GROUP II MAIN

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The Cell		
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LIFE SCIENCE

The Cell

11th Bio-Botany

Unit – 6 - The Cell: The Unit of Life

I. Cell Theory

- In 1833, German botanist Matthias Schleiden and German zoologist Theodor Schwann proposed that all plants and animals are composed of cells and that cells were the basic building blocks of life.

These observations led to the formulation of modern cell theory.

- All organisms are made up of cells.
- New cells are formed by the division of pre-existing cells.
- Cells contains genetic material, which is passed on from parents to daughter cells.
- All metabolic reactions take place inside the cells.

Cell Doctrine (Cell Principle)

The features of cell doctrine are as follows:

- All organisms are made up of cells.
- New cells are produced from the pre-existing cells.
- Cell is a structural and functional unit of all living organisms.
- A cell contains hereditary information which is passed on from cell to cell during cell division.
- All the cells are basically the same in chemical composition and metabolic activities.
- The structure and function of cell is controlled by DNA.
- Sometimes the dead cells may remain functional as tracheids and vessels in plants and horny cells in animals.

Protoplasm Theory

- Corti first observed protoplasm. Felix Dujardin (1835) observed a living juice in animal cell and called it "Sarcode" . Purkinje (1839) coined the term protoplasm for sap inside a plant cell. Hugo Va n Mo h l (1846) indicated importance of protoplasm.

- Max Schultze (1861) established similarity between Protoplasm and Sarcode and proposed a theory which later on called "Protoplasm Theory" by O.

Hertwig (1892). Huxley (1868) proposed Protoplasm as a "physical basis of life".

II. Types of cells

- On the basis of the cellular organization and the nuclear characteristics, the cell can be divided into

❖ Prokaryotes
❖ Mesokaryotes and
❖ Eukaryotes

Prokaryotes

- Those organisms with primitive nucleus are called as prokaryotes (pro – primitive; karyon – nucleus). The DNA lies in the 'nucleoid' which is not bound by the nuclear membrane and therefore it is not a true nucleus and is also a primitive type of nuclear material. The DNA is without histone proteins. Example: Bacteria, blue green algae, Mycoplasma, Rickettsiae and Spirochaetae.

Mesokaryotes

- In the year 1966, scientist Dodge and his coworkers proposed another kind of organisms called mesokaryotes. These organisms which shares some of the characters of both prokaryotes and eukaryotes. In other words these are organisms intermediate between pro and eukaryotes. These contains well organized nucleus with nuclear membrane and the DNA is organized into chromosomes but without histone protein components divides through amitosis similar withprokaryotes.CertainProtozoa like Noctiluca, some phytoplanktons like Gymnodinium,Peridinium and Dinoflagellates are representatives of mesokaryotes.

Eukaryotes

- Those organisms which have true nucleus are called Eukaryotes (Eu – True; karyon – nucleus). The DNA is associated with protein bound histones forming the chromosomes. Membrane bound organelles are present. Few organelles may be arisen by endosymbiosis which is a cell living inside another cell. The organelles like mitochondria and chloroplast well support this theory.

- The first cell might have evolved approximately 3.8 billion years ago. The primitive cell would have been similar to present day protists

III. Plant and Animal cell

Ultra Structure of Eukaryotic Cell

- The eukaryotic cell is highly distinct in its organisation. It shows several variations in different organisms. For instance, the eukaryotic cellsin plants and animals vary greatly.

Animal Cell

- Animal cells are surrounded by cell membrane or plasma membrane. Inside this membrane the gelatinous matrix called protoplasm is seen to contain nucleus and other organelles which include the endoplasmic reticulum, mitochondria, golgi bodies, centrioles, lysosomes, ribosomes and cytoskeleton.

Plant cell

- A typical plant cell has prominent cell wall, a large central vacuole and plastids in addition to other organelles present in animal cell.

Protoplasm

- Protoplasm is the living content of the cell that is surrounded by plasma membrane. It is a colourless material that exists throughout the cell together with the cytoplasm, nucleus and other organelles. Protoplasm is composed of a mixture of small particles, such as ions, amino acids, monosaccharides, water, macromolecules like nucleic acids, proteins, lipids andpolysaccharides. It appears colourless, jelly like gelatinous, viscous elastic and granular. It appears foamy due to the presence of large number of vacuoles. It responds to the stimuli like heat, electric shock, chemicals and so on.

IV. Cell Wall

- Cell wall is the outermost protective cover of the cell. It is present in bacteria, fungi and plants whereas it is absent in animal cell. It was first observed by Robert Hooke. It is an actively growing portion. It is made up of different complex material in various organism. In bacteria it is composed of peptidoglycan, in fungi chitin and fungal cellulose, in algae cellulose, galactans and mannans. In plants it is made up of cellulose, hemicellulose, pectin, lignin, cutin, suberin and silica.

- In plant, cell wall shows three distinct regions (a) Primary wall (b) Secondary wall (c) Middle lamellae (Figure 6.11).

Primary wall

- It is the first layer inner to middle lamellae, primarily consisting of loose network of cellulose microfibrils in a gel matrix. It is thin, elastic and extensible. Cells such as parenchyma and meristems have only primary wall.

Secondary wall

- Secondary wall is laid during maturation. It plays a key role in determining the shape of a cell. It is thick, inelastic and is made up of cellulose and lignin.

Middle lamellae

- It is the outermost layer made up of calcium and magnesium pectate, deposited at the time of cytokinesis. It is a thin amorphous layer which cements two adjacent cells. It is optically inactive (isotropic).

Plasmodesmata and Pits

- Plasmodesmata act as a channel between the protoplasm of adjacent cells through which many substances pass through.

Functions of cell wall

- The cell wall plays a vital role in holding several important functions given below

    1. Offers definite shape and rigidity to the cell.
    2. Serves as barrier for several molecules to enter the cells.
    3. Provides protection to the internal protoplasm against mechanical injury.
    4. Prevents the bursting of cells by maintaining the osmotic pressure.
    5. Plays a major role by acting as a mechanism of defense for the cells.

Cell Membrane

- The cell membrane is also called cell surface (or) plasma membrane. It is a thin structure which holds the cytoplasmic content called 'cytosol'. It is extremely thin (less than 10nm).

Function of Cell Membrane

- The functions of the cell membrane is enormous which includes cell signalling, transporting nutrients and water, preventing unwanted substances entering into the cell, and so on.

Cell Transport

- Cell membrane act as a channel of transport for molecules. The membrane is selectively permeable to molecules. It transports molecules through energy dependant process and energy independent process. The membrane proteins (channel andcarrier) are involved in movement of ions and molecules across the membrane.

Endocytosis and Exocytosis

- Cell surface membrane are able to transport individual molecules and ions. There are processes in which a cell can transport a large quantity of solids and liquids into cell (endocytosis) or out of cell (exocytosis).

- **Endocytosis:**During endocytosis the cell wraps the cell surface membrane around the material and brings it into cytoplasm inside a vesicle. There are two types of endocytosis:

1. Phagocytosis – Particle is engulfed by membrane, which folds around it and forms a vesicle. The enzymes digest the material and products are absorbed by cytoplasm.
2. Pinocytosis – Fluid droplets are engulfed by membrane, which forms vesicles around them.

- **Exocytosis:** Vesicles fuse with plasma membrane and eject contents. This passage of material out of the cell is known as exocytosis. This material may be a secretion in the case of digestive enzymes, hormones or mucus.

Cytoplasm

- Cytoplasm is the main arena of various activities of a cell. It is the semifluid gelatinous substance that fills the cell. It is made up of eighty percent water and is usually clear and colourless. The cytoplasm is sometimes described as non nuclear content of protoplasm. The cytoplasm serves as a molecular soup where all thecellular organelles are suspended and bound together by a lipid bilayer plasma membrane. It constitutes dissolved nutrients, numerous salts and acids to dissolve waste products. It is a very good conductor of electricity. It gives support and protection to the cell organelles. It helps movement of the cellular materials around the cell through a process called cytoplasmic streaming. Further, most cellular activities such as many metabolic pathways including glycolysis and cell division occur in cytoplasm.

V. Cell Organelles

Endomembrane System

- The system of membranes in a eukaryotic cell, comprising the plasma membrane, nuclear membrane, endoplasmic reticulum, golgi apparatus, lysosomes and vacuolar membranes (tonoplast). Endomembranes are made up of phospholipids with embedded proteins that are similar to cell membrane which occur within the cytoplasm. The endomembrane system is evolved from the inward growth of cell membrane in the ancestors of the first eukaryotes.

Endoplasmic Reticulum

- The largest of the internal membranes is called the endoplasmic reticulum (ER). The name endoplasmic reticulum was given by K.R. Porter (1948). It consists of double membrane. Morphologically the structure of endoplasmic reticulum consists of:

1. Cisternae are long, broad, flat, sac like structures arranged in parallel bundles or stacks to form lamella. The space between membranes of cisternae is filled with fluid.
2. Vesicles are oval membrane bound vacuolar structure.
3. Tubules are irregular shape, branched, smooth walled, enclosing a space

- Endoplasmic reticulum is associated with nuclear membrane and cell surface membrane. It forms a network in cytoplasm and gives mechanical support to the cell. Its chemical environment enables protein folding and undergo modification necessary for their function. Misfolded proteins are pulled out and are degraded in endoplasmic reticulum. When ribosomes are present in the outer surface of the membrane it is called as rough endoplasmic reticulum(RER), when the ribosomes are absent in the endoplasmic reticulum it is called as smooth Endoplasmic reticulum(SER). Rough endoplasmic reticulum is involved in protein synthesis and smooth endoplasmic reticulum are the sites of lipid synthesis. The smooth endoplasmic reticulum contains enzymes that detoxify lipid soluble drugs, certain chemicals and other harmful compounds.

Golgi Body (Dictyosomes)

- In 1898, Camillo Golgi visualized a netlike reticulum of fibrils near the nucleus, were named as Golgi bodies. In plant cells theyare found as smaller vesicles termed as dictyosomes. Golgi apparatus is a stack of flat membrane enclosed sacs. It consist of cisternae, tubules, vesicles and golgi vacuoles. In plants the cisternae are 10-20 in number placed in piles separated from each other by a thin layer of inter cisternal cytoplasm often flat or curved.

Peripheral edge of cisternae forms a network of tubules and vesicles. Tubules interconnect cisternae and are 30-50nm in dimension. Vesicles are large round or concave sac. They are pinched off from the tubules.They are smooth/secretary or coated type. Golgi vacuoles are large spherical filled with granular or amorphous substance, some function like lysosomes. The Golgi apparatus compartmentalises a series of steps leading to the production of functional protein.Small pieces of rough endoplasmic reticulum are pinched off at the ends to form small vesicles. A number of these vesicles then join up and fuse together to make a Golgi body. Golgi complex plays a major role in post translational modification of proteins and glycosidation of lipids (Figure 6.16 and 6.17).

Functions:

- Glycoproteins and glycolipids are produced
- Transporting and storing lipids.
- Formation of lysosomes.
- Production of digestive enzymes.
- Cell plate and cell wall formation
- Secretion of Carbohydrates for the formation of plant cell walls and insect cuticles.
- Zymogen granules (proenzyme/pre-cursor of all enzyme) are synthesised.

Mitochondria

- It was first observed by A. Kolliker (1880). Altmann (1894) named it as Bioplasts. Later Benda (1897, 1898), named as mitochondria. They are ovoid, rounded, rod shape and pleomorphic structures. Mitochondrion consists of double membrane, the outer and inner membrane. The outer membrane is smooth, highly permeable to small molecules and it contains proteins called Porins, which form channels that allows free diffusion of molecules smaller than about 1000 daltons and the inner membrane divides the mitochondrion into two compartments, outer chamber between two membranes and the inner chamber filled with matrix.

- The inner membrane is convoluted (infoldings), called crista (plural: cristae). Cristae contain most of the enzymes for electron transport system. Inner chamber ofthe mitochondrion is filled with proteinaceous material called mitochondrial matrix. The inner membrane consists of stalked particles called elementary particles or Fernandez Moran particles, F1 particles or Oxysomes. Each particle consists of a base, stem and a round head. In the head ATP synthase is present for oxidative phosphorylation. Inner membrane is impermeable to most ions, small molecules and maintains the proton gradient that drives oxidative phosphorylation

- Mitochondria contain 73% of proteins, 25-30% of lipids, 5-7 % of RNA, DNA (in traces) and enzymes (about 60 types). Mitochondria are called Power house of a cell, as they produce energy rich ATP.

- All the enzymes of Kreb's cycle are found in the matrix except succinate dehydrogenase. Mitochondria consist of circular DNA and 70S ribosome. They multiply by fission and replicates by strand displacement model. Because of the presence of DNA it is semi-autonomous organelle. Unique characteristic of mitochondria is that they are inherited from female parent only. Mitochondrial DNA comparisons are used to trace human origins. Mitochondrial DNA is used to track and date recent evolutionary time because it mutates 5 to 10 time faster than DNA in the nucleus.

Plastids

- The term plastid is derived from the Greek word Platikas (formed/moulded) and used by A.F.U. Schimper in 1885. He classified plastids into following types according to their structure, pigments and function. Plastids multiply by fission.

- According to Schimper, different kind of plastids can transform into one another.

Chloroplast

- Chloroplasts are vital organelle found in green plants. Chloroplast has a double membrane the outer membrane and the inner membrane separated by a space called periplastidial space. The space enclosed by the inner membrane of chloroplast is filled with gelatinous matrix, lipo-proteinaceous fluid called stroma. Inside the stroma there is flat interconnected sacs called thylakoid. The membrane of thylakoid enclose a space called thylakoid lumen.

- Grana (singular: Granum) are formed when many of these thylakoids are stacked together like pile of coins. Light is absorbed and converted into chemical energy in the granum, which is used in stroma to prepare carbohydrates. Thylakoid contain chlorophyll pigments. The chloroplast contains osmophilic granules, 70s ribosomes, DNA (circular and non histone) and RNA. These chloroplast genome encodes approximately 30 proteins involved in photosynthesis including the components of photosystem I & II, cytochrome bf complex and ATP synthase. One of the subunits of Rubisco is encoded by chloroplast DNA. It is the major protein component of chloroplast stroma, single most abundant protein on earth. The thylakoid contain small, rounded photosynthetic units called quantosomes. It is a semi-autonomous organelle and divides by fission

Functions:

- Photosynthesis
- Light reactions takes place in granum,
- Dark reactions take place in stroma,
- Chloroplast is involved in photo-respiration.

Ribosome

- Ribosomes were first observed by George Palade (1953) as dense particles or granules in the electron microscope. Electron microscopic observation reveals that ribosomes are composed of two rounded sub units, united together to form a complete unit. Mg2+ is required for structural cohesion of ribosomes. Biogenesis of ribosome are denova formation, auto replication and nucleolar origin. Each ribosome is made up of one small and one large sub-unit Ribosomes are the sites of protein synthesis in the cell. Ribosome is not a membrane bound organelle.

- Ribosome consists of RNA and protein: RNA 60 % and Protein 40%. During protein synthesis many ribosomes are attached to the single mRNA is called polysomes or polyribosomes. The function of polysomes is the formation of several copies of a particular polypeptide during protein synthesis. They are free in non-protein synthesising cells. In protein synthesising cells they are linked together with the help of Mg2+ ions.

Lysosomes (Suicidal Bags of Cell)

- Lysosomes were discovered by Christian de Duve (1953), these are known as suicidal bags. They are spherical bodies enclosed by a single unit membrane. They are found in eukaryotic cell. Lysosomes are small vacuoles formed when small pieces of golgi body are pinched off from its tubules.

- They contain a variety of hydrolytic enzymes, that can digest material within the cell. The membrane around lysosome prevent these enzymes from digesting the cell itself.

Functions:

- Intracellular digestion: They digest carbohydrates, proteins and lipids present in cytoplasm.
- Autophagy: During adverse condition they digest their own cell organelleslikemitochondria and endoplasmic reticulum
- Autolysis: Lysosome causes self destruction of cell on insight of disease they destroy the cells.
- Ageing: Lysosomes have autolytic enzymes that disrupts intracellular molecules.

- Phagocytosis: Large cells or contents are engulfed and digested by macrophages, thus forming a phagosome in cytoplasm. These phagosome fuse with lysosome for further digestion.
- Exocytosis: Lysosomes release their enzymes outside the cell to digest other cells.

Peroxisomes

- Peroxisomes were identified as organelles by Christian de Duve (1967). Peroxisomes are small spherical bodies and single membrane bound organelle. It takes part in photorespiration and associated with glycolate metabolism. In plants, leaf cells have many peroxisomes. It is also commonly found in liver and kidney of mammals. These are also found in cells of protozoa and yeast (Figure 6.23).

Glyoxysomes

- Glyoxysome was discovered by Harry Beevers (1961). Glyoxysome is a single membrane bound organelle. It is a sub cellular organelle and contains enzymes of glyoxylate pathway. β-oxidation of fatty acid occurs in glyoxysomes of germinating seeds Example: Castor seeds.

Microbodies

- Eukaryotic cells contain many enzyme bearing membrane enclosed vesicles called microbodies. They are single unit membrane bound cell organelles: Example: peroxisomes and glyoxysomes.

Sphaerosomes

- It is spherical in shape and enclosed by single unit membrane. Example: Storage of fat in the endosperm cells of oil seeds.

Centrioles

- Centriole consist of nine triplet peripheral fibrils made up of tubulin. The central part of the centriole is called hub, is connected to the tubules of the peripheral triplets by radial spokes (9+0 pattern). The centriole form the basal body of cilia or flagella and spindle fibers which forms the spindle apparatus in animal cells. The membrane is absentin centriole (non-membranous organelle)

Vacuoles

- In plant cells vacuoles are large, bounded by a single unit membrane called Tonoplast. The vacuoles contain cell sap, which is a solution of sugars, amino acids, mineral salts, waste chemical and anthocyanin pigments. Beetroot cells contains anthocyanin pigments in their vacuoles. Vacuoles accumulate products like tannins. The osmotic expansion of a cell kept in water is chiefly regulated by vacuole and the water enters the vacuoles by osmosis.

- The major function of plant vacuole is to maintain water pressure known as turgor pressure, which maintains the plant structure. Vacuoles organises itself into a storage/sequestration compartment. Example: Vacuoles store, most of the sucrose of the cell.

1. Sugar in Sugar beet and Sugar cane.
2. Malic acid in Apple.
3. Acids in Citrus fruits.
4. Flavonoid pigment Cyanidin 3 rutinoside in the petals of Antirrhinum.
5. Tannins in Mimosa pudica.
6. Raphide crystals in Dieffenbachia.
7. Heavy metals in Mustard (Brassica).

Latex in Rubber tree and Dandelion stem.

VI. Nucleus

- Nucleus is an important unit of cell which control all activities of the cell. Nucleus holds the hereditary information. It is the largest among all cell organelles. It may be spherical, cuboidal, ellipsoidal or discoidal.

- It is surroundedby a double membrane structure called nuclearenvelope, which has the inner and outer membrane. The inner membrane is smooth without ribosomes and the outer membrane is rough by the presence of ribosomes and is continues with irregular and infrequent intervals with the endoplasmic reticulum. The membrane is perforated by pores known as nuclear pores which allows materials such as mRNA, ribosomal units, proteins and other macromolecules to pass in and out of the nucleus. The pores enclosed by circular structures called annuli. The pore and annuli forms the pore complex. The space between two membranes is called perinuclear space.

- Nuclear space is filled with nucleoplasm, a gelatinous matrix has uncondensedchromatin network and a conspicuous nucleoli. The chromatin network is the uncoiled, indistinct and remain thread like during the interphase. It has little amount of RNA and DNA bound to histone proteins in eukaryotic cells.

