the kinetochores to pull the sister chromatids apart.
2. The sister chromosomes move towards the opposing poles.

Telophase II

1. The meiosis II process ends at this stage, this stage is similar to the telophase I.
2. In this phase there is uncoiling and lengthening of the chromosomes and disappearance of the spindle. There is also reformation of nuclear envelope.
3. Cleavage or cell wall forms which eventually produces a total of four daughter cells, each cell having its own haploid set of chromosomes.

The significance of meiosis-

1. It maintains the same chromosome umber in the sexually reproducing organisms. From a diploid cell, haploid gametes are produced which in turn fuse to form a diploid cell.

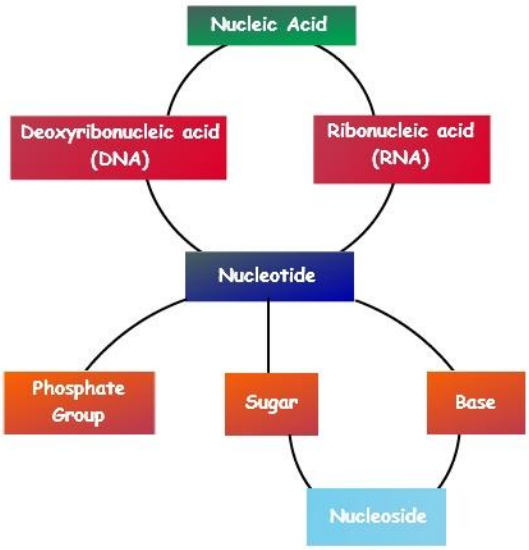
2. It restricts the multiplication of chromosome number and maintains the stability of the species.
3. Maternal and paternal genes get exchanged during crossing over. It results in variations among the offspring.
4. All the four chromatids of a homologous pair of chromosomes segregate and go over separately to four different daughter cells. This leads to variation in the daughter cells genetically.

Nucleic Acids

Nucleic acids are large organic compounds found in the chromosomes of living cells and viruses. They are strong acids found in the nucleus of the cells. They are DNA and the RNA. They are the hereditary determinants of living organisms The nucleic acids are biopolymers with mononucleotides ad their repeating units. The monomers are known as nucleotides, they are made up of three units a sugar, an amine and a phosphate group.

History

1. In 1869, Friedrich Miescher isolated nuclei from pus cell and found that they contained phosphate-rich substance, he named it nuclein.
2. Fischer in the 1880s, discovered purine and pyramidine bases in nucleic acids.
3. In 1944, Oswald T. Avery, Colin M. MacLeod and Maclyn McCarty, experimented that DNA is directly involved in inheritance.
4. In 1953, James D. Watson and Francis H.C. Crick constructed the double helical model for the DNA molecule.



Functions of Nucleic Acids

1. The main functions is store and transfer genetic information.
2. To use the genetic information to direct the synthesis of new protein.
3. The deoxyribonucleic acid is the storage for place for genetic information in the cell.
4. DNA controls the synthesis of RNA in the cell.
5. The genetic information is transmitted from DNA to the protein synthesizers in the cell.
6. RNA also directs the production of new protein by transmitting genetic information to the protein building structures.
7. The function of the nitrogenous base sequences in the DNA backbone determines the proteins being synthesized.
8. The function of the double helix of the DNA is that no disorders occur in the genetic information if it is lost or damaged.
9. RNA directs synthesis of proteins.
10. m-RNA takes genetic message from RNA.
11. t-RNA transfers activated amino acid, to the site of protein synthesis.

DEOXYRIBONUCLEIC ACID OR DNA

Definition

DNA is a polymer of nucleotides which codes for amino acid sequences during the process of protein synthesis. DNA carries genetic information on genes which are required to construct molecules like proteins.