- During cell division chromatin is condensed into an organized form called chromosome. The portion of Eukaryotic chromosome which is transcribed into mRNA contains active genes that are not tightly condensed during interphase is called Euchromatin. The portion of a Eukaryotic chromosome that is not transcribed into mRNA which remains condensed during interphase and stains intensely is called Heterochromatin. I Nucleolus is a small, dense, spherical structure either present singly or in multiples inside nucleus and it's not membrane bound. Nucleoli possesses genes for rRNA and tRNA.

Functions of the nucleus

- Controlling all the cellular activities
- Storing the genetic or hereditary information.
- Coding the information in the DNA for the production of enzymes and proteins.
- DNA duplication and transcription takes place in the nucleus.
- In nucleolus ribosomal biogenesis takes place.

Chromosomes

- Strasburger (1875) first reported its present in eukaryotic cell and the term 'chromosome' was introduced by Waldeyer in 1888. Bridges (1916) first proved that chromosomes are the physical carriers of genes. It is made up of DNA and associated proteins.

Unit -7 Cell Cycle

Cell Cycle

- Definition: A series of events leading to the formation of new cell is known as cell cycle. The phenomenonal changes leading to formation of new population take place in the cell cycle. It was discovered by Prevost and Dumans (1824). The series of events include several phases.

Duration of Cell Cycle

- Different kinds of cells have varied duration for cell cycle phases. Eukaryotic cell divides every 24 hours. The cell cycle is divided into mitosis and interphase. In cell cycle 95% is spent for interphase whereas the mitosis and cytokinesis last only for an hour.The different phases of cell cycle are as follows.

Interphase

- Longest part of the cell cycle, but it is of extremely variable length. At first glance the nucleus appears to be resting but this is not the case at all. The chromosomes previously visible as thread like structure, have dispersed. Now they are actively involved in protein synthesis, at least for most of the interphase.

G_1 Phase

- The first gap phase – 2C amount of DNA in cells of G_1. The cells become metabolically active and grows by producing proteins, lipids, carbohydrates and cell organelles including mitochondria and endoplasmic reticulum. Many checkpoints controlthe cell cycle. The checkpoint called the restriction point at the end of G_1, determines a cells fate whether it will continue in the cell cycle and divide or enter a stage called G_0 as a quiescent stage and probably as specified cell or die. Cells are arrested in G_1 due to
- Nutrient deprivation
- Lack of growth factors or density dependant inhibition
- Undergo metabolic changes and enter into G_0 state.

- Biochemicals inside cells activates the cell division. The proteins called kinases and cyclins activate genes and their proteins to perform cell division. Cyclins act as major checkpoint which operates in G_1 to determine whether or not a cell divides.

G_0Phase

- Some cells exit G_1 and enters a quiescent stage called G_0, where the cells remain metabolically active without proliferation. Cells can exist for long periods in G_0 phase. In G_0 cells cease growth with reduced rate of RNA and protein synthesis. The G_0 phase isnot permanent. Mature neuron and skeletal muscle cell remain permanently in G_0. Many cells in animals remains in G_0 unless called on to proliferate by appropriate growth factors or other extracellular signals. G_0 cells are not dormant.

S phase – Synthesis phase – cells with intermediate amounts of DNA.

- Growth of the cell continues as replication of DNA occur, protein molecules called histones are synthesised and attach to the DNA. The centrioles duplicate in the cytoplasm. DNA content increases from 2C to 4C.

G2 – Te second Gap phase – 4C amount of DNA in cells of G2 and mitosis

- Cell growth continues by protein and cell organelle synthesis, mitochondria and chloroplasts divide. DNA content remains as 4C. Tubulin is synthesised and microtubules are formed. Microtubles organise to form spindle fbre. Te spindle begins to form and nuclear division follows.

- One of the proteins synthesized only in the G2 period is known as Maturation Promoting Factor (MPF). It brings about condensation of interphase chromosomes into the mitotic form.

- DNA damage checkpoints operates in G1 S and G2 phases of the cell cycle.

Cell Division
Amitosis (Direct Cell Division)

- Amitosis is also calleddirect or incipient cell division. Here there is no spindle formation and chromatin material does not condense. It consist of two steps: (Figure 7.2).

Karyokinesis:

- Involves division of nucleus.
- Nucleus develops a constriction at the center and becomes dumbell shaped.
- Constriction deepens and divides the nucleus into two.

Cytokinesis:

- Involves division of cytoplasm.
- Plasma membrane develops a constriction along nuclear constriction.
- It deepens centripetally and finally divides the cell into two cells.

- Example: Cells of mammalian cartilage, macronucleus of Paramecium and old degenerating cells of higher plants.

Drawbacks of Amitosis

- Causes unequal distribution of chromosomes.
- Can lead to abnormalities in metabolism and reproduction.

Mitosis

- The most important part of cell division concerns events inside the nucleus. Mitosis occurs in shoot and root tips and other meristematic tissues of plants associated with growth. The number of chromosomes in the parent and the daughter (Progeny) cells remain the same so it is also called as equational division.

Closed and Open Mitosis

- In closed mitosis, the nuclear envelope remains intact and chromosomes migrate to opposite poles of a spindle within the nucleus (Figure 7.3).Example: Many single celled eukaryotes including yeast and slime molds.

- open mitosis, the nuclear envelope breaks down and then reforms around the 2 sets of separated chromosome.
- Example: Most plants and animalsMitosis is divided into four stages prophase, metaphase, anaphase and telophase.

Prophase

- Prophase is the longest phase in mitosis. Chromosomes become visible as long thin thread like structure, condenses to form compact mitotic chromosomes. In plant cells initiation of spindle fibres takes place, nucleolus disappears. Nuclear envelope breaks down. Golgi apparatus and endoplasmic reticulum are not seen.

- In animal cell the centrioles extend a radial array of microtubules towards the plasma membrane when they reach the poles of the cell. T is arrangement of microtubules is called an aster. Plant cells do not form asters.

Metaphase

- Chromosomes (two sister chromatids) are attached to the spindle fibres by kinetochore of the centromere. The spindle fibres is made up of tubulin. The alignment of chromosome into compact group at the equator of the cell is known as metaphase plate. This is the stagewhere the chromosome morphology can be easily studied.

- Kinetochore is a DNA–Protein complex present in the centromere DNA where the microtubules are attached. It is a trilaminar disc like plate.The spindle assembly checkpoint which decides the cell to enter anaphase.

Anaphase

- Each chromosome split simultaneously and two daughter chromatids begins to migrate towards two opposite poles of a cell. Each centromere splits longitudinally into two, freeing the two sister chromatids from each other. Shortening of spindle f bre and longitudinal splitting of centromere creates a pull which divides chromosome into two halves. Each half receive two chromatids (that is sister chromatids are separated). When the sister chromatids separate the actual partitioning of the replicated genome is complete.

- Aubiquitine ligase is activated called as the anaphase-promoting complex cyclosome (APC/C) leads to degradation ofthe key regulatory proteins at the transition of metaphase to anaphase. APC is a cluster of proteins that induces the breaking down of cohesion proteins which leads to the separation of chromatids during mitosis (Figure 7.5).

Telophase

- Two sets of daughter chromosomes reach opposite poles of the cell, mitotic spindle disappears. Division of genetic material is completed afer this karyokinesis, cytokinesis (division of cytoplasm) is completed, nucleolus and nuclear membranes reforms. Nuclear membranes form around each set of sister chromatids now called chromosomes, each has its own centromere. Now the chromosomes decondense. In plants, phragmoplast are formed between the daughter cells. Cell plate is formed between the two daughter cells, reconstruction of cell wall takes place. Finally the cells are separated by the distribution of organelles, macromolecules into two newly formed daughter cells.

Significance of Mitosis

- Exact copy of the parent cell is produced by mitosis (genetically identical).

1. Genetic stability – daughter cells are genetically identical to parent cells.
2. Growth – as multicellular organisms grow, the number of cells making up their tissue increases. The new cells must be identical to the existing ones.
3. Repair of tissues - damaged cells must be replaced by identical new cells by mitosis.
4. Asexual reproduction – asexual reproduction results in offspring that are identical to the parent. Example Yeast and Amoeba.

5. In flowering plants, structure such as bulbs, corms, tubers, rhizomes and runners are produced by mitotic division. When they separate from the parent, they form a new individual.The production of large numbers of ofsprings in a short period of time, is possible only by mitosis. In genetic engineering and biotechnology, tissues are grown by mitosis (i.e. in tissue culture).
6. Regeneration – Arms of star fish

Meiosis

- In Greek meioum means to reduce. Meiosis is unique because of synapsis, homologous recombination and reduction division. Meiosis takes place in the reproductiveorgans. It results in the formation of gametes with half the normal chromosome number.Haploid sperms are made in testes; haploid eggs are made in ovaries of animals.

1. In flowering plants meiosis occurs during microsporogenesis in anthers and megasporogenesis in ovule. In contrast to mitosis, meiosis produces cells that are not genetically identical. So meiosis has a key role in producing new genetic types which results in genetic variation.

Stages in Meiosis

- Meiosis can be studied under two divisions i.e., meiosis I and meiosis II. As with mitosis, the cell is said to be in interphase when it is not dividing.

Meiosis I-Reduction Division

- **Prophase I** – Prophase I is of longer duration and it is div ided into 5 substages – Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis**Leptotene** – Chromosomes are visible under light microscope. Condensation of chromosomes takes place. Paired sister chromatids begin to condense.

- Zygotene – Pairing of homologous chromosomes takes place and it is known as synapsis. Chromosome synapsis is made by the formation of synaptonemal complex. The complex formed by the homologous chromosomes are called as bivalent (tetrads).

- **Pachytene**– At this stage bivalent chromosomes are clearly visible as tetrads. Bivalent of meiosis I consists of 4chromatids and 2 centromeres. Synapsis is completed and recombination nodules appear at a site where crossing over takes place between non-sister chromatids of homologous chromosome. Recombination of homologous chromosomes is completed by the end of the stage but the chromosomes are linked at the sites of crossing over. This is mediated by the enzyme recombinase.

- **Diplotene**– Synaptonemal complex disassembled and dissolves. The homologous chromosomes remain attached at one or more points where crossing over has taken place. These points of attachment where 'X' shaped structures occur at the sites of crossing over is called Chiasmata. Chiasmata are chromatin structures at sites where recombination has been taken place. They are specialised chromosomal structures that hold the homologous chromosomes together. Sister chromatids remain closely associated whereas the homologous chromosomes tend to separate from each other but are held together by chiasmata. This substage may last for days or years depending on the sex and organism. The chromosomes are very actively transcribed in females as the egg stores up materials for use during embryonic development. In animals, the chromosomes have prominent loops called lampbrush chromosome.

- **Diakinesis** – Terminalisation of chiasmata. Spindle fbres assemble. Nuclear envelope breaks down. Homologous chromosomes become short and condensed. Nucleolus disappears.

Metaphase I

- Spindle fibres are attached to the centromeres of the two homologouschromosomes. Bivalent (pairs of homologous chromosomes) aligned at theequator of the cell known as metaphase plate. Each bivalent consists of two centromeres and four chromatids.
- The random distribution of homologous chromosomes in a cell in Metaphase I is called independent assortment.

Anaphase I

- Homologous chromosomes are separated from each other. Shortening of spindle fibers takes place. Each homologous chromosomes with its two chromatids and undivided centromere move towards the opposite poles of the cells. The actual reduction in the number of chromosomes takes place at this stage. Homologous chromosomes which move to the opposite poles are either paternal or maternal in origin. Sister chromatids remain attached with their centromeres.

Telophase I

- Haploid set of chromosomes are present at each pole. The formation of two daughter cells, each with haploid number of chromosomes. Nuclei are reassembled. Nuclear envelope forms around the chromosome and the chromosomes becomes uncoiled. Nucleolus reappears.

- In plants, after karyokinesis cytokinesis takes place by which two daughter cells are formed by the cell plate between 2 groupsof chromosomes known as dyad of cells (haploid).The stage between the two meiotic divisions is called interkinesis which is short-lived.

Meiosis II – Equational division.

- This division is otherwise called mitotic meiosis. Since it includes all the stages of mitotic divisions.

Prophase II

- chromosome with 2 chromatids becomes short, condensed, thick and becomes visible. New spindle develops at right angles to the cell axis. Nuclear membrane and nucleolus disappear.

Metaphase II

- Chromosome arranged at the equatorial plane of the spindle. Microtubules of spindle gets attached to the centromere of sister chromatids.

Anaphase II

- Sister chromatids separate. The daughter chromosomes move to the opposite poles due to shortening of microtubules. Centromere of each chromosome split, allowing to move towards opposite poles of the cells holding the sister chromatids.

Telophase II

- Four groups of chromosomes are orgamnised into dour haploid nuclei. The spindle disappears. Nuclear envelope, nucleolus reappears.

- After karyokinesis, cytokinesis follows and four haploid daughter cells are formed, called tetrads.

Significance of Meiosis

- This maintains a definite constant mumber of chromosomes is organisms.
- Crossing over takes place and exchange of genetic material leads to variations amog species. These variations are the raw materials to evolution. Meiosis leads to genetic variability by partitioning different combinations of genes into gametes through independent assortment.
- Adaptation of organisms to various environmental stress.

Mitogens

- The factors which promote cell cycle proliferation is called mitogens. Plant mitogens include gibberellin, ethylene, Indole acetic acid, kinetin. These increase mitotic rate.

Unit -8 Biomolecules

Carbohydrates

- Carbohydrates are organic compounds made of carbon and water. Thus one molecule of water combines with a carbon atom to form CH2O and is repeated several (n) times to form (CH2O)n where n is an integer ranging from 3–7. These are also called as saccharides. The common term sugar refers to a simple carbohydrate such as a monosaccharide or disaccharide that tastes sweet are soluble in water.

Monosaccharides – The Simple Sugars

- Monosaccharides are relatively small molecules constituting single sugar unit. Glucose has a chemical formula of C6H12O6. It is a six carbon molecule and hence is called as hexose
- All monosaccharides contain one of two functional groups. Some are aldehydes, like glucose and are referred as aldoses; other are ketones, like fructose and are referred as ketoses.

Disaccharides

- Disaccharides are formed when two monosaccharides join together. An example is sucrose. Sucrose is formed from a molecule of α-glucose and a molecule of fructose.

- In the reverse process, a disaccharide is digested to the component monosaccharide in a hydrolysis reaction. This reaction involves addition of a water (hydro) molecule and splitting (lysis) of the glycosidic bond.

Polysaccharides

- These are made of hundreds of monosaccharide units. Polysaccharides also called "Glycans". Long chain of branched or unbranchedmonosaccharides are held together by glycosidic bonds. Polysaccharide is an example of giant molecule, a macromolecule and consists of only one type of monomer.

- This is a condensation reaction releasing water. The bond formed between the glucose and fructose molecule by removal of water is called glycosidic bond. This is another example of strong, covalent bond.aresweetless. Cellulose is an example built from repeated units of glucose monomer.Depending on the function, polysaccharides are of two types -storage polysaccharide and structural polysaccharide (Figure 8.8).

Starch

- Starch is a storage polysaccharides made up of repeated units of amylose and amylopectin. Starch grains are made up of successive layers of amylose and amylopectin, which can be seen as growth rings. Amylose is a linear, unbranched polymer which makes up 80% of starch. Amylopectin is a polymer with some 1, 6 linkages that gives it a branched structure.

Chitin

- Chitin is a homo polysaccharide with amino acids added to form mucopolysaccharide. The basic unit is anitrogen containing glucosederivative known as N-acetyl glucoseamine.It forms the exoskeleton of insects and other arthropods. It is also present in the cell walls of fungi.

Lipids

- The term lipid is derived from greek word lipos, meaning fat. These substances are not soluble in polar solvent such as water but dissolve in non-polar solvents such as benzene, ether, chloroform. This is because they contain long hydrocarbon chains that are non-polar and thus hydrophobic. The main groups of compounds classifiedas lipids are triglycerides, phospholipids, steroids and waxes.

Triglycerides

- Triglycerides are composed of single molecule of glycerol bound to 3 fatty acids. These include fats and oils. Fatty acids are long chain hydrocarbons with a carboxyl group at one end which binds to one of the hydroxyl groups of glycerol, thus forming an ester bond. Fatty acids are structural unit of lipids and are carboxylic acid of long chain hydrocarbons. The hydrocarbon can vary in length from 4 – 24 carbons and the fat may be saturated or unsaturated. In saturated fatty acids the hydrocarbon chain is single bonded (Eg. palmitic acid, stearic acid) and in unsaturated fatty acids (Eg. Oleic acid,linoleic acid) the hydrocarbon chain is double bonded (one/two/three). In general solid fats are saturated and oils are unsaturated, in which most are globules.

Membrane Lipids

- A class of lipids that serves as major structural component of cell membrane is phospholipids. These contain only 2 fatty acids attached to the glycerol, while the third glycerol binding site holds a phosphate group. This phosphate group is in turn bonded to an alcohol. These lipids have both hydrophobicand hydrophilic regions. The structure of lipid bilayer helps the membrane in function such as selective permeability and fluid nature (Figure 8.15).

Steroids

- These are complex compounds commonly found in cell membrane and animal hormones. Eg. Cholesterol which reinforces the structure of the cell membrane in animal cells and in an unusual group of cell wall deficient bacteria – Mycoplasma.

Waxes

- These are esters formed between a long chain alcohol and saturated fatty acids.Lecithin is a food additive and dietery supplement

- Fur, feathers, fruits, leaves, skin and insect exoskeleton are naturally waterproofed with a coating of wax.

Proteins

- Proteins are the most diverse of all macromolecule. Proteins make up 2/3 of total dry mass of a cell. The term protein was coined by Gerardus Johannes Mulder and is derived form a greek word proteos which means of the first rank.

- Amino acids are building blocks of proteins. There are about 20 different amino acids exist naturally. All amino acids have a basic skeleton consisting of a carbon (a-carbon) linked to a basic amino group.(NH2), an acidic carboxylic group (COOH) and a hydrogen atom (H) and side chain or variable R group. The amino acid is both an acid and a base and is called amphoteric.

- A zwitterion also called as dipolar ion, is a molecule with two or more functional groups, of which at least one has a positive and other has a negative electrical charge and the net charge of the entire molecule is zero. The pH at which this happens is known as the isoelectric point (Figure 8.19).

Classification of Amino acids

- Based on the R group amino acids are classified as acidic, basic, polar, non-polar.The amino group of one amino acid reacts with carboxyl group of other amino acid, forming a peptide bond. Tw o amino acids can react together with the loss of water to form a dipeptide. Long strings of amino acids linked by peptide bonds are called polypeptides. In 1953 Fred Sanger first sequenced the Insulin protein (Figure 8.18 and 8.20 a and b).

Structure of Protein

- Protein is synthesised on the ribosome as a linear sequence of amino acids which are held together by peptide bonds. After synthesis,the protein attains conformational change into a specific 3D form for proper functioning. According to the mode of folding, four levels of protein organisation have been recognised namely primary, secondary, tertiary and quaternary.
- The primary structure is linear arrangement of amino acids in a polypeptide chain.
- Secondary structure arises when various functional groups are exposed on outer surface of the molecular interaction by forming hydrogen bonds. This causes the aminoacid chain to twist into coiled configuration called α-helix or to fold into a flat β-pleated sheets.
- Tertiary protein structure arises when the secondary level proteins fold into globular structure called domains.
- Quaternary protein structure may be assumed by some complex proteins in which more than one polypeptide forms a large multiunit protein. The individual polypeptide chains of the protein are called subunits and the active protein itself is called amultimer.

- For example: Enzymes serve as catalyst for chemical reactions in cell and are non-specific. Antibodies are complex glycoproteins with specific regions of attachment for various organisms.

Protein Denaturation

- Denaturation is the loss of 3D structure of protein. Exposure to heat causes atoms to vibrate violently, and this disrupts the hydrogen and ionic bonds. Under these conditions, protein molecules become elongated, disorganised strands. Agents such as soap, detergents, acid, alcohol and some disinfectants disrupt the interchain bond and cause the molecule to be nonfunctional (Figure 8.25).

Enzymes

- Enzymes are globular proteins that catalyse the many thousands of metabolic reactions taking place within cells and organism. The molecules involved in such reactions are metabolites. Metabolism consists of chains and cycles of enzyme-catalysed reactions, such as respiration, photosynthesis, protein synthesis and other pathways. These reactions are classified as

    - **anabolic** (building up of organic molecules). Synthesis of proteins from amino acids and synthesis of polysaccharides from simple sugars are examples of anabolic reactions.
    - **catabolic** (breaking down of larger molecules). Digestion of complexfoods and the breaking down of sugar in respiration are examples of catabolic reactions.

- Enzymes can be extracellular enzyme as secreted and work externally exported from cells. Eg. digestive enzymes; or intracellular enzymes that remain within cells and work there. These are found inside organelles or within cells. Eg. insulin

Properties of Enzyme

- All are globular proteins.
- They act as catalysts and effective even in small quantity.
- They remain unchanged at the end of the reaction.
- They are highly specific.
- They have an active site where the reaction takes place.
- Enzymes lower activation energy of the reaction they catalyse.

- As molecules react they become unstable, high energy intermediates, but they are in this transition state only momentarily. Energy is required to raise molecules to this transitionstate and this minimum energy needed is called the activation energy. This could be explained schematically by 'boulder on hillside' model of activation energy.

Lock and Key Mechanism of Enzyme

- In a enzyme catalysed reaction, the starting substance is the substrate. It is converted to the product. The substrate binds to the specially formed pocket in the enzyme – the active site, this is called lockand key mechanism of enzyme action. As the enzyme and substrate form a ES complex, the substrate is raised in energy to a transition state and then breaks down into products plus unchanged enzyme.

Factors Affecting the Rate of Enzyme Reactions

- Enzymes are sensitive to environmental condition. It could be affected by temperature, pH, substrate concentration and enzyme concentration.

- The rate of enzyme reaction is measured by the amount of substrate changed or amount of product formed, during a period of time.

Nucleic Acids

- As we know DNA and RNA are the two kinds of nucleic acids. These were originally isolated from cell nucleus. They are present in all known cells and viruses with special coded genetic programme with detailed and specific instructions for each organism heredity.DNA and RNA are polymers of monomers called nucleotides, each of which is composed of a nitrogen base, a pentose sugar and a phosphate. A purine or a pyrimidine and a ribose or deoxyribose sugar is called nucleoside. A nitrogenous base is linked to pentose sugar through n-glycosidic linkage and forms a nucleoside. When a phosphate group is attached to a nucleoside it is called a nucleotide. The nitrogen base is aheterocyclic compound that can be either a purine (two rings) or a pyrimidine (one ring). There are 2 types of purines –adenine (A) and guanine (G) and 3 types of pyrimidines – cytosine (C), thymine (T) and uracil (U) (Figure 8.38).

- A characteristic feature that differentiates DNA from RNA is that DNA contains nitrogen bases such as Adenine, guanine, thymine (5-methyl uracil) and cytosine and the RNA contains nitrogen bases such as adenine, guanine, cytosine and uracil instead of thymine. The nitrogen base is covalently bonded to the sugar ribose in RNA and to deoxyribose (ribose with one oxygen removed from C2) in DNA. Phosphate group is a derivative of (PO43-) phosphoric acid, and forms phosphodiester linkages with sugar molecule (Figure 8.39).

Formation of Dinucleotide and Polynucleotide

- Two nucleotides join to form dinucleotide that are linked through 3′-5′ phosphodiester linkage by condensation between phosphate groups of one with sugar of other. This is repeated many times to make polynucleotide.

Structure of DNA

- Watson and Crick shared the Nobel Prize in 1962 for their discovery, along with Maurice Wilkins, who had produced the crystallographic data supporting the model. Rosalind Franklin (1920–1958) had earlier produced the first clear crystallographic evidence for a helical structure. James Watson and Francis Crick (Figure 8.40) of Cavendish laboratory in Cambridge built a scale model of double helical structure of DNA which is the most prevalent form of DNA, the B-DNA. This is the secondary structure of DNA.

- As proposed by James Watson and Francis Crick, DNA consists of right handed double helix with 2 helical polynucleotide chains that are coiled around a common axis to form righthanded B form of DNA. The coils are held together by hydrogen bonds which occur between complementary pairs of nitrogenous bases. The sugar is called 2′-deoxyribose because there is no hydroxyl at position 2′. Adenine and thiamine base pairs has two hydrogen bonds while guanine and cytosine base pairs have three hydrogen bonds.

- As published by Erwin Chargaff in 1949, a purine pairs with pyrimidine and vice versa. Adenine (A) always pairs with Thymine (T) by double bond and Guanine (G) always pairs with Cytosine (C) by triple bond.

Features of DNA

- If one strand runs in the 5'-3' direction, the other runs in 3'-5' direction and thus are antiparallel (they run in opposite direction). The 5' end has the phosphate group and 3end has the OH group.

- The angle at which the two sugars protrude from the base pairs is about 120°, for the narrow angle and 240° for the wide angle. The narrow angle between the sugars generates a minor groove and the large angle on the other edge generates major groove.
- Each base is 0.34 nm apart and a complete turn of the helix comprises 3.4 nm or 10 base pairs per turn in the predominant B form of DNA.

- DNA helical structure has a diameter of 20 A° and a pitch of about 34 A°. X-ray crystal study of DNA takes a stack of about 10 bp to go completely around the helix (360°).

- Thermodynamic stability of the helix and specificity of base pairing includes (i) the hydrogen bonds between the complementary bases of the double helix (ii) stacking interaction between bases tend to stack about each other perpendicular to the direction of helical axis. Electron cloud interactions (Ft - n) between the bases in the helical stacks contribute to the stability of the double helix.

- The phosphodiesterlinkages gives an inherent polarity to the DNA helix. They form strong covalent bonds, gives the strength and stability to the polynucleotide chain.

- Plectonemic coiling - the two strands of the DNA are wrapped around each other in a helix, making it impossible to simply move them apart withoutbreaking the entire structure. Whereas in paranemic coiling the two strands simply lie alongside one another, making them easier to pull apart.

- Based on the helix and the distance between each turns, the DNA is of three forms – A DNA, B DNA and Z DNA.

Ribonucleic Acid (RNA)

- Ribonucleic acid (RNA) is a polymeric molecule essential in various biological roles in coding, decoding, regulation and expression of genes. RNA is single stranded and is unstable when compared to DNA.

Types of RNA

- mRNA (messenger RNA): Single stranded, carries a copy of instructions for assembling amino acids into proteins. It is very unstable and comprises 5% of total RNA polymer. Prokaryotic mRNA (Polycistronic) carry coding sequences for many polypeptides. Eukaryotic mRNA (Monocistronic) contains information for only one polypeptide.

- tRNA (transfer RNA): Translates the code from mRNA and transfers aminoacids to the ribosome to build proteins. It is highly folded into an elaborate 3D structure and comprises about 15% of total RNA. It is also called as soluble RNA.

- rRNA (ribosomal RNA): Single stranded, metabolically stable, make up the two subunits of ribosomes. It constitutes 80% of the total RNA. It is a polymer with varied length from 120–3000 nucleotides and gives ribosomes their shape. Genes for rRNA are highly conserved and employed for phylogenetic studies.

7th Std term(II)
Unit – 4 Cell Biology

Cell Structure

- As we have mentionedbefore, all cells have somecommon structure.

These are

1. Cell membrane
2. Cytoplasm, and
3. Nucleus (In most eukaryotic cells).

- The structure of a typical plant and animal cellshows following peculiarities:

Cell membrane

- The boundary of an animal cell is theplasma membrane, which is also calledascellmembrane

Cell wall - "Supporter and Protector"

- All animal and plant cells are enclosed orsurrounded by a cell membrane asyoulearnedbefore. However, as you might have noticedpreviously that, animalcells often have anirregular shape, whereas plant cells have a muchmore regular and rigid shape.

- Plant cells have an additional layer on theouter side of the cell membrane.This is calledas the cell wall that provides a frame work forsupport and stability.The cell wall is formed from variouscompounds, the main one being cellulose.Cellulose helps to maintain the shape of theplant cell. This allows the plant toremainrigidand upright even if it grows to great heights.Each cell is interconnectedwith its neighbouringcells through openings called Plasmodesmata.

Stem Cells

Stem cells are quite amazingas they can divide andmultiply while at the sametime with their ability to develop into anyother type of cell. Embryonic stem cellsarevery special as they can become absolutelyany type of cell in the body, forexample,blood cell, nerve cell, muscle cell or glandcell. So they are utilized by theScientistand Medicos, to cure and prevent somediseases like Spinal cord injury.

Cytoplasm - I am the "Area of Movement".

- When you look at the temporary mountsof an onion peel, you can see a largeregionofeach cell an enclosed by the cell membrane. Thisregion takes up very littlestain. It is called thecytoplasm.

- The cytoplasm includes all living parts ofthe cell with in the cell membrane,excludingthenucleus. The cytoplasm is made up of the cytosoland cell organelles.The cytosol is a watery, jellylikemedium made up of 70% - 90% water andusuallycolourless.

- Cell organelles and structures presentin a cell are endoplasmic reticulum,vacuole,ribosome, Golgi body, lysosome, mitochondria,centriole, chloroplast,surrounded by plasmamembrane and cell wall.

Protoplasm vs. Cytoplasm

- In particular, the material inside and outsidethe nuclear membrane is knownasProtoplasmThe fluid inside the nucleus is known as thenuclear fluid or nucleoplasm and outside thenucleus is called as cytoplasm.

Inside the cytoplasm Mitochondria - "Power house of the Cell"

- Do you remember learning about the foodas the energy source for the body?Just as woodis burnt to release the stored potential energyto make a fire to heatsome water The food thatyou ate to be broken down in order to releasetheenergywhich can be used by your body tofunction. Mitochondria are responsible to dothisfunction.
- Very active cells have more mitochondriathan cells that are less active. Whichtype of cell,do you think, will have more mitochondria, amuscle cells or a bonecell?

- Mitochondrian is an oval or rod shapeddouble membrane bounded organelle.Aerobicrespiratory reactions take place within themitochondrion to release energy.So it is knownas "the Power House" of the cell. The energyproduced within themitochondrion is used forall the metabolic activities of the cell

Chloroplast- "Food Producers"

- Do you notice the green organellespresent in plant cells and absent in animalcells.Chloroplasts are the only cell organelles thatcan produce food from thesunenergy. Only plants withchloroplast are able to dophotosynthesis because theycontain the very importantgreen pigment, chlorophyll.Chlorophyll can absorbradiant energy fromthe Sun and convert it to the chemical energywhich can beused by the plants and animals.Animal cells lack chloroplasts and are unable todophotosynthesis.

Golgi complex- I need a break

- Membrane bounded sacs are stacked on topof the other with associatedsecretory vesicles arecollectively known as Golgi complex. FunctionsofGolgicomplex are the production of secretorysubstances, packaging and secretion. This isthesecret behind the change in the colour and tasteof fruits

Lysosome- "Suicidal Bag"
Everything I touch, I destroy

- You will find organelles called aslysosomes, which are very small to viewusinga light microscope. They are the main digestivecompartments of the cell. Theylyse a cell, hencethey are called "suicidal bag".

Centrioles

- They are generally found close to thenucleus and are made up of tube-likestructures.Centrioles or centrosomes are present only inanimal cells and absent inplant cells. It helpsin the separation of chromosomes during celldivision.

Endoplasmic reticulum - You guys, be quiet, I have so much work to do

- It is an inter membranous network madeup of flat or tubular sacs within thecytoplasm.Endoplasmic reticulum is of two types. Theyare rough endoplasmicreticulum and smoothendoplasmic reticulum.

- **Rough endoplasmic reticulum**: are rough dueto the ribosomes attached to themembrane.which helps in the synthesis of protein.

- **Smooth endoplasmic reticulum**. It is a networkof tubular sacs withoutribosomes on themembrane. They play a role in the synthesis oflipids, steroids andalso transport them withinthe cell.

Nucleus - Everyone do what I say. Acting like the "Brain" of the cell

- Plant and animal cells have a nucleus insidethe cytoplasm. It is surrounded by anuclearenvelope. One or two nucleolus and thechromatin body are present insidethenucleus. During cell division, the chromatinbody is organised into achromosome.Storage of genetic material and transfersheredity characters fromgenerationtogeneration are the functions of chromosome.

Functions of Nucleus

- In controls all the processes and chemicalreactionsthat take place inside the cell
- Inheritance of character from one generation to another

Red blood cells

Red bloodcells do notcontainanucleus. Without a nucleus,these cells diequickly; about two millionred blood cells die every second! Luckily,thebodyproduces new red blood cellsevery day.

6th Term (II)
Unit 5. The Cell

The Structural Organization Of The Cell

A typical cell consists of three major parts:

1. An outer cell membrane.
2. A liquid cytoplasm.
3. A nucleus.

- Analogous to the body's internal organ, like eyes, heart, lungs organelles are specialized structures and perform valuable functions necessary for normal cellular operation. Many of miniscule but distinct structures called Organelles lie within the cell.

Size of the cell

- The size of cells may vary from a micrometer (a million of a metre) to a few centimeters. Most cells are microscopic and cannot be seen with the nacked eye. They can be observed only through the Microscope.

- Smallest size of the cell is present in Bacteria. The size of the bacterial cell ranges from 0.01 micrometer to 0.5 micro meter.

- On the other hand the largest cell is the egg of an ostrich with 170 millimeter width. We can see this with the nacked eye. In Human body the nerve cells are believed to be the longest cells.

Cell size has no relation to the size of an organism. It is not necessary that the cells of, say an elephant be much larger than those of a mouse.

Shapes

- Cells are of different shapes. For example some shapes are given in the below pictures.

Number

- The number of cells present in different organisms may vary. Organisms may be either unicellular (single cell) or multicellular. Organisms such as Bacteria, Amoeba, Chlamydomonas, and Yeast are unicellular. On the other hand, organisms such as Spirogyra, Mango, and Human beings are multicellular. (i.e) made up of a few hundreds to million cells.

Approximate number of cells in the human body is 3.7 X1013 or 37,000,000,000,000

Differences between Prokaryotic cell Eukaryotic cell

Prokaryotic cell	Eukaryotic cell
It's diameter ranges from 1 to 2 micron	It's diameter ranges from 10 t0 100 micron
Absence of membrane bound organelles	Presence of membrane bound organelles
Nucleus consisting of no nuclear membrane	True nucleus consisting of nuclear membrane
Absence of nucleoli	Presence of nucleoli

Plant cell and Animal cell

- Both plant and animals are made up of cells. Both cells are eukaryotic in nature, having a well defined membrane – bound nucleus.

Plant cell

- ❖ It is usually larger in size. It is hard in nature.
- ❖ Plant cell have a cell wall in addition to their cell membrane.
- ❖ Plant cell have chloroplast which contain chlorophyll
- ❖ Plant cells have large vacuoles. Centrioles are absent.

Animal cell

- ❖ Animal cells are generally smaller than plant cells. It is not so hard as plant cell.
- ❖ A cell wall is absent.
- ❖ Chloroplast is usually absent.
- ❖ An animal cell may have many small vacuoles.
- ❖ Centrioles are found in animal cells

Cell components and their functions

S. No	Cell Components	Main Functions	Special Name

1.	Cell wall	• Surrounds and protects the cell • Make the cell stiff and strong	Supporter and protector
2.	Cellmembrane	• Holds and protects the cell • Controls the movement of materials in and out of the cell	Gate of the cell
3.	Cytoplasm	• A watery, gel-like material in • which cellparts move	Area of movement
4.	Mitochondria	• Produce and supply most of Theenergyfor the cell	Power house of the cell
5.	Chloroplasts	• Contain green pigment chlorophyll • Capture the energy of sunlight and use it to produce food for the cell by photosynthesis.	Food producers for the cell (Plant cell)
6.	Vacuoles	• Store food, water, and chemicals	Storage tanks
7.	Nucleus	• Acts as 'brain' of the cell • Regulates and controls all the cell activities	Control centre
8.	Nucleusmembrane	• Surrounds and protects the nucleus control the movement materials in and out of the nucleus	Gate of the nucleus

Physiology
11^{th} zoology
Unit – 6 -Respiration

Respiratory functions

The five primary functions of the respiratory system are –

i. To exchange O2 and CO2 between the atmosphere and the blood.
ii. To maintain homeostatic regulation of body pH.
iii. To protect us from inhaled pathogens and pollutants.
iv. To maintain the vocal cords for normal communication (vocalization).
v. To remove the heat produced during cellular respiration through breathing.

Human Respiratory System

The respiratory system includes the external nostrils, nasal cavity, the pharynx, the larynx, the trachea, the bronchi and bronchioles and the lungs which contain the alveoli. The parts starting from the external nostrils up to the terminal bronchioles constitute the conducting zone, whereas the alveoli and the ducts are called the respiratory zone. The parts of the conducting zone, humidifies and warms the incoming air.

In human beings, air enters the upper respiratory tract through the external nostrils. The air passing through the nostrils is filtered by fine hairs and mucus lining the passage. The external nostrils lead to the nasal chamber which opens into the nasopharynx which opens through the glottis of the larynx region into the trachea. The ciliated epithelial cells lining the trachea, bronchi and bronchioles secrete mucus. Mucus membrane lining the airway contains goblet cells which secrete mucus, a slimy material rich in glycoprotein. Microorganisms and dust particles attach in the mucus films and are carried upwards to pass down the gullet during normal swallowing. During swallowing a thin elastic flap called epiglottis prevents the food from entering into the larynx and avoids choking of food.

The trachea is semiflexible tube supported by multiple cartilaginous rings which extends up to the midthoracic cavity and at the level of the 5th thoracic vertebra where it divides into right and left primary bronchi, one bronchus to each lung. Within the lungs the bronchi divides repeatedly into secondary and tertiary bronchi and further divides into terminal bronchioles and respiratory bronchioles.

Bronchi have 'C' shaped curved cartilage plates to ensure that the air passage does not collapse or burst as the air pressure changes during breathing. The bronchioles are without cartilaginous rings and have rigidity that prevent them from collapsing but are surrounded by smooth muscle which contracts or relaxes to adjust the diameter of these airways.

The fine respiratory bronchioles terminate into highly vascularised thin walled pouch like air sacs called alveoli meant for gaseous exchange. The diffusion membrane of alveolus is made up of three layers – the thin squamous epithelial cells of the alveoli, the endothelium of the alveolar capillaries and the basement substance found in between them. The thin squamous epithelial cells of the alveoli are composed of Type I and Type II cells. Type I cells are very thin so that gases can diffuse rapidly through them. Type II cells are thicker, synthesize and secrete a substance called Surfactant.

The lungs are light spongy tissues enclosed in the thoracic cavity surrounded by an airtight space. The thoracic cavity is bound dorsally by the vertebral column and ventrally by the sternum, laterally by the ribs and on the lower side by the dome shaped diaphragm.