DNA Structure

Primary Structure

1. DNA is a polymer sequence made up of subunits of nucleotides. Nucleotides of the DNA are made of a sugar(deoxyribose), a nitrogenous base and a phosphate group.
2. Nitrogenous bases of four types are present in a DNA molecule, namely adenine, guanine, cytosine and guanine, a sugar molecule is the 5-carbon sugar deoxyribose and one or more phosphate groups.
3. Adenine and guanine are purine nitrogen bases, cytosine and thymine are pyrimidines.
4. A phosphodiester bond is formed with the phosphate group of the nitrogen bases with the OH group of the sugar.
5. The nucleic acid sequence on the nucleotides are complementary to another sequence of the DNA strand.

Secondary Structure

1. Secondary structure of DNA is the interaction between the bases, of which strands are bound to each other.
2. In the double helical structure of DNA, the strands are held together by hydrogen bonds, where the nucleotides on one strand pairs with nucleotide on the other strand.
3. The secondary structure gives shape to the nucleic acids. The purine base pairs with pyrimidine base by hydrogen bonds.
4. The secondary structure determines the base-pairing of the strands to form a double helix.
5. A major groove and a minor groove is formed in the double helix. The strands of DNA are not symmetrical with one another, hence the grooves are unequal. The major groove is 22 Å wide and minor groove is 12 Å wide.

Tertiary Structure

1. Tertiary structure of DNA is it location in three-dimensional space. There are 4 different structural variations in DNA forms
2. Right or left handed
3. Length of the helix turn
4. Number of base pairs per turn
5. Difference in size between the major and minor grooves.

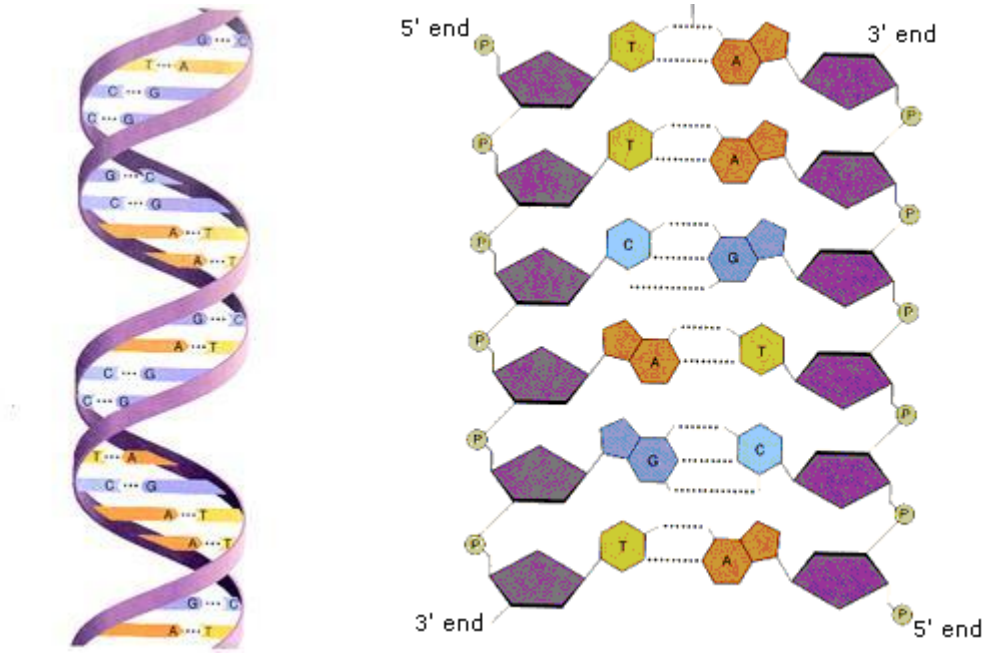
Structure of DNA

The structure of the DNA molecule and the arrangement of nitrogenous bases in the two polynucleotide chains, are very well explained by the double helix model proposed by Watson and Crick in 1953.

Watson and Crick Model

According to the double helix model, DNA molecule shows the following salient features

1. The two polynucleotide chains are coiled around each other like a spiral stair case (double helix).
2. The cross-rungs (steps) are formed by the nitrogen bases while phosphates and sugars form the uprights.
3. The two polynucleotide chains run in opposite directions (antiparallel). One chain runs in the 3'-5' direction. While for the other chain 3'-5' direction is opposite.
4. The average distance between the two chains is $20A^0$.
5. One full turn of the helix, called gyre, measures $34A^0$ in length.
6. The distance between two successive sugar molecules is $3.4A^0$. Thus, each gyre accommodates 10 nucleotides.



Double Helix of DNA

adenine(A), guanine (G), thymine(T), cytocine(C), phosphate(P)

Base pairing in DNA

- The nitrogen bases of the two opposite chains exhibit highly specific base pairing. A purine in one chain always pairs with a pyrimidine in the opposite chain

- Among purines adenine (A) pairs only with the pyrimidine thymine (T) and vice versa. Similarly guanine (G) pairs only with cytosine (C) and vice versa.
- There are two weak hydrogen bonds between A and T or T and A. There are three weak hydrogen bonds between G and C or C and G.
- The total amount of purines is equal to the total amount of pyrimidines (A+G)=(C+T).
- The two polynucleotide chains of DNA molecule are not identical to each other but complementary to each other.

RIBINUCLIC ACID (RNA)

RNA is a single polynucleotide chain composed of nucleotides of adenine, guanine, cytosine and uracil. Thymine nucleotides are absent.RNA occurs mostly in the cytoplasm in the eukaryotic cells. A small amount occurs in the nucleus of the cell, as a constituent of nucleolus.

Classification of RNA

There are three types of RNA

Messenger RNA (mRNA)

It represents about 5 to 10% of the total RNA. It is synthesized from DNA as and when necessary. It carries the genetic information in the form of a specific sequence of nitrogen bases arranged in triplet codons, which are copies from the code in DNA.

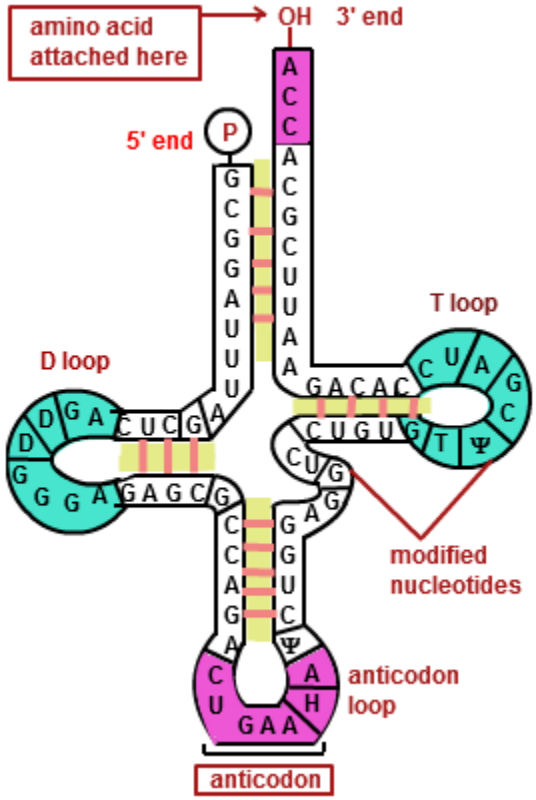
- Messenger RNA is synthesized by a gene segment of DNA.
- This segment contains the information regarding the protein synthesis in the form of sequence of amino acids.
- These RNA acts as carrier for this information from nucleus to protein synthesis site which is ribosome located in cytoplasm, thus they named as messenger RNA.
- This sequence of amino acids carry by mRNA is called as genetic code and every code word is termed as codon.

Transfer RNA (tRNA)

It represents about 10 to 15% of the total RNA in the cell. It has the shortest molecule having only about 80 to 100 nucleotides. The polynucleotide chain is folded on itself to have the shape of a cloverleaf. The molecule has three lateral loops, a DHU loop, a t loop and an anticodon loop. The anticodon loop bears a triplet combination of nitrogen bases, called anticodon. It is complementary to a codon of mRNA.