The lungs are covered by double walled pleural membrane containing a several layers of elastic connective tissues and capillaries, which encloses the pleural fluid. Pleural fluid reduces friction when the lungs expand and contract.

The steps involved in respiration are

i. The exchange of air between the atmosphere and the lungs.
ii. The exchange of $O2$ and $CO2$ between the lungs and the blood.
iii. Transport of $O2$ and $CO2$ by the blood.
iv. Exchange of gases between the blood and the cells.
v. Uptake of $O2$ by the cells for various activities and the release of $CO2$.

SURFACTANTS are the thin non–cellular films made of protein and phospholipids covering the alveolar membrane. The surfactant lowers the surface tension in the alveoli and prevents the lungs from collapsing. It also prevents pulmonary oedema. Premature Babies have low levels of surfactant in the alveoli may develop the new born respiratory distress syndrome (NRDS) because the synthesis of surfactants begins only after the 25th week of gestation.

Mechanism of breathing

The movement of air between the atmosphere and the lungs is known as ventilation or breathing. Inspiration and expiration are the two phases of breathing. Inspiration is the movement of atmospheric air into the lungs and expiration is the movement of alveolar air that diffuse out of the lungs.

Lungs do not contain muscle fibres but expands and contracts by the movement of the ribs and diaphragm. The diaphragm is a sheet of tissue which separates the thorax from the abdomen. In a relaxed state, the diaphragm is domed shaped.

Ribs are moved by the intercostal muscles. External and internal intercostal muscles found between the ribs and the diaphragm helps in creating pressure gradients. Inspiration occurs if the pressure inside the lungs (intrapulmonary pressure) is less than the atmospheric pressure likewise expiration takes place when the pressure within the lungs is higher than the atmospheric pressure.

Exchange of gases

The primary site for the exchange of gases is the alveoli. The uptake of O2 and the release of CO2 occur between the blood and tissues by simple diffusion driven by partial pressure gradient of O2 and CO2. Partial pressure is the pressure contributed by an individual gas in a mixture of gases. It is represented as pO2 for oxygen and pCO2 for carbon–dioxide. Due to pressure gradients, O2 from the alveoli enters into the blood and reaches the tissues. CO2 enters into the blood from the tissues and reaches alveoli for elimination. As the solubility of CO2 is 20–25 times higher than that of O2, the partial pressure of CO2 is much higher than that of O2 (Tab.6.1 and Figure 6.6).

Transport of gases

Transport of oxygen

Molecular oxygen is carried in blood in two ways: bound to haemoglobin within the red blood cells and dissolved in plasma. Oxygen is poorly soluble in water, so only 3% of the oxygen is transported in the dissolved form. 97% of oxygen binds with haemoglobin in a reversible manner to form oxyhaemoglobin (HbO_2). The rate at which haemoglobin binds with O_2 is regulated by the partial pressure of O_2. Each haemoglobin carries maximum of four molecules of oxygen. In the alveoli high pO_2, low pCO_2, low temperature and less H+ concentration, favours the formation of oxyhaemoglobin, whereas in the tissues low pO2, high pCO_2, high H+ and high temperature favours the dissociation of oxygen from oxyhaemoglobin.

A sigmoid curve (S–shaped) is obtained when percentage saturation of haemoglobin with oxygen is plotted against pO_2. This curve is called oxygen haemoglobin dissociation curve. This S–shaped curve has a steep slope for pO_2 values between 10 and 50mmHg and then flattens between 70 and 100 mm Hg.

Under normal physiological conditions, every 100mL of oxygenated blood can deliver about 5mL of O_2 to the tissues.

Transport of Carbon–dioxide

Blood transports CO_2 from the tissue cells to the lungs in three ways

i. Dissolved in plasma About 7 – 10% of CO_2 is transported in a dissolved form in the plasma.

ii. Bound to haemoglobin About 20 – 25% of dissolved CO2 is bound and carried in the RBCs as carbaminohaemoglobin (Hb CO2) CO2 + Hb $\rightleftharpoons$ Hb CO2

iii. As bicarbonate ions in plasma about 70% of CO2 is transported as bicarbonate ions.

This is influenced by pCO2 and the degree of haemoglobin oxygenation. RBCs contain a high concentration of the enzyme, carbonic anhydras, Whereas small amounts of carbonic anhydrase is present in the plasma.

At the tissues the pCO2 is high due to catabolism and diffuses into the blood to form HCO3 – and H+ ions. When CO2 diffuses into the RBCs, it combines with water forming carbonic acid (H2CO3) catalyzed by carbonic anhydrase. Carbonic acid is unstable and dissociates into hydrogen and bicarbonate ions.

Carbonic anhydrase facilitates the reaction in both directions.

$$CO_2 + H_2O \overset{\text{carbonic anhydrase}}{\rightleftharpoons} H_2CO_3 \overset{\text{carbonic anhydrase}}{\rightleftharpoons} HCO_3^- + H^+$$

The HCO_3– moves quickly from the RBCs into the plasma, where it is carried to the lungs. At the alveolar site where pCO_2 is low, the reaction is reversed leading to the formation of CO_2 and water. Thus CO_2 trapped as HCO_3– at the tissue level it is transported to the alveoli and released out as CO_2. Every 100mL of deoxygenated blood delivers 4mL of CO_2 to the alveoli for elimination.

Problems in Oxygen transport

When a person travels quickly from sea level to elevations above 8000ft, where the atmospheric pressure and partial pressure of oxygen are lowered, the individual responds with symptoms of acute mountain sickness (AMS)–headache, shortness of breath, nausea and dizziness due to poor binding of O2 with haemoglobin. When the person moves on a long–term basis to mountains from sea level is body begins to make respiratory and haematopoietic adjustments. To overcome this situation kidneys accelerate production of the hormone erythropoietin, which stimulates the bone marrow to produce more RBCs.

Allergy is caused by allergens. When we enter a polluted area, immediately we start sneezing and coughing. The allergens in that place affect our respiratory tracts and the responses to the allergens start within minutes. Allergens provoke an inflammatory response. A common manifestation of allergy is Asthma.

When a person descends deep into the sea, the pressure in the surrounding water increases which causes the lungs to decrease in volume. This decrease in volume increases the partial pressure of the gases within the lungs. This effect can be beneficial, because it tends to drive additional oxygen into the circulation, but this benefit also has a risk, the increased pressure can also drive nitrogen gas into the circulation. This increase in blood nitrogen content can lead to a condition called nitrogen narcosis. When the diver ascends to the surface too quickly a condition called 'bends' or decompression sickness occurs and nitrogen comes out of solution while still in the blood forming bubbles. Small bubbles in the blood are not harmful, but large bubbles can lodge in small capillaries, blocking blood flow or can press on nerve endings. Decompression sickness is associated with pain in joints and muscles and neurological problems including stroke. The risk of nitrogen narcosis and bends is common in scuba divers.

During carbon–dioxide poisoning, the demand for oxygen increases. As the O_2 level in the blood decreases it leads to suffocation and the skin turns bluish black.

Disorders of the Respiratory system

Respiratory system is highly affected by environmental, occupational, personal and social factors. These factors may be responsible for a number of respiratory disorders. Some of the disorders are discussed here.

Asthma – It is characterized by narrowing and inflammation of bronchi and bronchioles and difficulty in breathing. Common allergens for asthma are dust, drugs, pollen grains, certain food items like fish, prawn and certain fruits etc.
Emphysema– Emphysema is chronic breathlessness caused by gradual breakdown of the thin walls of the alveoli decreasing the total surface area of a gaseous exchange. i.e., widening of the alveoli is called emphysema. The major cause for this disease is cigarette smoking, which reduces the respiratory surface of the alveolar walls.

Bronchitis– The bronchi when it gets inflated due to pollution smoke and cigarette smoking, causes bronchitis. The symptoms are cough, shortness of breath and sputum in the lungs.

Pneumonia– Inflammation of the lungs due to infection caused by bacteria or virus is called pneumonia. The common symptoms are sputum production, nasal congestion, shortness of breath, sore throat etc.

Tuberculosis– Tuberculosis is caused by Mycobacterium tuberculae. This infection mainly occurs in the lungs and bones. Collection of fluid between the lungs and the chest wall is the main complication of this disease.

Occupational respiratory disorders– The disorders due to one's occupation of working in industries like grinding or stone breaking, construction sites, cotton industries, etc. Dust produced affects the respiratory tracts.

Long exposure can give rise to inflammation leading to fibrosis.

Silicosis and asbestosis are occupational respiratory diseases resulting from inhalation of particle of silica from sand grinding and asbestos into the respiratory tract. Workers, working in such industries must wear protective masks.

Effects of Smoking

Today due to curiosity, excitement or adventure youngsters start to smoke and later get addicted to smoking. Research says about 80% of the lung cancer is due to cigarette smoking.

Smoking is inhaling the smoke from burning tobacco. There are thousands of known chemicals which includes nicotine, tar, carbon monoxide, ammonia, sulphur–dioxide and even small quantities of arsenic. Carbon monoxide and nicotine damage the cardiovascular system and tar damages the gaseous exchange system. Nicotine is the chemical that causes addiction and is a stimulant which makes the heart beat faster and the narrowing of blood vessels results in raised blood pressure and coronary heart diseases. Presence of carbon monoxide reduces oxygen supply. Lung cancer, cancer of the mouth and larynx is more common in smokers than non–smokers. Smoking also causes cancer of the stomach, pancreas and bladder and lowers sperm count in men. Smoking can cause lung diseases by damaging the airways and alveoli and results in emphysema and chronic bronchitis. These two diseases along with asthma are often referred as Chronic Obstructive Pulmonary Disease (COPD). When a person smokes, nearly 85% of the smoke released is inhaled by the smoker himself and others in the vicinity, called passive smokers, are also affected. Guidance or counselling should be done in such users to withdraw this habit.

Gaseous Exchange

Respiration

- The term respiration was coined by Pepys (1966). Respiration is a biological process in which oxidation of various food substances like carbohydrates, proteins and fats take place and as a result of this, energy is produced where O2 is taken in and CO2 is liberated. Theorganic substances which are oxidized during respiration are called respiratory substrates. Among these, glucose is the commonest respiratory substrate. Breaking of C-C bonds of complex organic compounds through oxidation within the cells leads to energy release. The energy released during respiration is stored in the form of ATP (Adenosine Tri Phosphate) as well as liberated heat. Respiration occurs in all the living cells of organisms. The overall process of respiration corresponds to a reversal of photosynthesis.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy
(686 K cal or 2868 KJ)

- Depending upon the nature of respiratory substrate, Blackman divided respiration into,

1. Floating respiration
2. Protoplasmic respiration

- When carbohydrate or fat or organic acid serves as respiratory substrate and it is called floating respiration. It is a common mode of respiration and does not produceany toxic product. Whereas respiration utilizing protein as a respiratory substrate, it is called protoplasmic respiration. Protoplasmic respiration is rare and it depletes structural and functional proteins of protoplasm and liberates toxic ammonia.

Types of Respiration: Respiration is classified into two types as aerobic and anaerobic respiration

Aerobic respiration

- Respiration occurring in the presence of oxygen is called aerobic respiration. During aerobic respiration, food materials like carbohydrates, fats and proteins are completely oxidised into CO_2, H_2O and energy is released. Aerobic respiration is avery complex process and is completed in four major steps:

1. Glycolysis
2. Pyruvate oxidation (Link reaction)
3. Krebs cycle (TCA cycle)
4. Electron Transport Chain (Terminal oxidation).

Anaerobic respiration

- In the absence of molecular oxygen glucose is incompletely degraded into either ethyl alcohol or lactic acid (Table 14.1). It includes two steps:

1. Glycolysis
2. Fermentation

Stages of Respiration

1. Glycolysis-conversion of glucose into pyruvic acid in cytoplasm of cell.
2. Link reaction-conversion of pyruvic acid into acetyl coenzyme-A in mitochondrial matrix.
3. Krebs cycle-conversion of acetyl coenzyme A into carbon dioxide and water in the mitochondrial matrix.
4. Electron transport chain and oxidative phosphorylation remove hydrogen atomsfrom the products of glycolysis, link reaction and Krebs cycle release water molecule with energy in the form of ATP in mitochondrial inner membrane (Figure 14.5).

Differences between aerobic and anaerobic respiration	
Aerobic respiration	**Anaerobic Respiration**
1. It occurs in all living cells of higher organisms.	1. It occurs yeast and some bacteria.
2. It requires oxygen for breaking the respiratory substrate.	2. Oxygen is not required from breaking the respiratory substrate.
3. The end products are CO2 and H2O	3. The end products are alcohol, and CO2 (or) lactic acid.
4. Oxidation of one molecule of glucose produces, 36 ATP molecules.	4. Only 2 ATP molecules are produced.
5. It consists of four stages –glycolysis, link reaction, TCA cycle and electron	5. It consists of two stages-glycolysis and fermentation.
6. It occurs in cytoplasm and mitochondria.	6. It occurs only in cytoplasm.

Krebs cycle or Citric acid cycle or TCA cycle:

- Two molecules of acetyl CoA formed from link reaction now enter into Krebs cycle. It is named after its discoverer, German Biochemist Sir Hans Adolf Krebs (1937). The enzymes necessary for TCA cycle are found in mitochondrial matrix except succinate dehydrogenase enzyme which is found in mitochondrial inner membrane (Figure 14.7).

Sir Hans Adolf Krebs was born in Germany on 25th August 1900. He was awarded Nobal Prize for his discovery of Citric acid cycle in Physiology in 1953.

- TCA cycle starts with condensation of acetyl CoA with oxaloacetate in the presence of water to yield citrate or citric acid. Therefore, it is also known as Citric Acid Cycle (CAC) or Tri Carboxylic Acid(TCA) cycle. It is followed by the action of different enzymes in cyclic manner. During the conversion of succinyl CoA to succinate by the enzyme succinyl CoA synthetase or succinate thiokinase, a molecule of ATP synthesis from substrate without entering the electron transport chain is called substrate level phosphorylation. In animals a molecule of GTP is synthesized from GDP+Pi. In a coupled reaction GTP is converted to GDP with simultaneous synthesis of ATP from ADP+Pi. In three steps (4, 5, 9) in this cycle NAD+ is reduced to NADH1 H1 and at step 7 (Figure14.8) where FAD is reduced to FADH2. The summary of link reaction and Krebs cycle in Mitochondria is

$$\text{Pyruvic acid} + 4NAD^+ + FAD + 4H_2O + ADP + Pi \xrightarrow{\text{Mitochondrial matrix.}} 3CO_2 + 4NADH + 4H^+ + FADH_2 + H_2O + ATP.$$

- Two molecules of pyruvic acid formed at the end of glycolysis enter into the mitochondrial matrix. Therefore, Krebs cycle is repeated twice for every glucose molecule where two molecules of pyruvic acid produces six molecules of CO2, eightmolecules of NADH 1 H1, two molecules of FADH2 and two molecules of ATP.

1. Significance of Krebs cycle:

1. TCA cycle is to provide energy in the form of ATP for metabolism in plants.
2. It provides carbon skeleton or raw material for various anabolic processes.
3. Many intermediates of TCA cycle are further metabolised to produce amino acids, proteins and nucleic acids.
4. Succinyl CoA is raw material for formation of chlorophylls, cytochrome, phytochrome and other pyrrole substances.

5. α-ketoglutarate and oxaloacetate undergo reductive amination and produce amino acids.
6. It acts as metabolic sink which plays a central role in intermediary metabolism.

Respiratory Quotient (RQ)

- The ratio of volume of carbon dioxide given out and volume of oxygen taken in during respiration is called Respiratory Quotient or Respiratory ratio. RQ value depends upon respiratory substrates and their oxidation.

$$RQ = \frac{\text{Volume of } CO_2 \text{ liberated}}{\text{Volume of } O_2 \text{ consumed}}$$

1. The respiratory substrate is a carbohydrate, it will be completely oxidised in aerobic respiration and the value of the RQ will be equal to unity.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2\uparrow + 6H_2O + \text{Energy}$$

$$\text{RQ of glucose} = \frac{6 \text{ molecules of } CO_2}{6 \text{ molecules of } O_2}$$

$$= 1 \text{ (unity)}$$

2. If the respiratory substrate is a carbohydrate it will be incompletely oxidised when it goes through anaerobic respiration and the RQ value will be infinity.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \longrightarrow 2CO_2\uparrow + \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + \text{Energy}$$

$$\left.\begin{matrix}\text{RQ of glucose}\\ \text{Anaerobically}\end{matrix}\right\} = \frac{2 \text{ molecules of } CO_2}{\text{zero molecule of } O_2}$$

$$= \infty \text{ (infinity)}$$

3. In some succulent plants like Opuntia, Bryophyllum carbohydrates are partially oxidised to organic acid, particularly malic acid without corresponding release of CO_2but O_2 is consumed hence the RQ value will be zero.

$$\underset{\text{Glucose}}{2C_6H_{12}O_6} + 3O_2 \longrightarrow \underset{\text{Malic acid}}{3C_4H_6O_5} + 3H_2O + \text{Energy}$$

$$\begin{matrix}\text{RQ of glucose}\\ \text{in succulents}\end{matrix} = \frac{\text{zero molecule of } CO_2}{3 \text{ molecules of } O_2}$$

$$= 0 \text{ (zero)}$$

4. When respiratory substrate is proteinor fat, then RQ will be less than unity.

$$2(C_{51}H_{98}O_6) + 145O_2 \longrightarrow 102CO_2\uparrow + 98H_2O + \text{Energy}$$
Tripalmitin(Fat)

$$\text{RQ of Tripalmitin} = \frac{102 \text{ molecules of } CO_2}{145 \text{ molecules of } O_2}$$

$$= 0.7 \text{ (less than unity)}$$

5. When respiratory substrate is an organic acid the value of RQ will be more than unity.

$$C_4H_6O_5 + 3O_2 \longrightarrow 4CO_2\uparrow + 3H_2O + \text{Energy}$$
Malic acid

$$\text{RQ of malic acid} = \frac{4 \text{ molecules of } CO_2}{3 \text{ molecules of } O_2}$$

$$= 1.33 \text{ (more than unity)}$$

Significance of RQ

1. RQ value indicates which type of respiration occurs in living cells, either aerobic or anaerobic.
2. It also helps to know which type of respiratory substrate is involved.

Red colour in various parts of plants is due to the presence of anthocyanin, synthesis of which require more O_2 than CO_2 evolved. RQ will be less than one.

Respiratory quotients of some other substances

Proteins	:	0.8 – 0.9
Oleic acid (Fat)	:	0.71
Palmitic acid (Fat)	:	0.36
Tartaric acid	:	1.6
Oxalic acid	:	4.0

Anaerobic Respiration

Fermentation

- Some organisms can respire in the absence of oxygen. This process is called fermentationoranaerobic respiration (Figure 14.12). There arethree types of fermentation:

1. Alcoholic fermentation
2. Lactic acid fermentation

3. Mixed acid fermentation

Characteristics of Anaerobic Respiration

1. Anaerobic respiration is less efficient than the aerobic respiration (Figure 14. 12) (Table 14.4).
2. Limited number of ATP molecules is generated per glucose molecule (Table 14.5).
3. It is characterized by the production of CO_2 and it is used for Carbon fixation in photosynthesis.

11th zoology

Unit – 7 - Body Fluids and Circulation

Composition of Blood

Blood is the most common body fluid that transports substances from one part of the body to the other. Blood is a connective tissue consisting of plasma (fluid matrix) and formed elements. The plasma constitutes 55% of the total blood volume. The remaining 45% is the formed elements that consist of blood cells. The average blood volume is about 5000ml (5L) in an adult weighing 70 Kg.