The tRNA molecule is meant for recognizing and carrying particular types of amino acids to the sites of protein synthesis.
This ribonucleic acid involves in the second step of protein synthesis (translation) and used to transfer amino acids according to the instructions produced by mRNA. Hence, it translates the language of nucleotides into the language of amino acids given by messenger RNA.

Each tRNA molecule contains around 90 nucleotides and modify by different enzymes to remove introns and change some of the bases in it. Finally tRNA has more than four types of nucleotides with three nucleotides; CCA at 3' end of every tRNA and structure like a 3-leafed clover.
Amino acids attached to a specific tRNA which recognize by enzymes and the bonded amino acid is called as charged amino tRNA. Each tRNA has specific anticodon for the recognition of codon.



Ribosomal RNA (rRNA)

It represents nearly 80% of the total RNA in the cell. It always occurs bound to basic proteins in ribosomes. It takes part in assembling the amino acids brought by tRNA, into a polypeptide chain, based on the sequence of codons in mRNA.

Dr.P.SANGEETHA, Head, Department of Zoology

Ribosomal RNA or rRNA is a main component of ribosome which acts as site for protein synthesis.
Unlike other RNA which are synthesized in nucleus of cell, rRNA synthesized in the nucleolus.
Depends upon the length of rRNA, they can be exist in three forms.

- 18 S
- 5.8 S
- 28 S

Where S = Sedimentation or density unit.

The density unit is used in describing the results of ultra centrifugation which further reflects the size and shape of molecules. Thus higher the value of S stands for bigger molecule. There are mainly two parts in ribosomes

- **60 S subunit** 28 S rRNA, 5.8 S rRNA, 5 S rRNA, , 45 - 50 different proteins
- **40 S subunit** 18 S rRNA and 30 different proteins.

Functions of RNA

1. mRNA has a significant role in genetic code.
2. tRNA is responsible for transferring amino acids to the site of protein synthesis (ribosomes).
3. rRNA assembles the amino acids into a polypeptide chain. It also serves as a primer for replication of DNA.
4. RNA serves as the genetic material in some plant viruses.

DNA Replication

What Is the Replication Fork?

Our DNA determines everything about us. And for this reason, a copy of our DNA is needed in every cell of our body, with the exception of our red blood cells.

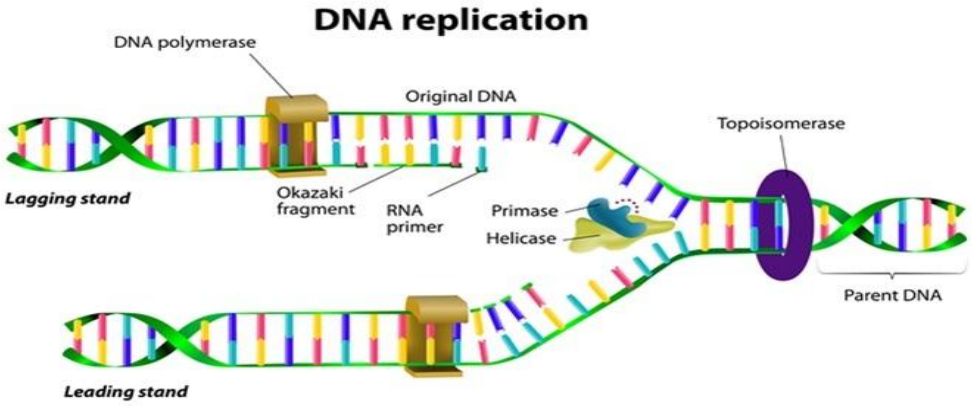
A copy of the DNA is made just prior to when a cell is going to split to create two cells. In order for this replication of DNA to take place, the DNA has to be in an orientation that will allow the replication machinery to make a copy. Our DNA is double-stranded, with the strands being held together by hydrogen bonds. The normal structure of our DNA when it is not being copied is a double helix. This looks very similar to a winding staircase.

In this normal form, the DNA cannot be copied. DNA helicase is needed in order to open the DNA to expose the nucleotide bases that are used as the template for replicating the DNA. The area of the DNA that is opened by DNA helicase is known as the **replication fork** because it looks very similar to a fork in the road.

The Function of the Replication Fork

The replication fork is the area where the replication of DNA will actually take place. There are two strands of DNA that are exposed once the double helix is opened. One strand is referred to as the leading strand, and the other strand is referred to as the lagging strand. The **leading strand** is exposed in the 5' - 3' direction, while the **lagging strand** is exposed in the 3' - 5' direction. DNA is always copied in the 5' - 3' direction.

As the leading strand is exposed, **DNA polymerase** will use the leading strand as a template to create a continuous complementary strand of DNA. As the lagging strand is exposed, RNA primers are needed in order to start the replication process. The RNA primer will attach to the most 5' end of the exposed portion of the lagging strand. This primer then allows DNA polymerase to attach and add the complementary strand to the lagging strand in small segments known as **Okazaki fragments**.



GENETIC CODE: MEANING, TYPES AND PROPERTIES

Genetic Code:

The genetic code may be defined as the exact sequence of DNA nucleotides read as three letter words or codons, that determines the sequence of amino acids in protein synthesis. In other words, 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.

Dr.P.SANGEETHA, Head, Department of Zoology

The main points related to genetic code are given below:

- The genetic code is 'read' in triplets of bases called codons. In other words, a set of three nucleotide bases constitutes a codon.
- In a triplet code, three RNA bases code for one amino acid.
- There are 64 codons which correspond to 20 amino acids and to signals for the initiation and termination of transcription.
- The code uses codons to make the amino acids that, in turn, constitute proteins.
- Each triplet [codon] specifies one amino acid in a protein structure or a start signal or stop signal in protein synthesis.
- The code establishes the relationship between the sequence of bases in nucleic acids (DNA and the complementary RNA) and the sequence of amino acids in proteins.
- The code explains the mechanism by which genetic information is stored in living organisms.

Types of Genetic Code:

The genetic code is of two types. The genetic code can be expressed as either RNA codons or DNA codons. RNA codons occur in messenger RNA (mRNA) and are the codons that are actually **"read"** during the synthesis of polypeptides (the process called translation).

But each mRNA molecule acquires its sequence of nucleotides by transcription from the corresponding gene [DNA], Because DNA sequencing has become so rapid and because most genes are now being discovered at the level of DNA before they are discovered as mRNA or as a protein product, it is extremely useful to have a table of codons expressed as DNA. Both tables are given here.

DNA Codons:

These are the codons as they are read on the sense (5′ to 3′) strand of DNA. Except that the nucleotide thymine (T) is found in place of uracil (U), they read the same as RNA codons. However, mRNA is actually synthesized using the antisense strand of DNA (3′ to 5′) as the template.

Types of Codon:

The genetic code consists of 64 triplets of nucleotides. These triplets are called codons. With three exceptions, each codon encodes for one of the 20 amino acids used in the synthesis of proteins. This produces some redundancy in the code.

Most of the amino acids are encoded by more than one codon. One codon that is AUG serves two related functions. It signals the start of translation and codes for the incorporation of the amino acid methionine (Met) into the growing polypeptide chain.

The codons are of two types, viz:

(1) Sense codons, and
(2) Signal codons.

These are defined below:

1. Sense Codon:

Those codons that code for amino acids are called sense codons. There are 61 sense codons in the genetic code which code for 20 amino acids.

2. Signal Codons:

Those codons that code for signals during protein synthesis are known as signal codons. There are four codons which code for signal. These are AUG, UAA, UAG and UGA.

Signal codons are of two types, viz:

(i) Start codons, and

(ii) Stop codons.

(i) Start Codons:

The codon which starts the translation process is known as start codonl. It is also known as initiation codon because it initiates the synthesis of polypeptide chain. Example of this codon is AUG. This codon also codes for the amino acid methionine. In some cases, valine (GUG) codes for start signal. In eukaryotes, the starting amino acid is methionine, while in prokaryotes it is N-formyl methionine.