Plasma

Plasma mainly consists of water (80-92%) in which the plasma proteins, inorganic constituents (0.9%), organic constituents (0.1%) and respiratory gases are dissolved. The four main types of plasma proteins synthesized in the liver are albumin, globulin, prothrombin and fibrinogen. Albumin maintains the osmotic pressure of the blood. Globulin facilitates the transport of ions, hormones, lipids and assists in immune function. Both Prothrombin and Fibrinogen are involved in blood clotting.

Formed elements

Red blood cells/corpuscles (erythrocytes), white blood cells/corpuscles (Leucocytes) and platelets are collectively called formed elements.

Blood groups

Commonly two types of blood groupings are done. They are ABO and Rh which are widely used all over the world.

ABO blood grouping

Depending on the presence or absence of surface antigens on the RBCs, blood group in individual belongs to four different types namely, A, B, AB and O. The plasma of A, B and O individuals have natural antibodies (agglutinins) in them. Surface antigens are called agglutinogens. The antibodies (agglutinin) acting on agglutinogen A is called anti A and the agglutinin acting on agglutinogen B is called anti B. Agglutinogens are absent in O blood group. Agglutinogens A and B are present in AB blood group and do not contain anti A and anti B in them. Distribution of antigens and antibodies in blood groups are shown in Table 7.1. A, B and O are major allelic genes in ABO systems. All agglutinogens contain sucrose, D-galactose, N-acetyl glucosamine and 11 terminal amino acids. The attachments of the terminal amino acids are dependent on the gene products of A and B. The reaction is catalysed by glycosyl transferase.

Blood group	Agglutinogens (antigens) on the RBC`	Agglutinin (antibodies) in the plasma
A	A	Anti B
B	B	Anti A
AB	AB	No antibodies
O	No antigens	Anti A and Anti B

Rh factor is a protein (D antigen) present on the surface of the red blood cells in majority (80%) of humans. This protein is similar to the protein present in Rhesus monkey, hence the term Rh. Individuals who carry the antigen D on the surface of the red blood cells are Rh1 (Rh positive) and the individuals who do not carry antigen D, are Rh2 (Rh negative). Rh factor compatibility is also checked before blood transfusion. When a pregnant women is Rh2 and the foetus is Rh1 incompatibility (mismatch) is observed. During the first pregnancy, the Rh2 antigens of the foetus does not get exposed to the mother's blood as both their blood are separated by placenta. However, small amount of the foetal antigen becomes exposed to the mother's blood during the birth of the first child. The mother's blood starts to synthesize D antibodies. But during subsequent pregnancies the Rh antibodies from the mother (Rh2) enters the foetal circulation and destroys the foetal RBCs. This becomes fatal to the foetus because the child suffers from anaemia and jaundice. This condition is called erythroblastosis foetalis. This condition can be avoided by administration of anti D antibodies (Rhocum) to the mother immediately after the first child birth.

Composition of lymph and its functions

About 90% of fluid that leaks from capillaries eventually seeps back into the capillaries and the remaining 10% is collected and returned to blood system by means of a series of tubules known as lymph vessels or lymphatics. The fluid inside the lymphatics is called lymph. The lymphatic system consists of a complex network of thin walled ducts (lymphatic vessels), filtering bodies (lymph nodes) and a large number of lymphocytic cell concentrations in various lymphoid organs. The lymphatic vessels have smooth walls that run parallel to the blood vessels, in the skin, along the respiratory and digestive tracts. These vessels serve as return ducts for the fluids that are continually diffusing out of the blood capillaries into the body tissues.

Lymph fluid must pass through the lymph nodes before it is returned to the blood. The lymph nodes that filter the fluid from the lymphatic vessels of the skin are highly concentrated in the neck, inguinal, axillaries, respiratory and digestive tracts. The lymph fluid flowing out of the lymph nodes flow into large collecting duct which finally drains into larger veins that runs beneath the collar bone, the subclavian vein and is emptied into the blood stream. The narrow passages in the lymph nodes are the sinusoids that are lined with macrophages. The lymph nodes successfully prevent the invading microorganisms from reaching the blood stream.

Cells found in the lymphatics are the lymphocytes. Lymphocytes collected in the lymphatic fluid are carried via the arterial blood and are recycled back to the lymph. Fats are absorbed through lymph in the lacteals present in the villi of the intestinal wall.

Blood vessels – Arteries, Veins and capillaries

The vessels carrying the blood are of three types; they are the arteries, veins and capillaries. These vessels are hollow structures and have complex walls surrounding the lumen. The blood vessels in humans are composed of three layers, tunica intima, tunica media and tunica externa. The inner layer, tunica intima or tunica interna supports the vascular endothelium, the middle layer, tunica media is composed of smooth muscles and an extra cellular matrix which contains a protein, elastin. The contraction and relaxation of the smooth muscles results in vasoconstriction and vasodilation. The outer layer, tunica externa or tunica adventitia is composed of collagen fibres. The structure of blood vessels is illustrated.

Arteries

The blood vessels that carry blood away from the heart are called arteries. The arteries usually lie deep inside the body. The walls of the arteries are thick, noncollapsible to withstand high pressure. Valves are absent and have a narrow lumen. All arteries carry oxygenated blood, except the pulmonary artery. The largest artery, the aorta (2.5 cm in diameter and 2 mm thick) branch into smaller arteries and culminates into the tissues as feed arteries. In the tissues the arteries branches into arterioles.

As blood enters an arteriole it may have a pressure of 85 mm Hg (11.3 KPa) but as it leaves and flows into the capillary, the pressure drops to 35 mm Hg (4.7 KPa). (Note 1 mm Hg =0.13 KPa. SI unit of mm Hg is KiloPascal (KPa)). Arterioles are small, narrow, and thin walled which are connected to the capillaries. A small sphincter lies at the junction between the arterioles and capillaries to regulate the blood supply. Arteries do not always branch into arterioles, they can also form anastomoses.

What are anastomoses? These are connections of one blood vessel (arteries) with another blood vessel. They provide alternate route of blood flow if the original blood vessel is blocked. For e.g., Arteries in the joints contain numerous anastomoses. This allows blood to flow freely even if one of the arteries closes during bending of the joints.

Capillaries

Capillary beds are made up of fine networks of capillaries. The capillaries are thin walled and consist of single layer of squamous epithelium. Tunica media and elastin fibres are absent. The capillary beds are the site for exchange of materials between blood and tissues. The walls of the capillaries are guarded by semilunar valves. The blood volume in the capillaries is high but the flow of blood is slow. Mixed blood (oxygenated and deoxygenated) is present in the capillaries. The capillary bed may be flooded with blood or may be completely bypassed depending on the body conditions in a particular organ.

Veins

Veins have thinner walls and a larger lumen and hence can be easily stretched. They carry deoxygenated blood except, the pulmonary vein. The blood pressure is low and the lumen has a wide wall which is collapsible. Tunica media is thinner in veins than in arteries. Unidirectional flow of blood in veins is due to the presence of semilunar valves that prevents backflow of blood. Blood samples are usually taken from the veins rather than artery because of low pressure in the veins.

Coronary blood vessels

Blood vessels that supply blood to the cardiac muscles with all nutrients and removes wastes are the coronary arteries and veins. Heart muscle is supplied by two arteries namely right and left coronary arteries. These arteries are the first branch of the aorta. Arteries usually surround the heart in the manner of a crown, hence called coronary artery (L. Corona - crown).

Right ventricle and posterior portion of left ventricle are supplied by the right coronary artery. Anterior and lateral part of the left ventricle is supplied by the left coronary arteries.

Circulatory pathways

There are two types of circulatory systems, open and closed circulatory systems. Open circulatory system has haemolymph as the circulating fluid and is pumped by the heart, which flows through blood vessels into the sinuses. Sinuses are referred as haemocoel. Open circulatory system is seen in Arthropods and most Molluscs. In closed circulatory system blood is pumped by the heart and flows through blood vessels. Closed circulating system is seen in Annelids, Cephalopods and Vertebrates.

All vertebrates have muscular chambered heart. Fishes have two chambered heart. The heart in fishes consists of sinus venosus, an atrium, one ventricle and bulbus arteriosus or conus arteriosus. Single circulation is seen in fishes. Amphibians have two auricles and one ventricle and no inter ventricular septum whereas reptiles except crocodiles have two auricles and one ventricle and an incomplete inter ventricular septum. Thus mixing of oxygenated and deoxygenated blood takes place in the ventricles. This type of circulation is called incomplete double circulation. The left atrium receives oxygenated blood and the right atrium receives deoxygenated blood. Pulmonary and systemic circuits are seen in Amphibians and Reptiles. The Crocodiles, Birds and Mammals have two auricles or atrial chambers and two ventricles, the auricles and ventricles are separated by inter auricular septum and inter ventricular septum. Hence there is complete separation of oxygenated blood from the deoxygenated blood. Pulmonary and systemic circuits are evident. This type of circulation is called complete double circulation.

Human circulatory system

The structure of the heart was described by Raymond de viessens, in 1706. Human heart is made of special type of muscle called the cardiac muscle. It is situated in the thoracic cavity and its apex portion is slightly tilted towards left. It weighs about 300g in an adult. The size of our heart is roughly equal to a closed fist. Heart is divided into four chambers, upper two small auricles or atrium and lower two large ventricles. The walls of the ventricles are thicker than the auricles due to the presence of papillary muscles. The heart wall is made up of three layers, the outer epicardium, middle myocardium and inner endocardium. The space present between the membranes is called pericardial space and is filled with pericardial fluid.

The two auricles are separated by inter auricular septum and the two ventricles are separated by inter ventricular septum The separation of chambers avoids mixing of oxygenated and deoxygenated blood. The auricle communicates with the ventricle through an opening called auriculo ventricular aperture which is guarded by the auriculo ventricular valves. The opening between the right atrium and the right ventricle is guarded by the tricuspid valve (three flaps or cusps), whereas a bicuspid (two flaps or cusps) or mitral valve guards the opening between the left atrium and left ventricle (Figure 7.6). The valves of the heart allows the blood to flow only in one direction, i.e., from the atria to the ventricles and from the ventricles to the pulmonary artery or the aorta. These valves prevent backward flow of blood.

The opening of right and left ventricles into the pulmonary artery and aorta are guarded by aortic and pulmonary valves and are called semilunar valves. Each semilunar valve is made of three halfmoon shaped cusps. The myocardium of the ventricle is thrown into irregular muscular ridges called trabeculae corneae. The trabeculae corneae are modified into chordae tendinae. The opening and closing of the semilunar valves are achieved by the chordae tendinae. The chordae tendinae are attached to the lower end of the heart by papillary muscles. Heart receives deoxygenated blood from various parts of the body through the inferior venacava and superior venacava which open into the right auricle. Oxygenated blood from lungs is drained into the left auricle through four pulmonary veins.

Cardiac Cycle

The events that occur at the beginning of heart beat and lasts until the beginning of next beat is called cardiac cycle. It lasts for 0.8 seconds. The series of events that takes place in a cardiac cycle.

PHASE 1: **Ventricular diastole-** The pressure in the auricles increases than that of the ventricular pressure. AV valves are open while the semi lunar valves are closed. Blood flows from the auricles into the ventricles passively.

PHASE 2: **Atrial systole -** The atria contracts while the ventricles are still relaxed. The contraction of the auricles pushes maximum volume of blood to the ventricles until they reach the end diastolic volume (EDV). EDV is related to the length of the cardiac muscle fibre. More the muscle is stretched, greater the EDV and the stroke volume.

PHASE 3: **Ventricular systole (isovolumetric contraction) –** The ventricular contraction forces the AV valves to close and increases the pressure inside the ventricles. The blood is then pumped from the ventricles into the aorta without change in the size of the muscle fibre length and ventricular chamber volume (isovolumetric contraction).

PHASE 4: **Ventricular systole (ventricular ejection) –** Increased ventricular pressure forces the semilunar valves to open and blood is ejected out of the ventricles without backflow of blood. This point is the end of systolic volume (ESV).

PHASE 5: **(Ventricular diastole) –**The ventricles begins to relax, pressure in the arteries exceeds ventricular pressure, resulting in the closure of the semilunar valves. The heart returns to phase 1 of the cardiac cycle.

Blood Pressure

Blood pressure is the pressure exerted on the surface of blood vessels by the blood. This pressure circulates the blood through arteries, veins and capillaries. There are two types of pressure, the systolic pressure and the diastolic pressure. Systolic pressure is the pressure in the arteries as the chambers of the heart contracts. Diastolic pressure is the pressure in the arteries when the heart chambers relax. Blood pressure is measured using a sphygmomanometer (BP apparatus). It is expressed as systolic pressure / diastolic pressure. Normal blood pressure in man is about 120/80mm Hg. Mean arterial pressure is a function of cardiac output and resistance in the arterioles. The primary reflex pathway for homeostatic control of mean arterial pressure is the baroreceptor reflex. The baroreceptor reflex functions every morning when you get out of bed. When you are lying flat the gravitational force is evenly distributed. When you stand up, gravity causes blood to pool in the lower extremities. The decrease in blood pressure upon standing is known as orthostatic hypotension. Orthostatic reflex normally triggers baroreceptor reflex.

This results in increased cardiac output and increased peripheral resistance which together increase the mean arterial pressure.

Electrocardiogram (ECG)

An electrocardiogram (ECG) records the electrical activity of the heart over a period of time using electrodes placed on the skin, arms, legs and chest. It records the changes in electrical potential across the heart during one cardiac cycle. The special flap of muscle which initiates the heart beat is called as sinu-auricular node or SA node in the right atrium. It spreads as a wave of contraction in the heart. The waves of the ECG are due to depolarization and not due to contraction of the heart. This wave of depolarisation occurs before the beginning of contraction of the cardiac muscle. A normal ECG shows 3 waves designated as P wave, QRS complex and T wave.

P Wave (Atrial depolarisation)

It is a small upward wave and indicates the depolarisation of the atria. This is the time taken for the excitation to spread through atria from SA node. Contraction of both atria lasts for around 0.8-1.0 sec.

PQ Interval (AV node delay)

It is the onset of P wave to the onset of QRS complex. This is from the start of depolarisation of the atria to the beginning of ventricular depolarisation. It is the time taken for the impulse to travel from the atria to the ventricles (0.12-0.21sec). It is the measure of AV conduction time.

QRS Complex (Ventricular depolarisation)

No separate wave for atrial depolarization in the ECG is visible. Atrial depolarization occurs simultaneously with the ventricular depolarisation. The normal QRS complex lasts for 0.06-0.09 sec. QRS complex is shorter than the P wave, because depolarization spreads through the Purkinjie fibres. Prolonged QRS wave indicates delayed conduction through the ventricle, often caused due to ventricular hypertrophy or due to a block in the branches of the bundle of His.

ST Segment

It lies between the QRS complex and T wave. It is the time during which all regions of the ventricles are completely depolarized and reflects the long plateau phase before repolarisation. In the heart muscle, the prolonged depolarisation is due to retardation of K+ efflux and is responsible for the plateau. The ST segment lasts for 0.09 sec.

T wave (Ventricular repolarisation)

It represents ventricular repolarisation. The duration of the T wave is longer than QRS complex because repolarisation takes place simultaneously throughout the ventricular depolarisation.

Disorders of the circulatory system

Hypertension

Hypertension is the most common circulatory disease. The normal blood pressure in man is 120/80 mmHg. In cases when the diastolic pressure exceeds 90 mm Hg and the systolic pressure exceeds 150 mm Hg persistently, the condition is called hypertension. Uncontrolled hypertension may damage the heart, brain and kidneys.

Coronary heart disease

Coronary heart disease occurs when the arteries are lined by atheroma. The buildupbuildup of atheroma contains cholesterol, fibres, dead muscle and platelets and is termed Atherosclerosis. The cholesterol rich atheroma forms plaques in the inner lining of the arteries making them less elastic and reduces the blood flow. Plaque grows within the artery and tends to form blood clots, forming coronary thrombus. Thrombus in a coronary artery results in heart attack.

Stroke

Stroke is a condition when the blood vessels in the brain bursts, (Brain haemorrhage) or when there is a block in the artery that supplies the brain, (atherosclerosis) or thrombus. The part of the brain tissue that is supplied by this damaged artery dies due to lack of oxygen (cerebral infarction).

Angina pectoris

Angina pectoris (ischemic pain in the heart muscles) is experienced during early stages of coronary heart disease. Atheroma may partially block the coronary artery and reduce the blood supply to the heart. As a result, there is tightness or choking with difficulty in breathing. This leads to angina or chest pain. Usually it lasts for a short duration of time.

Myocardial infarction (Heart failure)

The prime defect in heart failure is a decrease in cardiac muscle contractility. The Frank- Starling curve shifts downwards and towards the right such that for a given EDV, a failing heart pumps out a smaller stroke volume than a normal healthy heart. When the blood supply to the heart muscle or myocardium is remarkably reduced it leads to death of the muscle fibres. This condition is called heart attack or myocardial infarction. The blood clot or thrombosis blocks the blood supply to the heart and weakens the muscle fibres. It is also called Ischemic heart disease due to lack of oxygen supply to the heart muscles. If this persists it leads to chest pain or angina. Prolonged angina leads to death of the heart muscle resulting in heart failure.

Rheumatoid Heart Disease

Rheumatic fever is an autoimmune disease which occurs 2-4 weeks after throat infection usually a streptococcal infection. The antibodies developed to combat the infection cause damage to the heart. Effects include fibrous nodules on the mitral valve, fibrosis of the connective tissue and accumulation of fluid in the pericardial cavity.

Diagnosis and Treatment

Angiogram

Angiogram is a procedure that uses a special dye and X-ray to see how blood flows through the coronary arteries of the heart and it can be used to detect abnormality in the blood vessels through out the body.

Angioplasty

Angioplasty is the stretching of an artery that is narrowed due to atherosclerosis. The risk involved in this procedure is minimal. During an angioplasty a small long balloon catheter is threaded through the blocked artery. A deflated balloon is attached to the catheter and the balloon is inflated to widen the arterial wall. Then the tube and the balloon are removed. A small metal scaffold called stent is left in place. This scaffolding keeps the blood vessel open and allows free flow of blood. Slow releasing stents are now available that can release chemicals to prevent further block of the artery.

Varicose veins The veins are so dilated that the valves prevent back flow of blood. The veins lose their elasticity and become congested. Common sites are legs, rectal-anal regions (haemorrhoids), the oesophagus and the spermatic cord.

Embolism is the obstruction of the blood vessel by abnormal mass of materials such as fragment of the blood clot, bone fragment or an air bubble. Embolus may lodge in the lungs, coronary artery or liver and leads to death. Aneurysm The weakened regions of the wall of the artery or veins bulges to form a balloon like sac. Unruptured aneurysm may exert pressure on the adjacent tissues or may burst causing massive haemorrhage.

Bypass Surgery

When the arteries that bring blood to the heart muscles (coronary artery) are blocked by plaque (accumulation of fat, cholesterol and other substances) the person is advised to undergo Bypass surgery. After the surgery the blood flow to coronary artery is increased and the person is relieved from chest pain. This is a major surgery where damaged blood vessel is replaced by the healthy one taken from different part of the body. Mostly it is taken from legs. During this surgery patients blood system is connected with a pump oxygenator (heart lung machine). After the completion of the surgery the blood vessel is connected to normal the circulation and the blood flows freely.

Heart Transplantation

A heart transplant is a surgical transplantation procedure which is done to replace a diseased or a damaged heart. This procedure is performed on a patient with end stage heart failure or severe coronary artery disease, when other medical ailments or surgical treatments have failed. The most common procedure is to take a functioning heart from a brain dead person (organ donor) and is transplanted in a person with a damaged heart. After the heart transplant the average life span of the person increases.

Cardio pulmonary resuscitation (CPR)

In 1956, James Elam and Peter Safar were the first to use mouth to mouth resuscitation. CPR is a life saving procedure that is done at the time of emergency conditions such as when a person's breath or heart beat has stopped abruptly in case of drowning, electric shock or heart attack. CPR includes rescue of breath, which is achieved by mouth to mouth breathing, to deliver oxygen to the victim's lungs by external chest compressions which helps to circulate blood to the vital organs. CPR must be performed within 4 to 6 minutes after cessation of breath to prevent brain damage or death. Along with CPR, defibrillation is also done. Defibrillation means a brief electric shock is given to the heart to recover the function of the heart.

Each year over several million people worldwide die of heart disease, than from other conditions. For some patients heart transplant is the only hope. Raju was 62 years old when muscles of both the ventricles had deteriorated. He was lucky enough because biomedical engineers were able develop a pumping device called 'total artificial heart'. Raju's heart was completely removed and an artificial heart was put in place. He was able to go home within a few weeks. This artificial heart would have kept him in alive until suitable real heart was available for transplant.

First heart transplantation was performed in the year 1959. Human heart transplant was performed by Prof. Christian Bernard in South Africa in the year 1967, December 3 at Groote Schuur Hospital, Cape Town. Dr Anangipalli Venugopal was the first to perform heart transplant at AIIMS, India on August 3, 1994

10th lesson
Unit – 14 Circulation in animals

Blood

Blood is the main circulatory medium in the human body. It is a red coloured fluid connective tissue. Components of Blood: The blood consists of two main components. The fluid plasma and the formed elements (blood cells) which are found suspended in the plasma.

Plasma:

It is slightly alkaline, containing non-cellular substance which constitutes about 55% of the blood. Organic substances like proteins, glucose, urea, enzymes, hormones, vitamins and minerals are present in the plasma.

Formed Elements of Blood:

Blood corpuscles are of three types
1. Red blood corpuscles (RBC) or Erythrocytes
2. White blood corpuscles (WBC) or Leucocytes
3.Blood platelets or Thrombocytes.

Red blood corpuscles (Erythrocytes)

They are the most abundant cells in the human body. RBCs are formed in the bone marrow. The RBCs impart red colour to the blood due to presence of respiratory pigment haemoglobin. Matured mammalian RBCs do not have cell organelles and nucleus. They are biconcave and disc-shaped. Their life span is about 120 days. RBC is involved in the transport of oxygen from lungs to tissues

White blood corpuscles (Leucocytes)

WBC's are colourless. They do not have haemoglobin and are nucleated cells. It is found in the bone marrow, spleen, thymus and lymph nodes. They are capable of amoeboid movement Erythrocytes The white blood corpuscles can be grouped into two categories:

1. Granulocytes
2. Agranulocytes.

Granulocytes They contain granules in their cytoplasm. Their nucleus is irregular or lobed. The granulocytes are of three types
1. Neutrophils
2. Eosinophils
3. Basophils

(i) Neutrophils They are large in size and have a 2 - 7 lobed nucleus. These corpuscles form 60% - 65% of the total leucocytes. Their numbers are increased during infection and inflammation.

(ii) Eosinophils It has a bilobed nucleus and constitute 2% - 3% of the total leucocytes. Their number increases during conditions of allergy and parasitic infections. It brings about detoxification of toxins.

(iii) Basophils Basophils have lobed nucleus. They form 0.5-1.0% of the total leucocytes. They release chemicals during the process of inflammation.

Agranulocytes

Granules are not found in the cytoplasm of these cells. The agranulocytes are of two types:

(i) Lymphocytes (ii) Monocytes

(i) Lymphocytes These are about 20-25% of the total leucocytes. They produce antibodies during bacterial and viral infections.

(ii) Monocytes They are the largest of the leucocytes and are amoeboid in shape. These cells form 5 - 6 % of the total leucocytes.They are phagocytic and can engulf bacteria.

Blood Platelets or Thrombocytes

These are small and colourless. They do not have nucleus. There are about 2,50,000 – 4,00,000 platelets / cubic mm of blood. Life span of platelets is 8–10 days. They play an important role in clotting of blood. Platelets form clot at the site of injury and prevent blood loss.

Functions of blood

i) Transport of respiratory gases (Oxygen and CO2).
ii) Transport of digested food materials to the different body cells.
iii) Transport of hormones.
iv) Transport of nitrogenous excretory products like ammonia, urea and uric acid.
v) It is involved in protection of the body and defense against diseases.
vi) It acts as buffer and also helps in regulation of pH and body temperature.
vii) It maintains proper water balance in the body

Structure of Human Heart

Heart is a muscular pumping organ that pumps out the blood into the blood vessels. Human heart is situated between the lungs,slightly tilted toward the left and above the diaphragm in the thoracic cavity. The heart is made of specialized type of muscle called the cardiac muscle. The heart is enclosed in a double walled sac called pericardium. It contains lubricating pericardial fluid which reduces friction during heart beat and protects it from mechanical injuries.

The human heart is four chambered. The two upper thin walled chambers of the heart are called auricle or atria (sing: atrium) and two lower thick walled chambers are called ventricles. The chambers are separated by partition called septum.

The septum between auricles and ventricles prevents the mixing of oxygenated and deoxygenated blood. The two auricles are separated from each other by interatrial septum.The left atrium is smaller than the right atrium. The right atrium receives deoxygenated blood from different parts of the body through the main veins superior vena cava, inferior vena cava and coronary sinus. Pulmonary veins bring oxygenated blood to the left atrium from the lungs. The right and left auricles pump blood into the right and left ventricles respectively.

The ventricles form the lower part of the heart. The two ventricles are separated from each other by an interventricular septum. The left and right ventricles have thick walls because the ventricles have to pump out blood with force away from the heart. From the right ventriclearises the pulmonary trunk which bifurcates to form right and left pulmonary arteries. The right and left pulmonary arteries supply deoxygenated blood to the lungs of the respective side. The left ventricle is longer and narrower than the right ventricle. The walls are about three times thicker than the right ventricle. The left ventricle gives rise to aorta. The oxygenated blood is supplied by the aorta to various organs of the body. The coronary arteries supply blood to the heart.

Valves:

The valves are the muscular flaps that regulate the flow of blood in a single direction and prevent back flow of blood. The heart contains three types of valves.

Right atrioventricular valve:

It is located between the right auricle and right ventricle. It has three thin triangular leaf like flaps and therefore called tricuspid valve. The apices of the flaps are held in position by chordae tendinae arising from the muscular projection of the ventricle wall known as papillary muscles.

Left atrioventricular valve:

It is located between the left auricle and left ventricle. It has two cusps and therefore called bicuspid or mitral valve.

Semilunar valves:

The major arteries (pulmonary artery and aorta) which leave the heart have semilunar valves which prevent backward flow of blood into the ventricles. They are the pulmonary and aortic semilunar valves.

Types of Blood Circulation

The blood circulates in our body as oxygenated and deoxygenated blood. The types of circulation are:

i Systemic circulation: Circulation of oxygenated blood from the left ventricle of the heart to various organs of the body and return of deoxygenated blood to the right atrium. Aorta carries oxygenated blood to all the organs of the body.

ii Pulmonary circulation: The path of pulmonary circulation starts in the right ventricle. Pulmonary artery arises from the right ventricle and reaches the lungs with deoxygenated blood. Pulmonary veins collect the oxygenated blood from the lungs and supplies it to the left atrium of the heart.

iii Coronary circulation: The supply of blood to the heart muscles (cardiac muscles) is called as coronary circulation. Cardiac muscles receive oxygenated blood from coronary arteries that originate from the aortic arch. Deoxygenated blood from the cardiac muscles drains into the right atrium by the coronary sinuses.

When the blood circulates twice through the heart in one complete cycle it is called double circulation. In double circulation the oxygenated blood do not mix with the deoxygenated blood. However, in some animals the oxygenated and deoxygenated blood are mixed and pass through the heart only once. This type of circulation is called single circulation. e.g., fishes, amphibians and certain reptiles.

ENDOCRINE SYSTEM

11th – Zoology
Unit – 11 Chemical Coordination & Integration

Human endocrine system

- Endocrine glandsinclude the pituitary,thyroid, parathyroid, pineal, adrenal,thymus and are also known as exclusiveendocrine glands. The hypothalamusalong with its neural function alsoproduces hormones and is consideredas a neuro endocrine gland. In additionseveral organs such as pancreas, gastrointestinal tract epithelium, kidney,heart, gonads and placenta are also haveendocrine tissues and are known aspartial endocrine glands.

Hypothalamus

- Hypothalamus is a small cone shapedstructure that projects downward fromthe brain ending into the pituitary stalk.It interlinks both the nervous systemand endocrine system. Though pituitarygland is known as master endocrineglands that controls the other endocrineglands, but it is, in turn controlledby the hypothalamus. Hypothalamuscontains groups of neurosecretory cells. It produces neurotransmitters whichregulate the secretions of the pituitary (Figure11. 2). The hormones produced bythe hypothalamus act either as a releasinghormone or as an inhibitory hormone. In the basal region of the brain, thehypothalamic hypophyseal portalblood vessel connects hypothalamus andanterior pituitary. It allows hypothalamichormones to control anterior pituitarysecretion. The posterior pituitary isconnected with hypothalamus by a nervebundle called hypothalamic hypophysealaxis. It produces nerve signal thatcontrol the posterior pituitary secretion. Hypothalamus maintains homeostasis,blood pressure, body temperature, cardioand fluid electrolyte balance of the body. As the part of limbic system it influencesvarious emotional responses.

Chemical nature of hormones

Class	Chemical properties	Example
Amines	Small, water soluble derived from tyrosine or tryptophan	Adrenalin, nor adrenalin, melatonin and thyroid hormone
Protein/Peptides	Water soluble	Insulin, glucagon and pituitary hormones
Steroids	Derived from cholesterol, mostly lipid soluble	Cortisol, aldosterone, testosterone, oestrogen, progesterone.

Pituitary gland or Hypophysis

- The pituitary gland (means to grow under)is ovoid in shape and is located in the sellaturcica, a bony cavity of the sphenoidbone at the base of brain and connectedto the hypothalamic region of the brain bya stalk called infundibulum. It is aboutone centimetre in diameter and 0.5 gmin weight. The pituitary consists of twolobes, anterior glandular adenohypophysisand posterior neural neurohypophysis.The anterior lobe originates from theembryonic invagination of pharyngealepithelium called Rathke's pouch andthe posterior lobe is originates fromthe base of the brain as an outgrowthof hypothalamus. Anatomically theadenohypophysis has three lobes or zonesnamely pars intermedia, pars distalis andparstuberalis. The neurohypophysis isotherwise known as pars nervosa.The anterior lobe of pituitary secretessix tropic hormones such as growthhormone (GH), thyroid stimulatinghormone (TSH), adrenocorticotropichormone (ACTH), follicle stimulatinghormone (FSH), luteinizing hormone(LH), luteotropic hormone (LTH) andmelanocyte stimulating hormone (MSH) (in lower animals only). The posterior lobe of pituitary secretes the hormones namely vasopressin and oxytocin.

Pineal gland

- In human, the pineal gland or epiphysiscerebri or conarium is located behind thethird ventricle of brain and is formed ofparenchymal cells and interstitial cells. Itsecretes the hormone, melatonin, whichplays a central role in the regulationof circadian rhythm of our body andmaintains the normal sleep wake cycle.It also regulates the timing of sexualmaturation of gonads. In additionmelatonin also influences metabolism,pigmentation, menstrual cycle anddefence mechanism of our body.

Iodine is requiredfor formation ofthyroxine:
To producenormal quantities ofthyroxine, about 1mg/week of iodine isrequired. To prevent iodine deficiencycommon table salt is iodised with 1part sodium iodide to every 1,00,000parts of sodium chloride

Thyroid gland

- The butterfly shaped thyroid gland is abilobed gland located below the larynx on each side of upper trachea. It is the largest endocrine gland in the body. Its two lateral lobes are connected by a median tissue mass called isthmus. Each lobe is made up of many lobules .The lobules consist of follicles called acini (acinus in singular). Each acinus is lined with glandular, cuboidal or squamous epithelial cells. Thelumen of acinus is filled with colloid, a thick glycoprotein mixture consisting of thyroglobulin molecules.

- Hormones of the thyroid gland are often called the major metabolic hormones. The follicular cells of thyroid gland secrete two hormones namely triiodothyronine (T3) and thyroxine or tetra- iodothyronine (T4). The parafollicular cells or 'C' cells of thyroid gland secrete a hormone called thyrocalcitonin. Iodine is essential for the normal synthesis of thyroid hormones. Thyroid releasing hormone from the hypothalamus stimulates the adenohypophysis to secrete TSH, which inturn stimulates the thyroid gland tosecrete the thyroid hormones. Thyroid hormones show a negative feedback effect on the hypothalamus and pituitary (Figure11. 4).

Parathyroid gland

- In human, four tiny parathyroid glands are found in the posterior wall of the thyroid glands. This gland is composed of two types of cells, the chief cells and oxyphilcells. The chief cells secrete parathyroidhormone (PTH) and the functions ofoxyphil cells are not known.

Parathyroid hormone or Parathormone (PTH)

- PTH is a hypercalcemic hormone. It is a peptide hormone involved in controlling the calcium and phosphate homeostasis. Th e secretion of PTH is controlled by calcium levelin the blood. It increases the blood calciumlevel by stimulating osteoclasts to dissolve the bone matrix. As a result calcium and phosphate are released into the blood. PTH enhancesthe reabsorption of calcium and excretion ofphosphates by the renal tubules and promotesactivation of vitamin D to increase calciumabsorption by intestinal mucosal cells.

Thymus gland

- Thymus gland is partially an endocrine and partially a lymphoid organ. It is a bilobed structure located just above the heart and aorta, behind the sternum. It is covered by fi brous capsule and anatomically it is divisible into an outer cortex and an inner medulla. It secretes four hormones such as thymulin, thymosin, thymopoietinandthymichumoral factor (THF). Th e primary function of thymus is the production of immuno competent 'T' lymphocytes whichprovides cell mediated immunity.

Adrenal gland

- A pair of adrenal glands are located at the **anterior end of the kidneys, hence also** called suprarenal glands. Anatomically the outer region is the cortex and the innerregion is the medulla. Histologically the adrenal cortex has three distinct zones, zonaglomerulosa, zonafasciculata and zonareticularis. Zonaglomerulosa an outer thin layer constitutes about 15% of adrenalcortex, and secretes mineralocorticoidsZonafasciculata, the middle widest constitutes about 75% of adrenal cortex and secretes glucocorticoids such as cortisol, corticosterone and trace amounts of adrenal androgen and oestrogen. Zonareticularis, an inner zone of adrenal cortex constitute about 10% of adrenal cortex and secretes the adrenal androgen, trace amount of oestrogen and glucocorticoids. Adrenal medulla: It is the central part of adrenal gland and is composed of ovoid and columnar cells, which are found around the network of blood capillaries. Adrenalin (epinephrine) and nor adrenalin (nor epinephrine) are the two hormones secreted by the adrenal medulla. Both adrenalin and nor adrenalin are catecholamines.

Pancreas

- Pancreas is a composite gland which performs both exocrine and endocrine functions. it is located just below the stomach as a leaf like structure. The pancreas is composed of two major tissues such the acini and islets of Langerhans. Acini secretes digestive enzymes and the islets of Langerhans secretes hormones like insulin and glucagon. Human pancreas has one to two million islets of Langerhans. In each islet about 60% cells are beta cells, 25% cells are alpha cells and 10% cells are delta cells. The alpha cells secrete glucagon, the beta cells secrete insulin and delta cells secrete somatostatin.

GonadsTestis:

- A pair of testis is present in the scrotal sac of males. The testis functionsas a sex organ and also as an endocrinegland. The testis is composed ofseminiferous tubules and interstitial cellsorLeydig cells. The Leydig cells secreteseveral male sex hormones, collectivelycalled androgens, mainly testosterone.Functions of testosterone: Under theinfluence of FSH and LH, testosteroneinitiates maturation of male reproductiveorgans, and the appearance of secondarysexual characters, muscular growth,growth of facial and axillary hair,masculine voice and male sexualbehaviour. It enhances the total bonematrix and plays a stimulating role in theprocess of spermatogenesis.

Hypo and Hyper activityof endocrine glands andrelated disorders

- The hyper secretion and hypo secretion ofhormones leads to several disordersDwarfism is due to hyposecretionof growth hormone (GH) in children,skeletal growth and sexual maturity isarrested. They attain a maximum height of 4 feet only.

- Gigantism is due to hypersecretionof growth hormone (GH) in children.Overgrowth of skeletal structure occurs(up to 8 feet) and the visceral growth is notappropriate with that of limbs.

- Acromegaly is due to excessive secretionof growth hormone in adults. Over growthof hand bones, feet bones, jaw bones, malfunctioning of gonads, enlargement ofviscera, tongue, lungs, heart, liver, spleen and endocrine gland like thyroid, adrenaletc., are the symptoms of acromegaly.

- In infants, hypothyroidism causescretinism. A cretin shows retarded skeletalgrowth, absence of sexual maturity, retardedmental ability, thick wrinkled skin, protrudedenlarged tongue, bloated face, thick andshort limbs occurs. The other symptoms arelow BMR, slow pulse rate, subnormal bodytemperature and elevated blood cholesterollevels.

- Hyposecretion of thyroid in adultscausesmyxodema. It is otherwisecalled Gull's disease. This disease ischaracterised by decreased mentalactivity, memory loss, slowness ofmovement, speech, and general weaknessof body, dry coarse skin, scarce hair, puffyappearance, disturbed sexual function, low BMR, poor appetite, and subnormalbody temperature. Grave's disease also called asthyrotoxicosisor exophthalmic goitre.This disease is caused due to hypersecretion of thyroid. It is characterisedbyenlargement of thyroid gland, increasedBMR (50% - 100%), elevated respiratoryand excretory rates, increased heart beat,high BP, increased body temperature,protrusion of eyeball and weakness of eyemuscles and weight loss. (Figure 11.13)

- Simple goitre is also known as Endemicgoitre. It is caused due to hyposecretionof thyroxine. The symptoms includesenlargement of thyroid gland, fall in serumthyroxine level, increased TSH secretion.

- Tetany is caused due to thehyposecretion of parathyroid hormone(PTH). Due to hyposecretion ofPTH serum calcium level decreases(Hypocalcemia), as a result serumphosphate level increases. Calcium and Generalized convulsion, locking of jawsincreased heart beat rate, increased bodytemperature, muscular spasm arethemajor symptoms of tetany.

- Hyperparathyroidism is caused dueto excess PTH in blood. Demineralisationof bone, cyst formation, softening of bone, loss of muscle tone, general weakness,renal disorders are the symptoms ofhyperparathyroidism.

- Addison's disease is caused due to hyposecretion of glucocorticoids andmineralocorticoids from the adrenalcortex. Muscular weakness, low BP., loss of appetite, vomiting, hyper pigmentationof skin, low metabolic rate, subnormaltemperature, reduced blood volume,weight loss are the symptoms that occurin Addison's disease (Figure 11.15). Reducedaldosterone secretion increases urinary excretion of Na Cl. and water and decreasespotassium excretion leading to dehydration.

- Cushing's syndrome is caused due toexcess secretion of cortisol. Obesity of theface and trunk, redness of face, hand, feet,thin skin, excessive hair growth, loss ofminerals from bone (osteoporosis) systolic hypertension are features of Cushing'ssyndrome. Suppression of sexual functionlike atrophy of gonads are the other symptoms of Cushing's syndrome.