(ii) Stop Codons:

Those codons that provide signal for termination of polypeptide chain are known as stop codons. These codons are also known as termination codons because they provide signal for the termination and release of polypeptide chain. Examples of stop codons are UAA, UAG and UGA. Since stop signal codons do not code for any amino acid they were earlier called as non-sense codons.

Signals of stop or termination codons are read by proteins called release factors. Stop signals are not read by tRNA molecules. In prokaryotes, release factors are RF1, RF2 and RF3. The factor RFI recognizes stop codons UAA and UAG, while RF2 recognizes UAA and UGA. The function of RF3 is to stimulate RFI and RF2. In eukaryotes, a single release factor (RF) recognizes all three stop codons.

Properties of Genetic Code:

Genetic code has some important properties.

The genetic code is:

(i) Triplet,
(ii) Universal,
(iii) Comma-less,
(iv) Non-overlapping,
(v) Non-ambiguous,
(vi) Redundant, and
(vii) Has polarity.

These are briefly discussed below:

1. The Code is Triplet:

The genetic code is triplet. The triplet code has 64 codons which are sufficient to code for 20 amino acids and also for start and stop signals in the synthesis of polypeptide chain. In a triplet code three RNA bases code for one amino acid.

2. The Code is Universal:

The genetic code is almost universal. The same codons are assigned to the same amino acids and to the same START and STOP signals in the vast majority of genes in animals, plants, and microorganisms. However, some exceptions have been found.

Most of these involve assigning one or two of the three STOP codons to an amino acid instead. Some exceptions have been reported for mitochondrial genome and in unicellular eukaryotes for synthesis of nonstandard proteins such as selenocysteine and pyrolysine.

3. The Code is Commaless:

It is believed that the genetic code is commaless. In other words, the codons are continuous and there are no demarcation lines between codons. Deletion of a single base in a commaless code alters the entire sequence of amino acids after the point of deletion

4. The Code is Non-Overlapping:

Three nucleotides or bases code for one amino acid. In a non-overlapping code, six bases will code for two amino acids. In a non-overlapping code, one letter is read only once. In overlapping code, six nucleotides or bases will code for 4 amino acids, because each base is read three times

Example: There are Bases : CATGAT

Non-overlapping Code : 2 that is CAT and GAT;

Overlapping Code : 4 that is CAT, GAT, ATG and TAT

If mutation of one base into another leads in alteration of one amino acid only, it indicates that the code is non-overlapping. Mutation experiments with TMV gave similar results which indicated that the code is non-overlapping.

5. The Code is Non-ambiguous:

The genetic code has 64 codons. Out of these, 61 codons code for 20 different amino acids. However, none of the codons codes for more than one amino acid. In other words, each codon codes only for one amino acid. This clearly indicates that the genetic code is non- ambiguous. In case of ambiguous code, one codon should code for more than one amino acid. In the genetic code there is no ambiguity.

6. The Code is Redundant:

In most of the cases several codons code for the same amino acid. Only two amino acids, viz. tryptophan and methionine are codded by one codon each. Nine amino acids are coded by two codons each, one amino acid [Isoleucine] by three codons, five amino acids by 4 codons each, and three amino acids by 6 codons each

This multiple system of coding is known as degenerate or redundant code system. Such system provides a protection to the organism against many harmful mutations, because if one base of a codon is mutated, there are other codons which will code for the same amino acid and there will be no alteration in the polypeptide chain.

The redundancy or degeneracy of the code is not random except for serine, leucine and arginine. All codons coding for same amino acid are in the same box (except above three). Thus the first two letters are GC in all four codons of alanine and GC and GU in all four codons of valine

7. The Code Has Polarity:

The code has a definite direction for reading of message, which is referred to as polarity. Reading of codon in opposite direction will specify for another amino acid due to alteration in the base sequences in the code.

In the following codons, reading of message from left to right and right to left will specify for different amino acids. Because the codon in the following case will be read as UUG from left to right and as GUU from right to left which codes for another amino acid.

This is well known that the message in mRNA is read in the 5 -3 direction. Thus the polarity of genetic code is from 5 end to 3 end.