Avoid use ofsynthetic soft drinks
The branded soft drinks damage ourendocrine system. While consumingsoft drinks, the sugar level increasesin blood which leads to elevatedinsulin secretion to reduce the bloodglucose level. The elevated insulinlevel diminishes immunity and causeobesity, cardio-vascular disorders etc.

- Hypoglycaemia is due to increasedsecretion of insulin thereby blood glucoselevel decreases. In this disorder bloodglucose level lowers than normal fastingindex. Increased heartbeat, weakness,Nervousness , headache, confusion, lack of co-ordination, slurred speech, serious brain defects like epilepsy and coma occurs.

- Hyperglycaemia is otherwise knownas Diabetes mellitus. It is caused due toreduced secretion of insulin. As the result,blood glucose level is elevated. Diabetesmellitus is of two types, Type I Diabetesand Type II Diabetes. Type I diabetes isalso known Insulin dependent diabetes,caused by the lack of insulin secretiondue to illness or viral infections. Type IIdiabetes is also known as Non-Insulindependent diabetes, caused due to reducedsensitivity to insulin, often called asinsulin resistance. Symptoms of diabetesincludes, polyurea (excessive urination),polyphagia (excessive intake of food), polydipsia (excessive consumption liquidsdue to thirst), ketosis (breakdown of fatinto glucose results in accumulation ofketone bodies) in blood. Gluconeogenesis(Conversion of non-carbohydrate formlike amino acids and fat into glucose) alsooccur in diabetes.

- Diabatesinsipidusis caused due tohyposecretion of vasopressin (ADH)from neurohypophysis. The symptomincludes frequent urination (polyurea)and excessive consumption of liquids dueto thirst (polydipsia).

10th lesson
Unit – 16 Plants and Animals Hormones

Endocrine glands

Pituitary Gland

- The pituitary gland or hypophysis is a pea shaped compact mass of cells located at the base of the midbrain attached to the hypothalamus by a pituitary stalk. The pituitarygland is anatomically composed of two lobes and perform different functions. They are the anterior lobe (adenohypophysis) and the posterior lobe (neurohypophysis). The intermediate lobe is non-existent in humans.

- The pituitary gland forms the major endocrine gland in most vertebrates. It regulates and controls other endocrine glands and so is called as the "Master gland".

- Hormones secreted by the anterior lobe (Adenohypophysis) of pituitary

- The anterior pituitary is composed of different types of cells and secrete hormones which stimulates the production of hormones by other endocrine glands. The hormones secreted by anterior pituitary are

➢ Growth Hormone
➢ Thyroid stimulating Hormone
➢ Adrenocorticotropic Hormone
➢ Gonadotropic Hormone which comprises the Follicle Stimulating Hormone and Luteinizing Hormone
➢ Prolactin

Growth hormone (GH)

- GH promotes the development and enlargement of all tissues of the body. It stimulates the growth of muscles, cartilage and long bones. It controls the cell metabolism.

- The improper secretion of this hormone leads to the following conditions.

Dwarfism: It is caused by decreased secretion of growth hormone in children. The characteristic features are stunted growth, delayed skeletal formation and mental disability.

Gigantism: Oversecretion of growth hormone leads to gigantism in children. It is characterised by overgrowth of all body tissues and organs. Individuals attain abnormal increase in height.

Acromegaly: Excess secretion of growth hormone in adults may lead to abnormal enlargement of head, face, hands and feet.

Thyroid stimulating hormone (TSH)

- TSH controls the growth of thyroid gland, coordinates its activities and hormone secretion.

Adrenocorticotropic hormone (ACTH)

- ACTH stimulates adrenal cortex of the adrenal gland for the production of its hormones. It also influences protein synthesis in the adrenal cortex.

Gonadotropic hormones (GTH)

- The gonadotropic hormones are follicle stimulating hormone and luteinizing hormone which are essential for the normal development of gonads.

Follicle stimulating hormone (FSH)

- In male, it stimulates the germinal epithelium of testes for formation of sperms. In female it initiates the growth of ovarian follicles and its development in ovary.

Luteinizing hormone (LH)

- In male, it promotes the Leydig cells of the testes to secrete male sex hormone testosterone. In female, it causes ovulation (rupture of mature graafian follicle), responsible for the development of corpus luteum and production of female sex hormones estrogen and progesterone.

Prolactin (PRL)

- PRL is also called lactogenic hormone. This hormone initiates development of mammaryglands during pregnancy and stimulates the production of milk after child birth.

Hormones secreted by the posterior lobe (Neurohypophysis) of pituitary

The hormones secreted by the posterior pituitary are

- Vasopressin or Antidiuretic hormone
- Oxytocin

Vasopressin or Antidiuretic hormone (ADH)

- In kidney tubules it increases reabsorption of water. It reduces loss of water through urine and hence the name antidiuretic hormone.

- Deficiency of ADH reduces reabsorption of water and causes an increase in urine output (polyuria). This deficiency disorder is called Diabetes insipidus.

Oxytocin

- It helps in the contraction of the smooth muscles of uterus at the time of child birth and milk ejection from the mammary gland after child birth.

Thyroid Gland

- The thyroid gland is composed of two distinct lobes lying one on either side of the trachea. The two lobes are connected by means of a narrow band of tissue known as the isthmus. This gland is composed of glandular follicles and lined by cuboidal epithelium.The follicles are filled with colloid material called thyroglobulin.

An amino acid tyrosine and iodine are involved in the formation of thyroid hormone. The hormones secreted by the thyroid gland are

- Triiodothyronine (T3)
- Tetraiodothyronine or Thyroxine (T4)

Functions of thyroid hormones

The functions of thyroid hormones are

- Production of energy by maintaining the Basal Metabolic Rate (BMR) of the body.
- Helps to maintain normal body temperature.
- Influences the activity of central nervous system.
- Controls growth of the body and bone formation.
- Essential for normal physical, mental and personality development .
- It is also known as personality hormone.
- Regulates cell metabolism.

Thyroid Dysfunction

- When the thyroid gland fails to secrete the normal level of hormones, the condition is called thyroid dysfunction. It leads to the following conditions

Hypothyroidism

- It is caused due to the decreased secretion of the thyroid hormones. The abnormal conditions are simple goitre, cretinism and myxoedema.

Goitre

- It is caused due to the inadequate supply of iodine in our diet. This is commonly prevalent in Himalayan regions due to low level of iodine content in the soil. It leads to the enlargement of thyroid gland which protrudes as a marked swelling in the neck and is called as goitre.

Cretinism

- It is caused due to decreased secretion of the thyroid hormones in children. The conditions are stunted growth, mental defect, lack of skeletal development and deformed bones. They are called as cretins.

Myxoedema

- It is caused by deficiency of thyroid hormones in adults. They are mentally sluggish, increase in body weight, puffiness of the face and hand, oedematous appearance.

Hyperthyroidism

- It is caused due to the excess secretion of the thyroid hormones which leads to Grave's disease. The symptoms are protrusion of the eyeballs (Exopthalmia), increased metabolic rate, high body temperature, profuse sweating, loss of body weight and nervousness.

Parathyroid Gland

- The parathyroid glands are four small oval bodies that are situated on the posterior surface of the thyroid lobes. The chief cells of the gland are mainly concerned with secretion of parathormone.

Functions of Parathormone

- The parathormone regulates calcium and phosphorus metabolism in the body.They act on bone, kidney and intestine to maintain blood calcium levels.

Parthyroid Dysfunction

- The secretion of parathyroid hormone can be altered due to the following conditions.

Removal of parathyroid glands during thyroidectomy (removal of thyroid) causes decreased secretion of parathormone. The conditions are

- Muscle spasm known as Tetany (sustained contraction of muscles in face, larynx, hands and feet).

- Painful cramps of the limb muscles

Pancreas (Islets of Langerhans)

- Pancreas is an elongated, yellowish gland situated in the loop of stomach and duodenum. It is exocrine and endocrine in nature. The exocrine pancreas secretes pancreatic juice which plays a role in digestion while, the endocrine portion is made up of Islets of Langerhans

- The Islets of Langerhans consists of two types of cells namely alpha cells and beta cells. The alpha cells secrete glucagon and beta cells secrete insulin.

Functions of Pancreatic hormones

- A balance between insulin and glucagon production is necessary to maintain blood glucose concentration.

Adrenal Gland

- The adrenal glands are located above each kidney. They are also called supra renal glands.

- The outer part is the adrenal cortex and the inner part is the adrenal medulla. The two distinct parts are structurally and functionally different.

Adrenal Cortex

- The adrenal cortex consists of three layers of cells. They are zonaglomerulosa, zonafasciculata and zonareticularis

Hormones of Adrenal Cortex

The hormones secreted by the adrenal cortex are corticosteroids. They are classified into

- Glucocorticoids
- Mineralocorticoids

Functions of adrenocortical hormones

Glucocorticoids

- The glucocorticoids secreted by the zonafasciculata are cortisol and corticosterone

- They regulate cell metabolism.
- It stimulates the formation of glucose from glycogen in the liver.
- It is an anti-inflammatory and anti-allergic agent.

Mineralocorticoids

- The mineralocorticoids secreted by zonaglomerulosa is aldosterone

- It helps to reabsorb sodium ions from the renal tubules.
- It causes increased excretion of potassium ions.
- It regulates electrolyte balance, body fluid volume, osmotic pressure and blood pressure.

Adrenal Medulla

- The adrenal medulla is composed of chromaffin cells.They are richly supplied with sympathetic and parasympathetic nerves.

Hormones of Adrenal Medulla

It secretes two hormones namely

- Epinephrine (Adrenaline)
- Norepinephrine (Noradrenaline)

- They are together called as "Emergency hormones". It is produced during conditions of stress and emotion. Hence it is also referred as "flight, fright and fight hormone".

Functions of adrenal medullary hormones

Epinephrine (Adrenaline)

- It promotes the conversion of glycogen to glucose in liver and muscles.
- It increases heart beat and blood pressure.
- It increases the rate of respiration by dilation of bronchi and trachea.
- It causes dilation of the pupil in eye.
- It decreases blood flow through the skin.

Norepinephrine (Noradrenalin)

- Most of its actions are similar to those of epinephrine.

Reproductive Glands (Gonads)

- The sex glands are of two types the testes and the ovaries. The testes are present in male, while the ovaries are present in female.

Testes

- Testes are the reproductive glands of the males. They are composed of seminiferous tubules, Leydig cells and Sertoli cells. Leydig cells form the endocrine part of the testes. They secrete the male sex hormone called testosterone.

Functions of testosterone

- It influences the process of spermatogenesis.
- It stimulates protein synthesis and controls muscular growth.
- It is responsible for the development of secondary sexual characters (distribution of hair on body and face, deep voice pattern, etc).

Ovary

- The ovaries are the female gonads located in the pelvic cavity of the abdomen. They secrete the female sex hormones

- Estrogen
- Progesterone

- Estrogen is produced by the Graafian follicles of the ovary and progesterone from the corpus luteum that is formed in the ovary from the ruptured follicle during ovulation.

Functions of estrogens

- It brings about the changes that occur during puberty.
- It initiates the process of oogenesis.
- It stimulates the maturation of ovarian follicles in the ovary.
- It promotes the development of secondary sexual characters (breast development, high pitched voice etc).

Functions of progesterone

- It is responsible for the premenstrual changes of the uterus.

- It prepares the uterus for the implantation of the embryo.
- It maintains pregnancy.
- It is essential for the formation of placenta

Thymus Gland

- Thymus is partly an endocrine gland and partly a lymphoid gland. It is located in the upper part of the chest covering the lower end of trachea. Thymosin is the hormone secreted by thymus.

Functions of Thymosin

- It has a stimulatory effect on the immune function.
- It stimulates the production and differentiation of lymphocytes.

Reproductive system

12th zoology

Chapter 2 – Human Reproduction

The major reproductive events in human beings are as follows:

- **Gametogenesis:** Formation of gametes by spermatogenesis and oogenesis.
- **Insemination:** Transfer of sperms by the male into the female genital tract.
- **Fertilisation:** Fusion of male and female gametes to form zygote, called fertilisation.
- **Cleavage:** Rapid mitotic divisionsofthe zygote which convert the single celled zygote into a multicellular structure called blastocyst.
- **Implantation:** Attachment of blastocyst to the uterine wall.
- **Placentation:** Formation of placenta which is the intimate connection between foetus and uterine wall of the mother for exchange of nutrients.
- **Gastrulation:** Process by which blastocyst is changed into a gastrula with three primary germ layers
- **Organogenesis:** Formation of specific tissues, organs and organ systems from three germ layers.
- **Parturition:** Expulsion of the foetus from the mother's womb.

- These functions are carried out by the primary and accessory reproductive organs. The primary reproductive organs namely the ovary and testis are responsible for producing the ova and sperms respectively. Hormones secreted by the pituitary gland and the gonads help in the development of the secondary sexual characteristics, maturation of the reproductive system and regulation of normal functioning of the reproductive system. The accessory organs help in transport and to sustain the gametes and to nurture the developing offspring.

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Chapter 3 – Reproductive Health

Need for reproductive health-Problems and strategies

- India is amongst the first few countries in the world to initiate the 'Family planning programme' since 1951 and is periodically assessed every decade. These programmes are popularly named as 'Reproductive and Child Health Care (RCH). Major tasks carried out under these programmes are:

- Creating awareness and providing medical assistance to build a healthy society.
- Introducing sex education in schools to provide information about adolescence and adolescence related changes.
- Educating couples and those in the marriageable age groups about theavailable birth control methods and family planning norms
- Creating awareness about care for pregnant women, post-natal care of mother and child and the importance of breast feeding.
- Encouraging and supporting governmental and non-governmental agencies to identify new methods and/or to improve upon the existing methods of birth control.

Globally, about 800 women die every day of preventable causes related to pregnancy and childbirth; 20 per cent of these women are from India. Similarly India's infant mortality rate was 44 per 1,000 live. Although, India has witnessed dramatic growth over the last two decades, maternal mortality still remains high as in comparison to many developing nations.

Health care programmes such as massive child immunization, supply of nutritional food to the pregnant women, JananiSurakshaYojana, JananiShishuSurakshaKaryakaram, RMNCH+A approach (an integrated approach for reproductive, maternal, new born, child and adolescent health), PradhanMantriSurakshitMatritvaAbhiyan, etc., are taken up at the national level by the Government of India

Social impact of sex ratio, female foeticide and infanticide

- The sex ratio is the ratio of males to the females in a population. In India, the child sex ratio has decreased over the decade from 927 to 919 female for every 1000 males. To correct this ratio, steps are needed to change the mind set and attitudes of people, especially in the young adults. Female foeticide and infanticide is the manifestation of gender discrimination in our society.

- Female foeticide refers to 'aborting the female in the mother's womb'; whereas female infanticide is 'killing the female child after her birth'. These have resulted in imbalance in sex ratio. In UNDP's GII 2018 (United nations developmental programmes gender inequality index) reflected that India was ranked at 135 out of 187 countries due to availability of very few economic opportunities to women as compared to men.

- In order to prevent female foeticide and infanticide, Government of India has taken various steps like PCPNDT Act (Preconception and Prenatal diagnostic technique act-1994) enacted to ban the identification of sex and to prevent the use of prenatal diagnostic techniques for selective abortion. Various measures are taken by the Government to ensure survival, provision of better nutrition, education, protection and empowerment of girls by eliminating the differences in the sex ratio, infant mortality rate and improving their nutritional and educational status. POCSO Act (Prevention of children from sexual offences), Sexual harassment at workplace (Prevention, prohibition and redressal) Act and the changes in the Criminal law based on the recommendations of Justice VermaCommittee, 2013 aims at creating a safe and secure environment for both females and males.

Population explosion and birth control

- Increased health facilities and better living conditions have enhanced longevity. According to a recent report from the UN, India's population has already reached 1.26 billion and is expected to become the largest country in population size, surpassing China around 2022. To overcome the problem of population explosion, birth control is the only available solution. People should be motivated to have smaller families by using various contraceptive devices. Advertisements by the Government in the media as well as posters/bills, etc., with a slogan Naamiruvarnamakkuiruvar (we two, ours two) and Naamiruvarnamakkuoruvar (we two, ours one) have also motivated to control population growth in Tamilnadu. Statutory rising of marriageable age of the female to 18 years and that of males to 21 years and incentives given to couples with small families are the other measures taken to control population growth in our country.

Birth control methods

- The voluntary use of contraceptive procedures to prevent fertilization or prevent implantation of a fertilized egg in the uterus is termed as birth control. An ideal contraceptive should be user friendly, easily available, with least side effects and should not interfere with sexual drive. The contraceptive methods are of two types – temporary and permanent. Natural, chemical, mechanical and hormonal barrier methods are the temporary birth control methods.

Natural method is used to prevent meeting of sperm with ovum. i.e., Rhythm method (safe period), coitus interruptus, continuous abstinence and lactational amenorrhoea.

Periodic abstinence/rhythm method Ovulation occurs at about the 14th day of the menstrual cycle. Ovum survives for about two days and sperm remains alive for about 72 hours in the female reproductive tract. Coitus is to be avoided during this time.

Continuous abstinence is the simplest and most reliable way to avoid pregnancy is not to have coitus for a defined period that facilitates conception.

Coitus interruptus is the oldest family planning method. The male partner withdraws his penis before ejaculation, thereby preventing deposition of semen into the vagina.

Lactational amenorrhoea Menstrual cycles resume as early as 6 to 8 weeks from parturition. However, the reappearance of normal ovarian cycles may be delayed for six months during breast-feeding. This delay in ovarian cycles is called lactational amenorrhoea. It serves as a natural, but an unreliable form of birth control. Suckling by the baby during breast-feeding stimulates the pituitary to secrete increased prolactin hormone in order to increase milk production. This high prolactin concentration in the mother's blood may prevent menstrual cycle by suppressing the release of GnRH (Gonadotropin Releasing Hormone) from hypothalamus and gonadotropin secretion from the pituitary.

Barrier methods In these methods, the ovum and sperm are prevented from meeting so that fertilization does not occur.

Chemical barrier Foaming tablets, melting suppositories, jellies and creams are used as chemical agents that inactivate the sperms in the vagina.

Mechanical barrier Condoms are a thin sheath used to cover the penis inmale whereas in female it is used to cover vagina and cervix just before coitus so as to prevent the entry of ejaculated semen into the female reproductive tract. This can prevent conception. Condoms should be discarded after a single use. Condom also safeguards the user from AIDS and STDs. Condoms are made of polyurethane, latex and lambskin.

Diaphragms, cervical caps and vaults are made of rubber and are inserted into the female reproductive tract to cover the cervix before coitus in order to prevent the sperms from entering the uterus.

Hormonal barrier

- It prevents the ovaries from releasing the ova and thickens the cervical fluid which keeps the sperm away from ovum.

Oral contraceptives — Pills are used to prevent ovulation by inhibiting the secretion of FSH and LH hormones. A combined pill is the most commonly used birth control pill. It contains synthetic progesterone and estrogen hormones. Saheli, contraceptive pill by Central Drug Research Institute (CDRI) in Lucknow, India contains a non-steroidal preparation called centchroman.

Intrauterine Devices (IUDs)

- Intrauterine devices are inserted by medical experts in the uterus through the vagina. These devices are available as copper releasing IUDs, hormone releasing IUDs and non-medicated IUDs. IUDs increase phagocytosis of sperm within the uterus. IUDs are the ideal contraceptives for females who want to delay pregnancy. It is one of the popular methods of contraception in India and has a success rate of 95 to 99%.

Copper releasing IUDs differ from each other by the amount of copper. Copper IUDssuch as Cu T-380 A, Nova T, Cu 7, Cu T 380 Ag, Multiload 375, etc. release free copper and copper salts into the uterus and suppress sperm motility. They can remain in the uterus for five to ten years.

Hormone-releasing IUDs such as Progestasert and LNG – 20 are often called as intrauterine systems (IUS). They increase the viscosity of the cervical mucus and thereby prevent sperms from entering the cervix.

Non-medicated IUDs are made of plastic or stainless steel. Lippes loop is a double S-shaped plastic device.

Permanent birth control methods are adopted by the individuals who do not want to have any more children.

- Surgical sterilisation methods are the permanent contraception methods advised for male and female partners to prevent any more pregnancies. It blocks the transport of the gametes and prevents conception. Tubectomy is the surgical sterilisation in women. In this procedure, a small portion of both fallopian tubes are cut and tied up through a small incision in the abdomen or through vagina. This prevents fertilization as well as the entry of the egg into the uterus. Vasectomy is the surgical procedure for male sterilisation. In this procedure, both vas deferens are cut and tied through a small incision on the scrotum to prevent the entry of sperm into the urethra. Vasectomy prevents sperm from heading off to penis as the discharge has no sperms in it.

Medical termination of pregnancy (MTP)

- Medical method of abortion is a voluntary or intentional termination of pregnancy in a non-surgical or non-invasive way. Early medical termination is extremely safe upto 12 weeks (the first trimester) ofpregnancy and generally has no impact on a women's fertility. Abortion during the second trimester is more risky as the foetus becomes intimately associated with the maternal tissue. Government of India legalized MTP in 1971 for medical necessity and social consequences with certain restrictions like sex discrimination and illegal female foeticides to avoid its misuse. MTP performed illegally by unqualified quacks is unsafe and could be fatal. MTP of the first conception may have serious psychological consequences.

Sexually transmitted diseases (STD)

- Sexually transmitted diseases (STD) or Venereal diseases (VD) or Reproductive tract infections (RTI) are called as Sexually transmitted infections (STI). Normally STI are transmitted from person to person during intimate sexual contact with an infected partner. Infections like Hepatitis-B and HIV are transmitted sexually as well as by sharing of infusion needles, surgical instruments, etc with infected people, blood transfusion or from infected mother to baby. People in the age of 15 to 24 years are prone to these infections. The bacterial STI are gonorrhoea, syphilis, chancroid, chlamydiasis and lymphogranulomavenereum. The viral STI are genital herpes, genital warts, Hepatitis-B and AIDS. Trichomoniasis is a protozoan STI, and candidiasis is a fungal STI. STI caused by bacteria, fungi and protozoa or parasites, can be treated with antibiotics or other medicines, whereas STI caused by virus cannot be treated but the symptoms can be controlled by antiviral medications. Latex condoms usage greatly reduces the risk, but does not completely eliminate the risk of transmission of STI

Prevention of STDs

- Avoid sex with unknown partner/ multiple partners
- Use condoms
- In case of doubt, consult a doctor for diagnosis and get complete treatment.

According to World Health Organization (WHO), 2017 more than one million people globally acquires a sexually transmitted infection every day. India has the third largest HIV epidemic in the world, with 2.1 million people living with HIV

TNHSP (Tamilnadu health systems project), a unit of the Health and family welfare department of the Government of Tamilnadu does free screening for cervical and breast cancer.

STD and their symptoms

Name of the Disease	Causative agent	Symptom	Incubation Period
	Bacterial STI		
Gonorrhoea	Neisseria gonorrhoeae	Affects the Urethra, rectum and throat and in females the cervix	2 to 5 days

		also get affected. Pain and pus discharge in the genital tract and burning sensation during Urination	
Syphilis	Treponema palladium	**Primary Stage** Formation of painless ulcer on the external genitalia. **Secondary Stage** Skin lesions, rashes, Swollen joints and fever and hair loss. **Tertiary Stage** Appearance of chronic ulcers on nose, lower legs and palate. Loss of movement, mental disorder, visual impairment, heart problems, gummas(Soft non – cancerous growths) etc.	10 to 90 days.
Chlamydiasis	Chlamydia trachomatis	Trachoma, affects the cells of the columnar epithelium in the urinogenital tract, respiratory tract and conjunctiva	
Lymphogranulom aVenereum	Chlamydia trachomatis	Cutaneous or mucosal genital damage, urethritis and endocervicitis Locally harmful ulcerations and genital elephantiasis	2 to 3 weeks or upto 6 weeks
Viral STI			
Genital herpes	Herpes simplex virus	Sores in and around the vulva, vagina, urethra in female or sores on or around the penis in male. Pain during urination, bleeding between periods. Swelling in the groin nodes.	2-21 days (average 6 days)
Genital Warts	Human Papilloma virus (HPV)	Hard outgrowths (Tumour) on the external genitalia, cervix and Perianal region	1-8 months
Hepatitis - B	Hepatitis – B virus (HBV)	Fatigue, jaundice, fever, rash and stomach pain Liver cirrhosis and liver failure occur in the later stage.	30-80 days
AIDS	Human immunodeficiency virus (HIV)	Enlarged lymph nodes, prolonged fever, prolonged diarrhoea, weight reduction, night sweating.	2 to 6 weeks even more than 10 years.
Fungal STI			

Candidiasis	Candida albicans	Attacks mouth, throat, intestinal tract and vagina. Vaginal itching or soreness, abnormal vaginal discharge and pain during urination	-
		Protozoan STI	
Trichomoniasis	Trichomonas vaginalis	Vaginitis, greenish Yellow vaginal discharge, itching and burning sensation, urethritis, epididymitis and prostatitis	4-28 days

Cervical cancer

- Cervical cancer is caused by a sexually transmitted virus called Human Papilloma virus (HPV). HPV may cause abnormal growth of cervical cells or cervical dysplasia.

- The most common symptoms and signs of cervical cancer are pelvic pain, increased vaginal discharge and abnormal vaginal bleeding. The risk factors for cervical cancer include

➢ Having multiple sexual partners
➢ Prolonged use of contraceptive pills

- Cervical cancer can be diagnosed by a Papanicolaou smear (PAP smear) combined with an HPV test. X-Ray, CT scan, MRI and a PET scan may also be used to determine the stage of cancer. The treatment options for cervical cancer include radiation therapy, surgery and chemotherapy.

- Modern screening techniques can detect precancerous changes in the cervix. Therefore screening is recommended for women above 30 years once in a year. Cervical cancer can be prevented with vaccination. Primary prevention begins with HPV vaccination of girls aged 9 – 13 years, before they become sexually active. Modification in lifestyle can also help in preventing cervical cancer. Healthy diet, avoiding tobacco usage, preventing early marriages, practicing monogamy and regular exercise minimize the risk of cervical cancer.

Infertility

- Inability to conceive or produce children even after unprotected sexual cohabitation is called infertility. That is, the inability of a man to produce sufficient numbers or quality of sperm to impregnate a woman or inability of a woman to become pregnant or maintain a pregnancy.

- The causes for infertility are tumours formed in the pituitary or reproductive organs, inherited mutations of genes responsible for the biosynthesis of sex hormones, malformation of the cervix or fallopian tubes and inadequate nutrition before adulthood. Long-term stress damages many aspects of health especially the menstrual cycle. Ingestion of toxins (heavy metal cadmium), heavy use of alcohol, tobacco and marijuana, injuries to the gonads and aging also cause infertility.

Other causes of infertility

- Pelvic inflammatory disease (PID), uterine fibroids and endometriosis are the most common causes of infertility in women.
- Low body fat or anorexia in women. i.e. a psychiatric eating disorder characterised by the fear of gaining weight.
- Undescended testes and swollen veins (varicocoele) in scrotum.
- Tight clothing in men may raise the temperature in the scrotum and affect sperm production.
- Under developed ovaries or testes.
- Female may develop antibodies against her partner's sperm.
- Males may develop an autoimmune response to their own sperm.

All women are born with ovaries, but some do not have functional uterus. This condition is called Mayer-Rokitansky syndrome

Assisted reproductive technology (ART)

- A collection of procedures, which includes the handling of gametes and/or embryos outside the body to achieve a pregnancy, is known as Assisted Reproductive Technology. It increases the chance of pregnancy in infertile couples. ART includes intra-uterine insemination (IUI), in vitro fertilization, (IVF) Embryo transfer (ET), Zygote intra-fallopian transfer (ZIFT), Gamete intrafallopian transfer (GIFT), Intra-cytoplasmic sperm injection (ICSI), Preimplantation genetic diagnosis, oocyte and sperm donation and surrogacy.

Intra-uterine insemination (IUI)

- This is a procedure to treat infertile men with low sperm count. The semen is collected either from the husband or from a healthy donor and is introduced into the uterus through the vagina by a catheter after stimulating the ovaries to produce more ova. The sperms swim towards the fallopian tubes to fertilize the egg, resulting in normal pregnancy.

In vitro fertilization (IVF) or Test tube baby

- In this technique, sperm and eggs are allowed to unite outside the body in a laboratory. One or more fertilized eggs may be transferred into the woman's uterus, where they may implant in the uterine lining and develop. Excess embryos may be cryopreserved (frozen) for future use. Initially, IVF was used to treat women with blocked, damaged, or absent fallopian tubes. Today, IVF is used to treat many causes of infertility. The basic steps in an IVF treatment cycle are ovarian stimulation, egg retrieval, fertilization, embryo culture, and embryo transfer.

- Egg retrieval is done by minor surgery under general anesthesia, using ultrasound guide after 34 to 37 hours of hCG (human chorionic gonadotropin) injection. The eggs are prepared and stripped from the surrounding cells. At the same time, sperm preparation is done using a special media. After preparing the sperms, the eggs are brought together. 10,000-1,00,000 motile sperms are needed for each egg. Then the zygote is allowed to divide to form 8 celled blastomere and then transferred into the uterus for a successful pregnancy. The transfer of an embryo with more than 8 blastomeres stage into uterus is called Embryo transfer technique.

Cryopreservation (or freezing) of embryos is often used when there are more embryos than needed for a single IVF transfer. Embryo cryopreservation can provide an additional opportunity for pregnancy, through a Frozen embryo transfer (FET), without undergoing another ovarian stimulation and retrieval.

Zygote intra-fallopian transfer (ZIFT)

- As in IVF, the zygote upto 8 blastomere stage is transferred to the fallopian tube by laparoscopy. The zygote continues its natural divisions and migrates towards the uterus where it gets implanted.

Intra uterine transfer (IUT)

- Embryo with more than 8 blastomeres is inserted into uterus to complete its further development.

Gamete intra-fallopian transfer (GIFT)

- Transfer of an ovum collected from a donor into the fallopian tube. In this the eggs are collected from the ovaries and placed with the sperms in one of the fallopian tubes. The zygote travels toward the uterus and gets implanted in the inner lining of the uterus.

Intra-cytoplasmic sperm injection (ICSI)

- In this method only one sperm is injected into the focal point of the egg to fertilize. The sperm is carefully injected into the cytoplasm of the egg. Fertilization occurs in 75 - 85% of eggs injected with the sperms. The zygote is allowed to divide to form an 8 celled blastomere and then transferred to the uterus to develop a protective pregnancy.

Detection of foetal disorders during early pregnancy

Ultrasound scanning

- Ultrasound has no known risks other than mild discomfort due to pressure from the transducer on the abdomen or vagina. No radiation is used during this procedure. Ultrasonography is usually performed in the first trimester for dating, determination of the number of foetuses, and for assessment of early pregnancy complications.

There are several types of ultrasound imaging techniques. As the most common type, the 2-D ultrasound provides a flat picture of one aspect of the baby. The 3-D image allows the health care provider to see the width, height and depth of the images, which can be helpful during the diagnosis. The latest technology is 4-D ultrasound, which allows the health care provider to visualize the unborn baby moving in real time with a three-dimensional image

Unit 17 – Reproduction in Animals

Sexual Reproduction in Human

- In human beings the male and female reproductive organs differ anatomically and physiologically. New individuals develop by the fusion of gametes. Sexual reproduction involves the fusion of two haploid gametes (male and the female gametes) to form a diploid individual (zygote).

Male Reproductive Organ - Structure of Testes

- Testes are the reproductive glands of the male that are oval shaped organs which lie outside the abdominal cavity of a man in a sac like structure called scrotum. Now we shall study the various cells which are present in the testes.
- Each testes is covered with a layer of fibrous tissue called tunica albuginea. Many septa from this layer divide the testes into pyramidal lobules, in which lie seminiferous tubules, cells of Sertoli, and the Leydig cells (interstitial cells).
- The process of spermatogenesis takes place in the seminiferous tubules. The Sertoli cells are the supporting cells and provide nutrients to the developing sperms. The Leydig cells are polyhedral in shape andlie between the seminiferous tubules and secrete testosterone. It initiates the process of spermatogenesis.

Female Reproductive Organ - Structure of Ovary

- The ovaries are located on either side of the lower abdomen composed of two almond shaped bodies, each lying near the lateral end of fallopian tube. Each ovary is a compact structure consisting of an outer cortex and an inner medulla. The cortex is composed of a network of connective tissue called as stroma and is lined by the germinal epithelium. The epithelial cells called the granulosa cells surround each ovum in the ovary together forming the primary follicle. As the egg grows larger, the follicle also enlarges and gets filled with the fluid and is called the Graafian follicle.

Gametogenesis

- The formation of the sperm in male and the ovum in female is called gametogenesis. It involves spermatogenesis (formation of spermatozoa) and oogenesis (the formation of ova). Gametes with haploid cells are produced through gametogenesis.

Structure of Human Sperm

- The spermatozoan consists of head, a middle piece and tail. The sperm head is elongated and formed by the condensation of nucleus. The anterior portion has a cap like structure called acrosome. It contains hyaluronidase an enzyme that helps the sperm to enter the ovum during fertilization. A short neck connects the head and middle piece which comprises the centrioles.The middle piece contains the mitochondria which provides energy for the movement of tail. It brings about sperm motility which is essential for fertilization.

Structure of Ovum

- The mature ovum or egg is spherical in shape.The ovum is almost free of yolk. It contains abundant cytoplasm and the nucleus. The ovum is surrounded by three membranes. The plasma membrane is surrounded by inner thin zonapellucida and an outer thick corona radiata. The corona radiata is formed of follicle cells. The membrane forming the surface layer of the ovum is called vitelline membrane. The fluid-filled space between zonapellucida and the surface of the egg is called perivitelline space.

Menstrual Cycle-Process of Ovulation

- The cyclic events that take place in a rhythmic fashion during the reproductive period of a woman's life is called menstrual cycle. In human females the menstrual cycle starts at the age of 11-13 years which marks the onset of puberty and is called menarche, and ceases around 48-50 years of age and this stage is termed menopause. The reproductive period is marked by characteristic events repeated almost every month in physiologically normal women (28 days with minor variation) in the form of a menstrual flow. The menstrual cycle consists of 4 phases.

- Menstrual or Destructive Phase
- Follicular or Proliferative Phase
- Ovulatory Phase
- Luteal or Secretory Phase

- These phases show simultaneous synchrony of events in both ovary and uterus. Changes in the ovary and the uterus areinduced by the pituitary hormones (LH and FSH) and ovarian hormones (estrogen and progesterone).

Fertilization to Foetal Development

Fertilization

- Fertilization in human is internal and occurs in the oviduct of the female genital tract. It takes place usually in the ampulla of the fallopian tube. An oocyte is alive for about 24 hours after it is released from the follicle. Fertilisation must take place within 24 hours. The sperm enters into the ovum and fuses with it, resulting in the formation of a 'zygote'. This process is called fertilization. The zygote is a fertilized ovum.

Cleavage and Formation of Blastula

- The first cleavage takes place about 30 hours after fertilization. Cleavage is a series of rapid mitotic divisions of the zygote to form many celled blastula (Blastocyst) which comprises an outer layer of smaller cells and inner mass of larger cells.

Implantation

- The blastocyst (fertilized egg) reaches the uterus and gets implanted in the uterus. The process of attachment of the blastocyst to the uterine wall (endometrium) is called implantation. The fertilized egg becomes implanted in about 6 to 7 days after fertilization

Gastrulation

- The transformation of blastula into gastrula and the formation of primary germ layers (ectoderm, mesoderm and endoderm) by rearrangement of the cells is called gastrulation. This takes place after the process of implantation.

Organogenesis

- The establishment of the germ layers namely ectoderm, mesoderm and endoderm initiates the final phase of embryonicdevelopment. During organogenesis the various organs of the foetus are established from the different germ layers attaining a functional state.

Formation of Placenta

- The placenta is a disc shaped structure attached to the uterine wall and is a temporary association between the developing embryo and maternal tissues. It allows the exchange of food materials, diffusion of oxygen, excretion of nitrogenous wastes and elimination of carbon dioxide. A cord containing blood vessels that connects the placenta with the foetus is called the umbilical cord.

Pregnancy (Gestation)

- It is the time period during which the embryo attains its development in the uterus. Normally gestation period of human last for about 280 days. During pregnancy the uterus expands upto 500 times of its normal size.

Parturition (Child Birth)

- Parturition is the expulsion of young one from the mother's uterus at the end of gestation. Oxytocin from the posterior pituitary stimulates the uterine contractions and provides force to expel the baby from the uterus, causing birth.

Sometimes ovaries releases two eggs and each is fertilised by a different sperm, resulting in Non-Identical Twins (Fraternal Twins). If single egg is fertilised and then divides into two foetus, Identical Twins develop.

Lactation

- The process of milk production after child birth from mammary glands of the mother is called lactation. The first fluid which is released from the mammary gland after child birth is called as colostrum. Milk production from alveoli of mammary glands is stimulated by prolactin secreted from the anterior pituitary.

- The ejection of milk is stimulated by posterior pituitary hormone oxytocin.

Personal Hygiene

- Hygiene is the practice of healthy living and personal cleanliness. Personal hygiene is caring of one's own body and health. Social hygiene is proper care of the surrounding environment. The main aspect of hygiene are body hygiene, food hygiene, sanitary hygiene and hygienic environment.

Body Hygiene

- Washing is vital to all age group of people which maintains our personal hygiene. A daily bath regularly keeps skin clean and free of germs. Hair should be kept clean by frequent washing. Mouth wash should be done after every meal. We should wash our hands many times during the day.

- Cloth towels used to dry our hands or body should be dried after each use and laundered regularly. Clothes, handkerchief, undergarments and socks should be washed daily. Washing prevents body odour, infections and skin irritation.

Toilet Hygiene

- The toilet has a lot to do with personal hygiene and general health as it is a place that cannot be avoided and used regularly. Parents should guide and practice their children on how to use the toilets at home, in schools and other public places so that it will protect the children from various contagious infections and diseases.The following measures can ensure toilet hygiene

➢ The floors of the toilet should be maintained clean and dry. This helps to reduce the bad odour and also infection.

➢ Toilet flush handles, door knobs, faucets, paper towel dispensers, light switches and walls should be cleaned with disinfectants to kill harmful germs and bacteria.

➢ Hands should be washed thoroughly with soap before and after toilet use.

Menstrual and Napkin Hygiene

- Women's health depends upon the level of cleanliness to keep them free from skin and genitourinary tract infection.

Menstrual hygiene

- Maintaining menstrual hygiene is important for the overall health of women. The basic menstrual hygiene ways are

➢ Sanitary pads should be changed regularly, to avoid infections due to microbes from vagina and sweat from genitals.

➢ Use of warm water to clean genitals helps to get rid of menstrual cramps

Wearing loose clothing rather than tight fitting clothes will ensure the airflow around the genitals and prevent sweating.